Environmental Impact of Anesthesia

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Art A&A 5/12

Learning Objectives

- Discuss the relationship between pollution and public health
- Define Life Cycle Analysis (LCA)
- Summarize key inhaled anesthetic pollution findings
- Identify opportunities for anesthesiology practice improvement

Disclosure: no relationships with industry

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#ClimateChange #ASA2019 #ClinicalSustainable

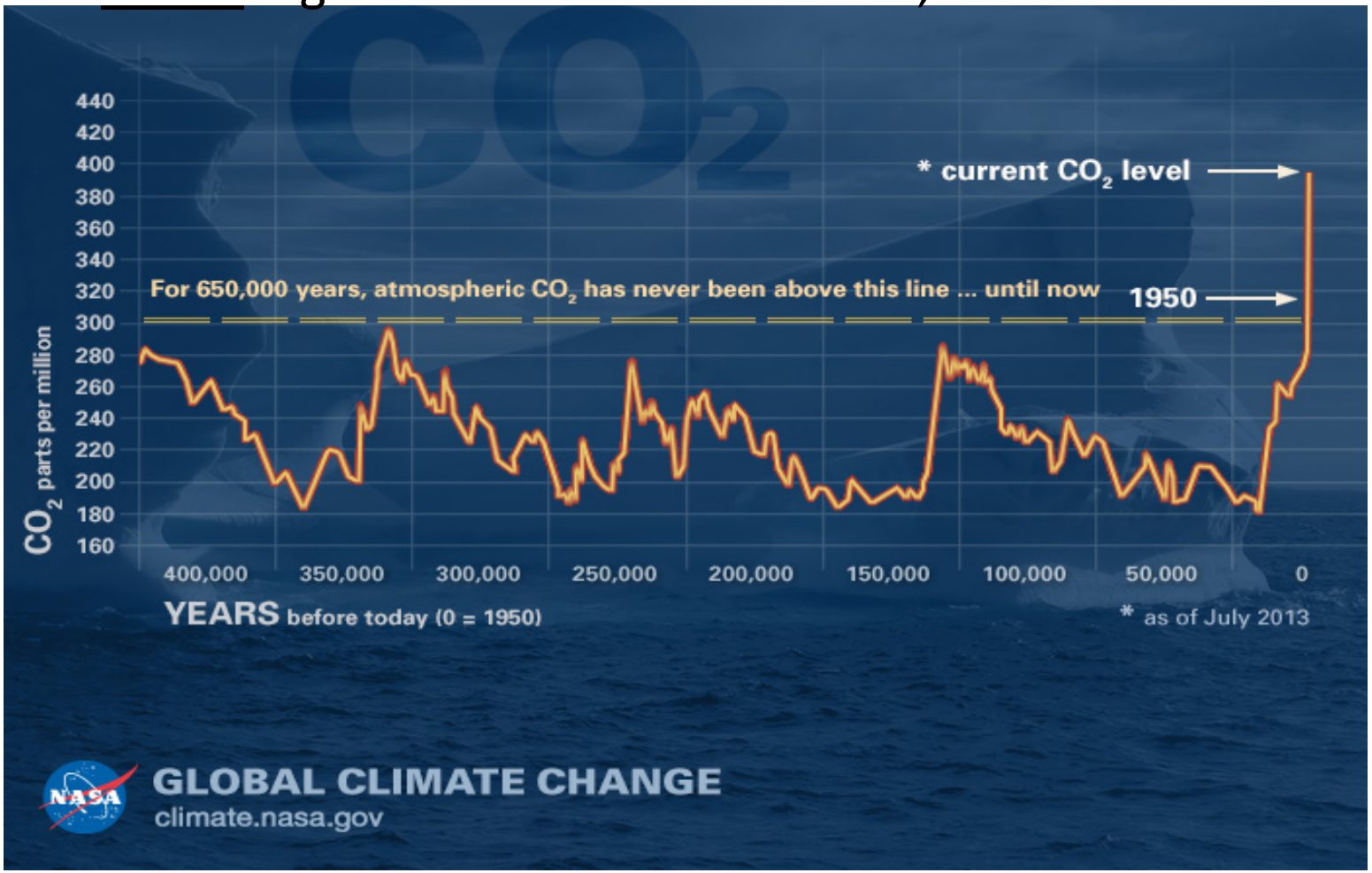
Why sustainability?

- We live in a finite world
- Human health is dependent on environmental health

"Climate Change is a Medical Emergency"

Lancet Commission on Health and Climate Change,
WHO, UN

7000+ higher education institutions, 6 continents

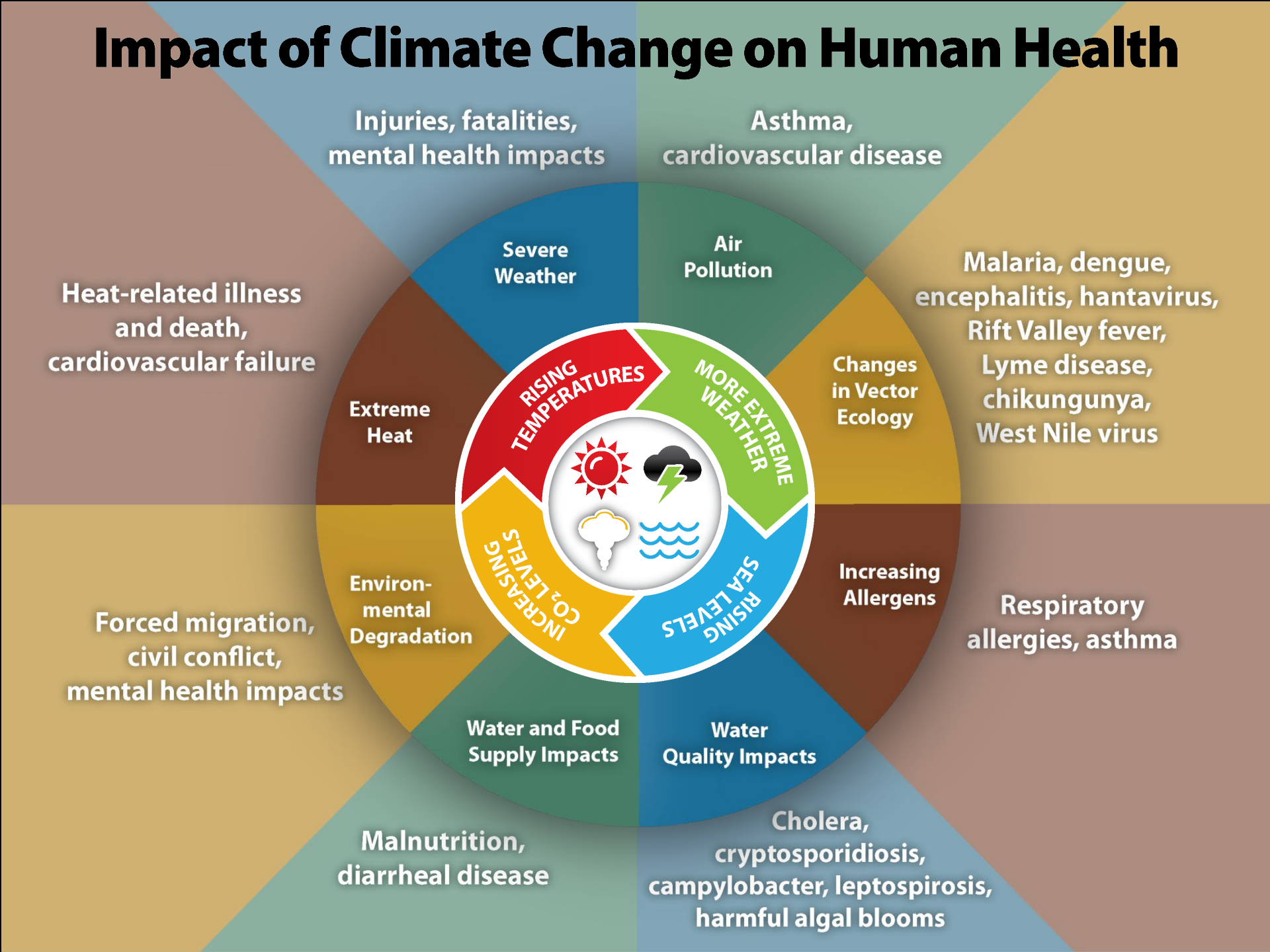


Pollution a leading cause of non-communicable disease/deaths

- 9 million premature deaths, 16% of all global deaths
- Disproportionately affects the poor
- Air pollution and climate change closely linked
- Welfare losses estimated at $4.6 TRN/year, 6.2% global output.
- Cost of inaction high, while ROI for pollution control significant

Lancet Commission on Pollution and Health, 2018

Impact of Climate Change on Human Health

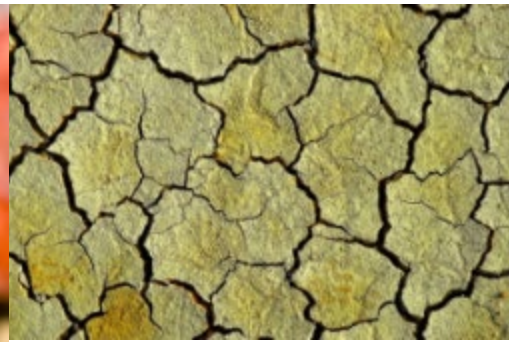





”Climate change will be the defining issue for health systems in the 21st Century. Health Professionals have the knowledge, cultural authority, and responsibility to protect health from climate change.“

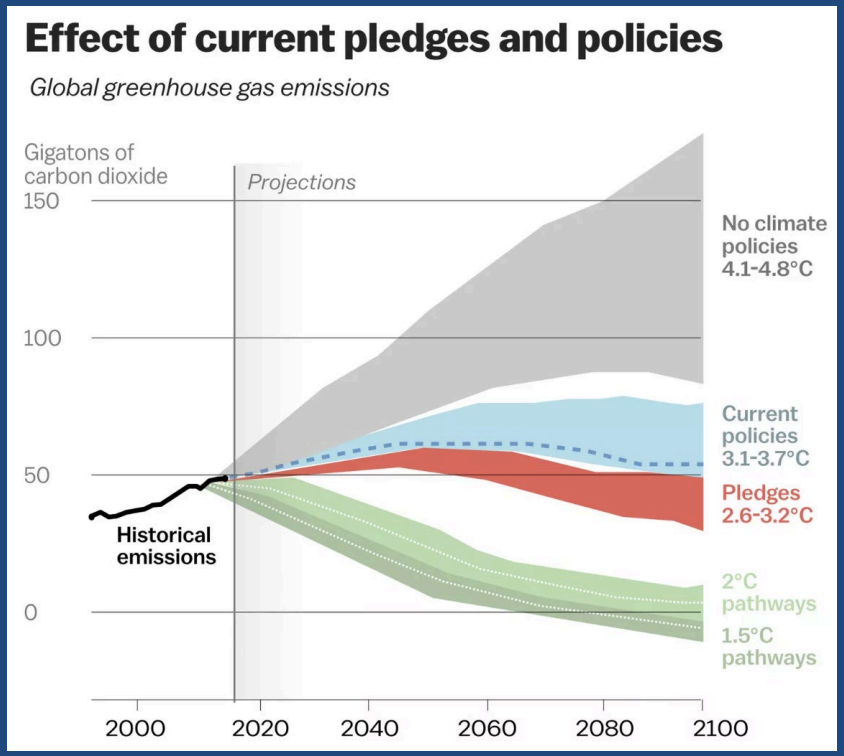
Margaret Chan, MD, Director General, World Health Organization



Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C

October 8, 2018



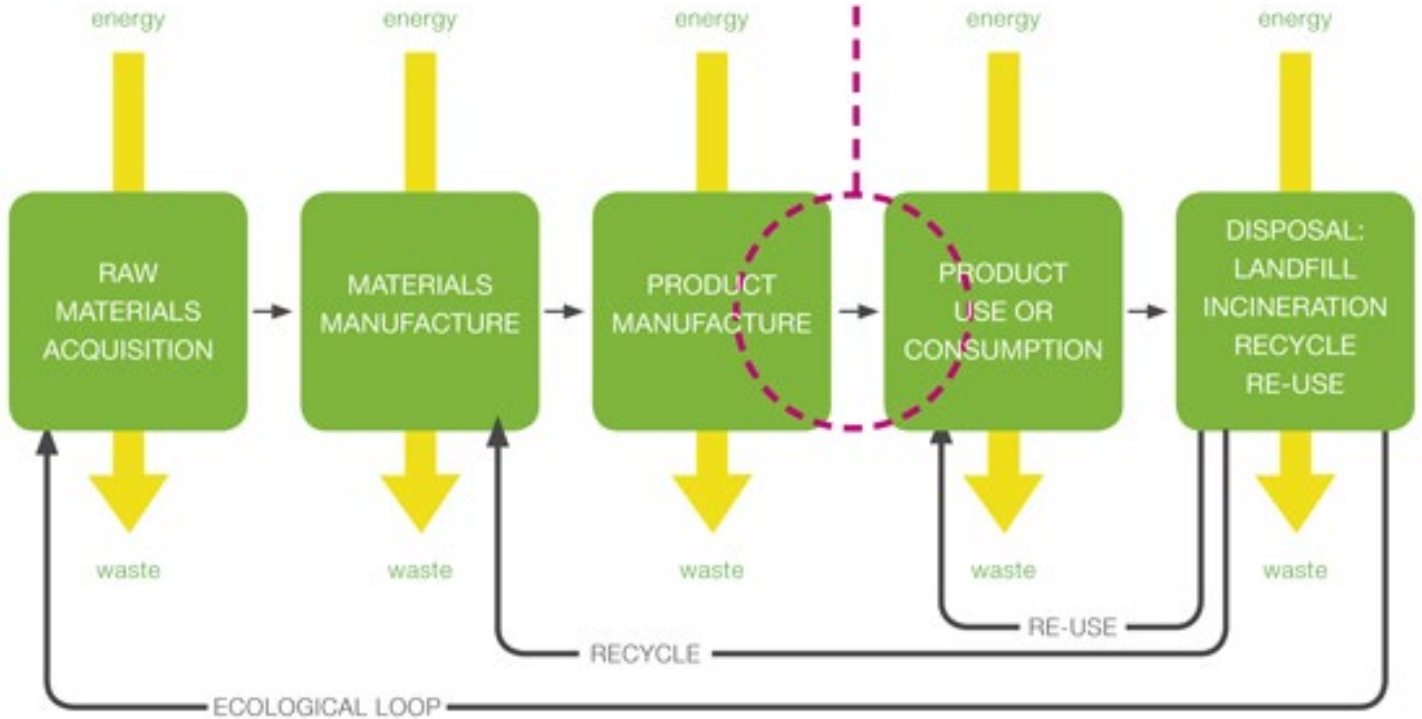
www.climateactiontracker.org

- Already seeing harm from 1°C global warming
- Likely to reach 1.5°C between 2030-2052
- Anthropogenic CO2 emissions need to fall by 45% by 2030, and reach 'net zero' by 2050 to limit to 1.5°C by 2100
- Possible within laws of chemistry and physics. Unprecedented in scale

"The next few years are probably the most important in all of human history."

Debra Roberts, IPCC Co-Chair

Life Cycle Assessment (ISO 14040)



- Environmental impacts can occur at each stage of the life cycle and can be non-intuitive
- Need to consider all stages in order to inform large-scale design or policy decisions
- Need to consider multiple environmental impacts, to ensure that we are not simply shifting burdens from one impact to another

Courtesy M. Eckelman

US health sector
10% of national GHGs emissions

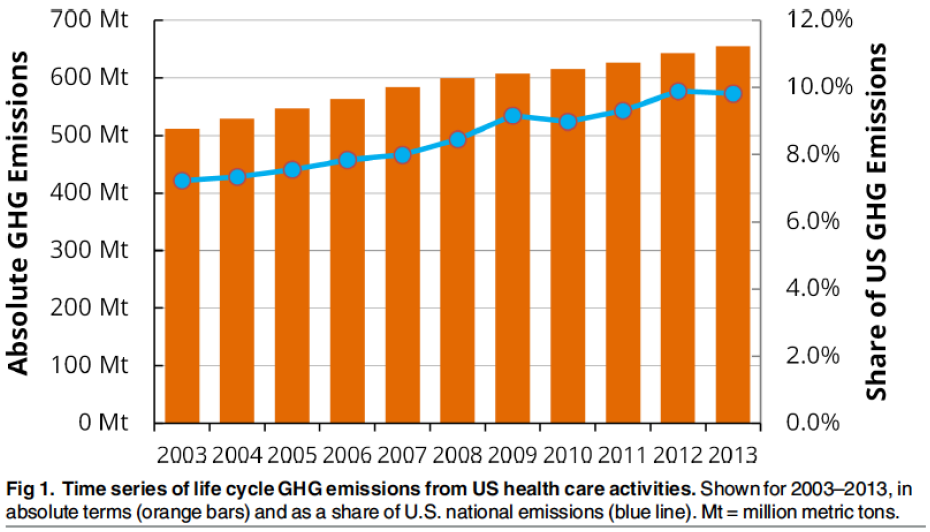
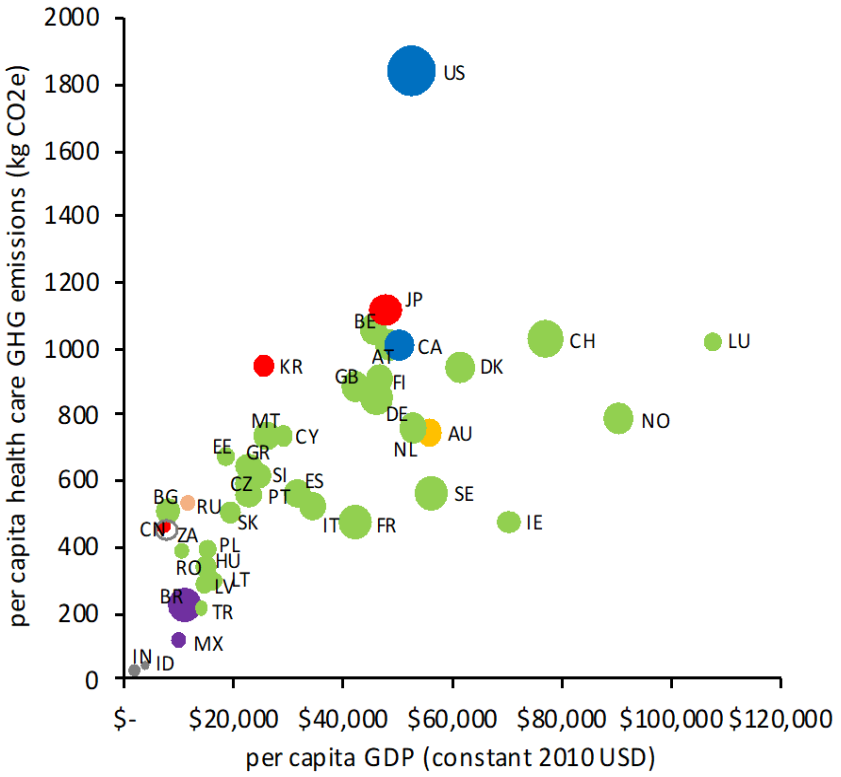


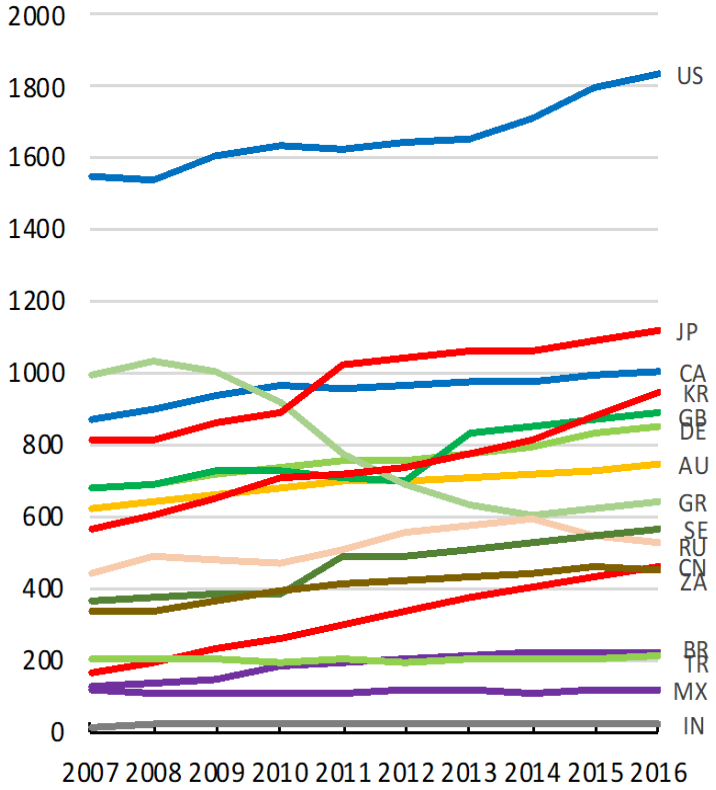
Fig 1. Time series of life cycle GHG emissions from US health care activities. Shown for 2003–2013, in absolute terms (orange bars) and as a share of U.S. national emissions (blue line). Mt = million metric tons.

- If health care were a country, it would rank 13th in the world for GHG emissions
- US health care public health damages from pollution 614,000 DALYs (especially air pollution + climate change)
- Similar in magnitude as the 44,000-88,000 deaths due to medical errors
- **Pollution prevention the new patient safety movement**

Eckelman, Sherman, PLoS ONE 2016
Eckelman, Sherman, Am. J. Public Health 2017

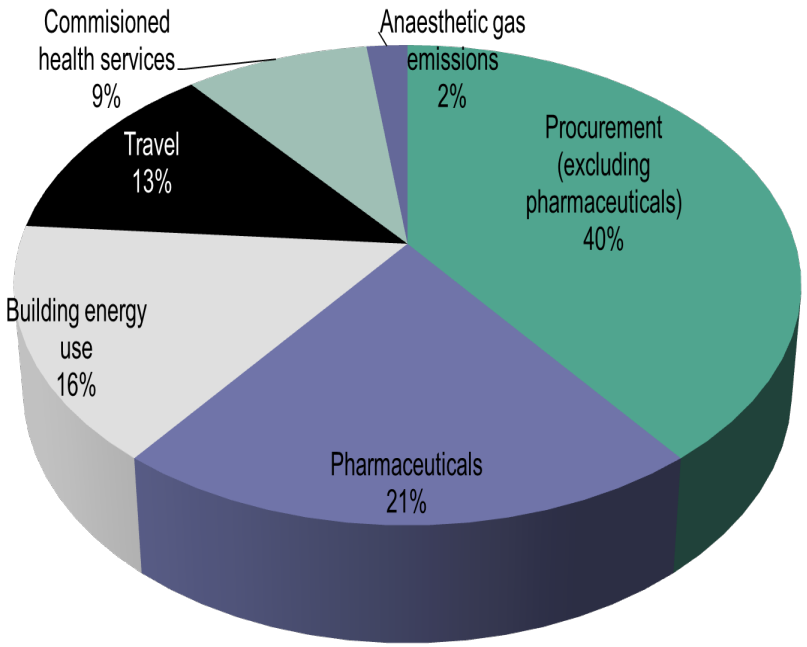
Global healthcare sector GHG emissions 4.6% of global total emissions (2250 Mt CO2e) in 2016





In Press: Courtesy Matt Eckelman, PhD

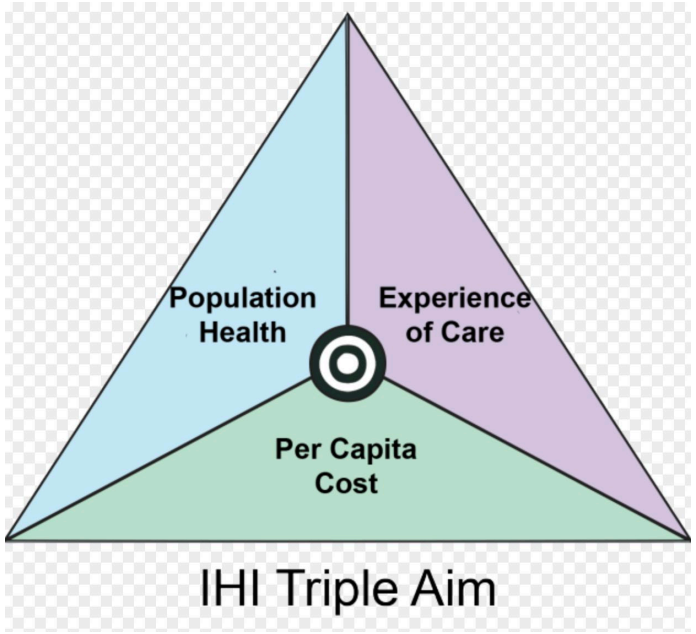
Relative National Health Sector GHG emissions in NHS-England



Sustainable Development Unit, NHS 2013 report

- Major categories:
  - building energy use
  - Travel (staff and patients)
  - Procurement
- 2.5% GHG emissions from anesthetic gases (in the UK, especially N_2O)
- 5% of acute care organization carbon footprint from anesthetic gases

Clinical Sustainability is central to the aims of Quality Improvement



IHI Triple Aim

- Deliver maximum health gain/experience of care
- At minimal financial cost
- While adding value at every opportunity, for the most people

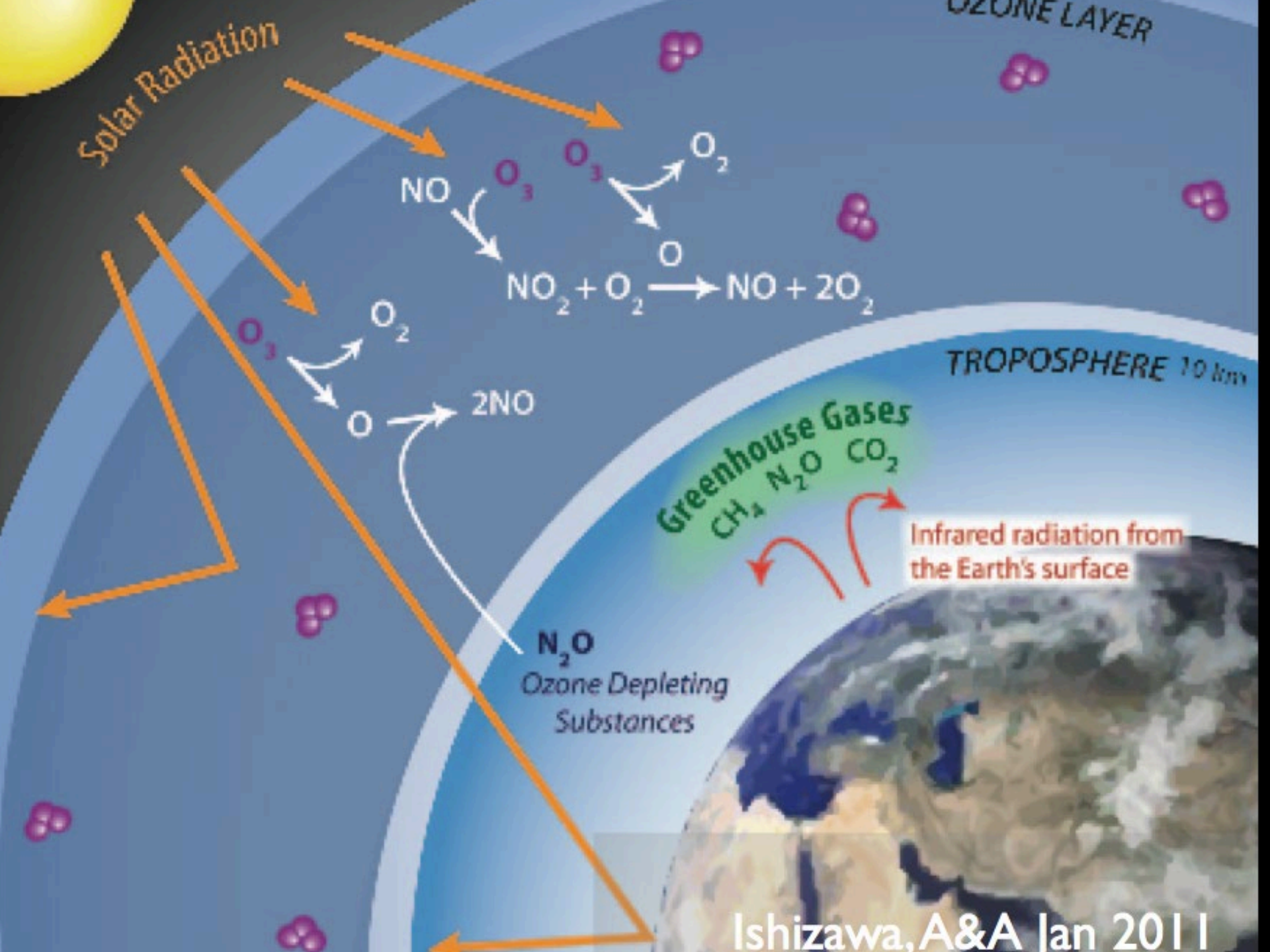
$$\textbf{VALUE} = \frac{\textbf{Outcomes for patients \& populations}}{\textbf{Environmental + Social + Financial costs}}$$

Sherman, et al., Reducing pollution from the health care industry, JAMA 2019

What happens to inhaled anesthetic

Courtesy S. Ryan, UCSF

- 95% vented out the roof of the hospital
- Destroy ozone layer
- Greenhouse gases
- Emissions not controlled


OZONE LAYER
Solar Radiation
NO
O_3
O_3
O_2
O
$NO_2 + O_2 \rightarrow NO + 2O_2$
O_3
O_2
O
2NO
TROPOSPHERE 10 km
Greenhouse Gases
CH_4 N_2O CO_2
Infrared radiation from the Earth's surface
N_2O
Ozone Depleting Substances
Ishizawa, A&A Jan 2011

WAG: One hour of anesthetic like driving a car….miles

(EPA 2012 USA fuel efficiency average, 23.9 mpg)

Courtesy S. Ryan

1-MAC-hour	Sevoflurane 2.2%	Isoflurane 1.2%	Desflurane 6.7%	N_2O* 0.6-MAC-hr
0.5 L/min	XXXX	4	93	29
1.0 L/min	**4**	7	189	57
2.0 L/min	8	15	378	112
5.0 L/min	19	38	939	282
10.0 L/min	38	74	1,876	564

Free Smart Phone App Calculator!

Yale Gassing Greener

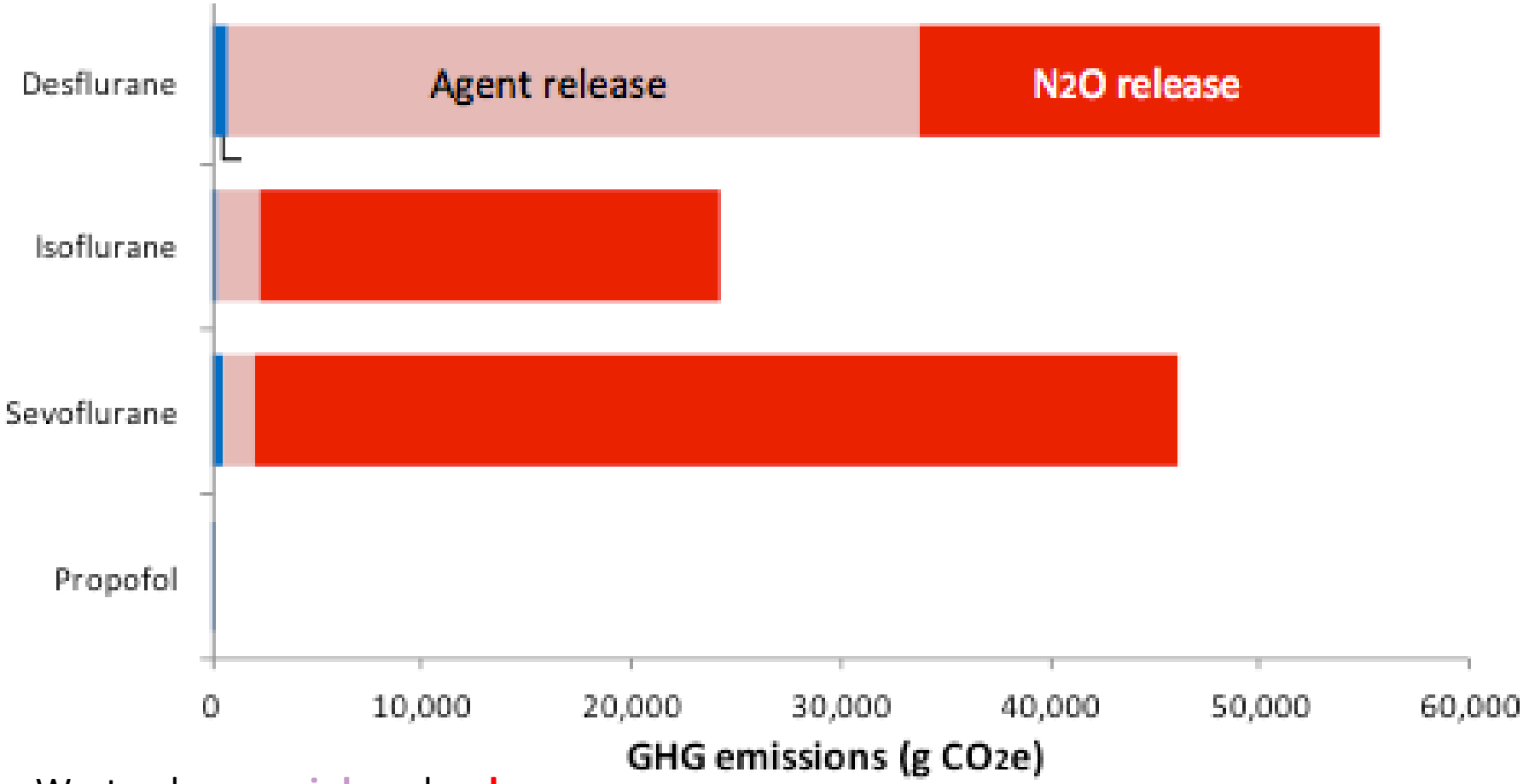
Yale

Free

Life Cycle Assessment (LCA)
Propofol vs. Inhaled Anesthetics

Sherman, Le, Lamers, Eckelman, A&A May 2012

Life Cycle Greenhouse Gases of Anesthetic Drugs (1-MAC-hr)



Waste phase = pink and **red**.

Non-waste phases (manufacturing, transportation, use) = **blue**.

NOTE: Des and Iso @ 1LPM, Sevo @ 2LPM, Prop @ 100 mcg/kg/min (70kg)

Sherman, Le, Lamers, Eckelman, A&A May 2012

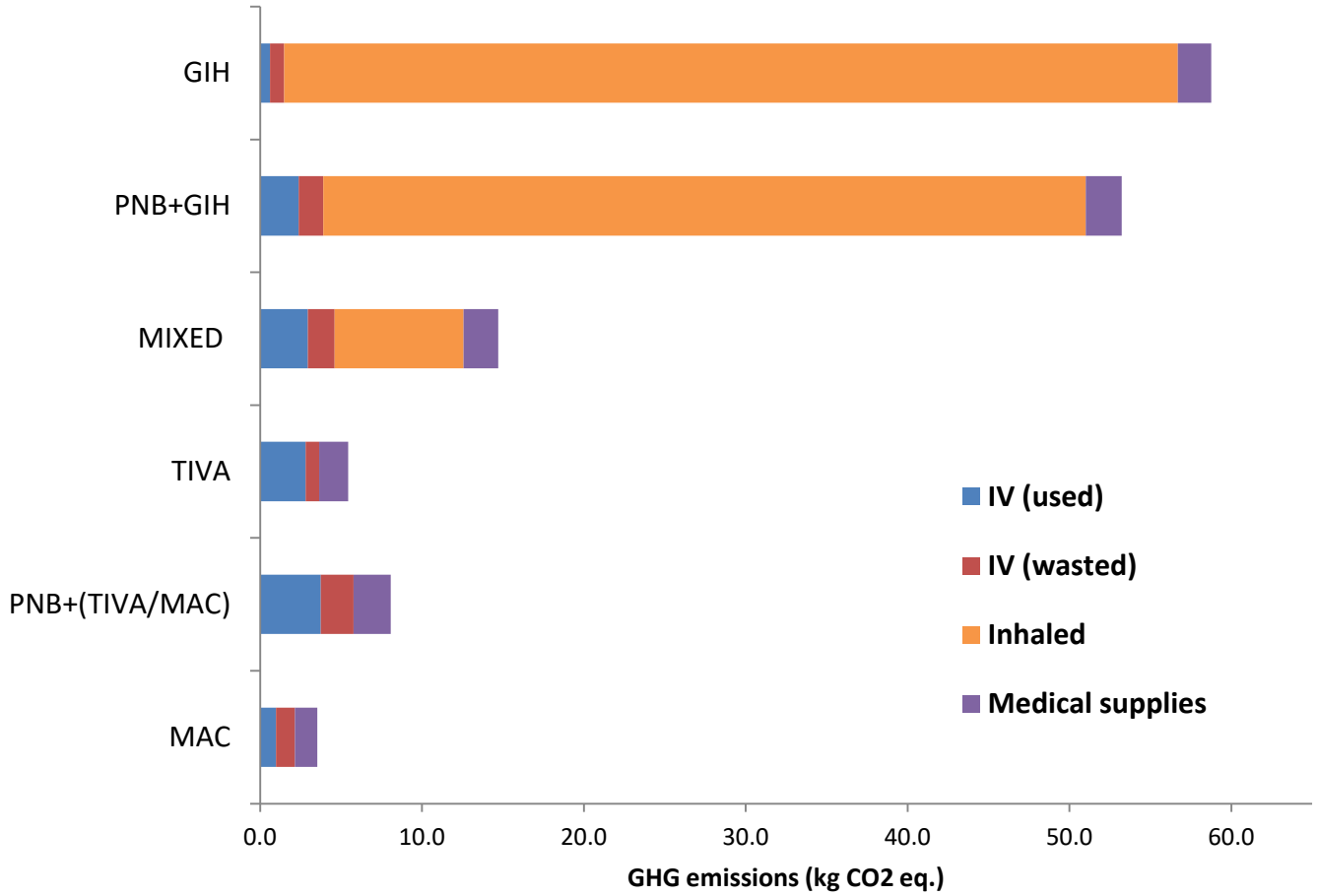
What about Non-inhaled Anesthetics?

- Regional/Peripheral Nerve Blocks

- Neuraxial

- Total Intravenous Anesthesia

Life Cycle GHG Emissions of Alternative Anesthetic Clinical Care Pathways

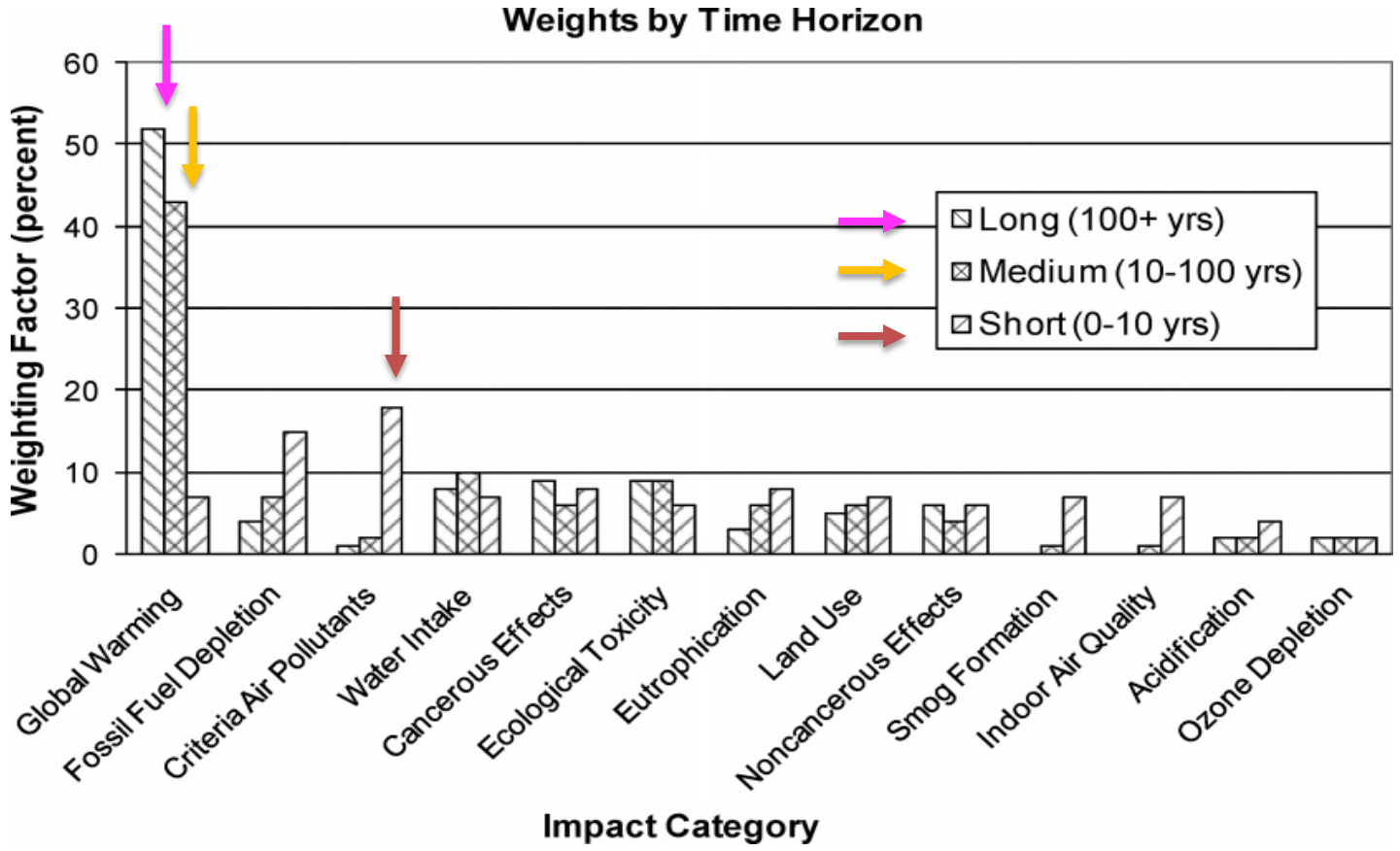


MAC=Monitored Anesthesia Care; PNB=Peripheral Nerve Block;
GIH=General Inhaled (Sevo); TIVA=Total Intravenous Anesthesia

APSF project

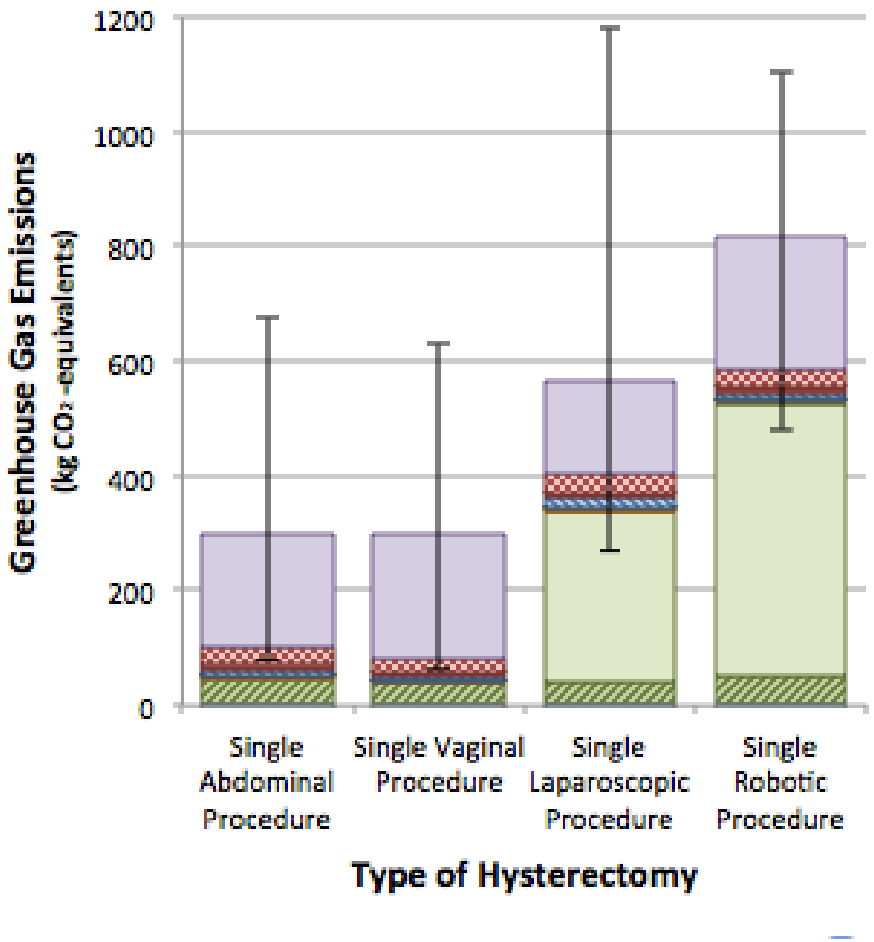
Sherman, Tunceroglu, Parvatker, Eckelman

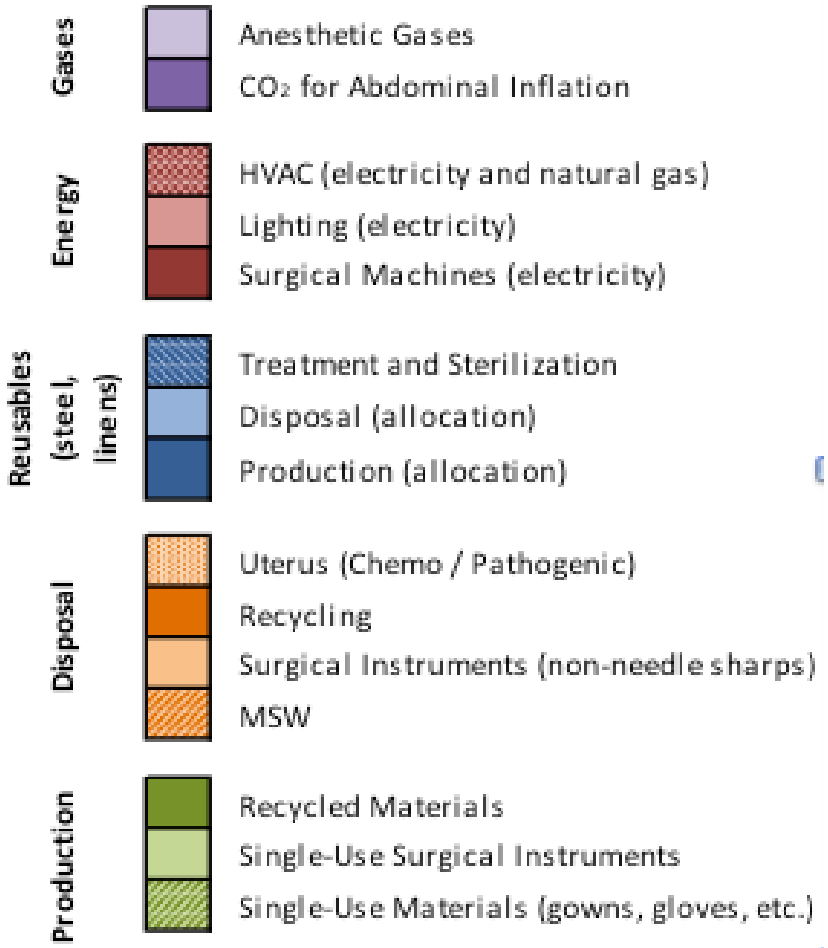
Environmental impact importance by time horizon



Lippiat, et al. Environ Sci Technol. 2007;41(21):7551-7557
Sherman, Barrick, "Pick your poison", A&A 2018

GHG Emissions and Hysterectomy





Thiel, et al., *Environ Sci Technol*, 2015

Example that choices matter: GHG Emissions and Operating Theatres in Three Health Systems

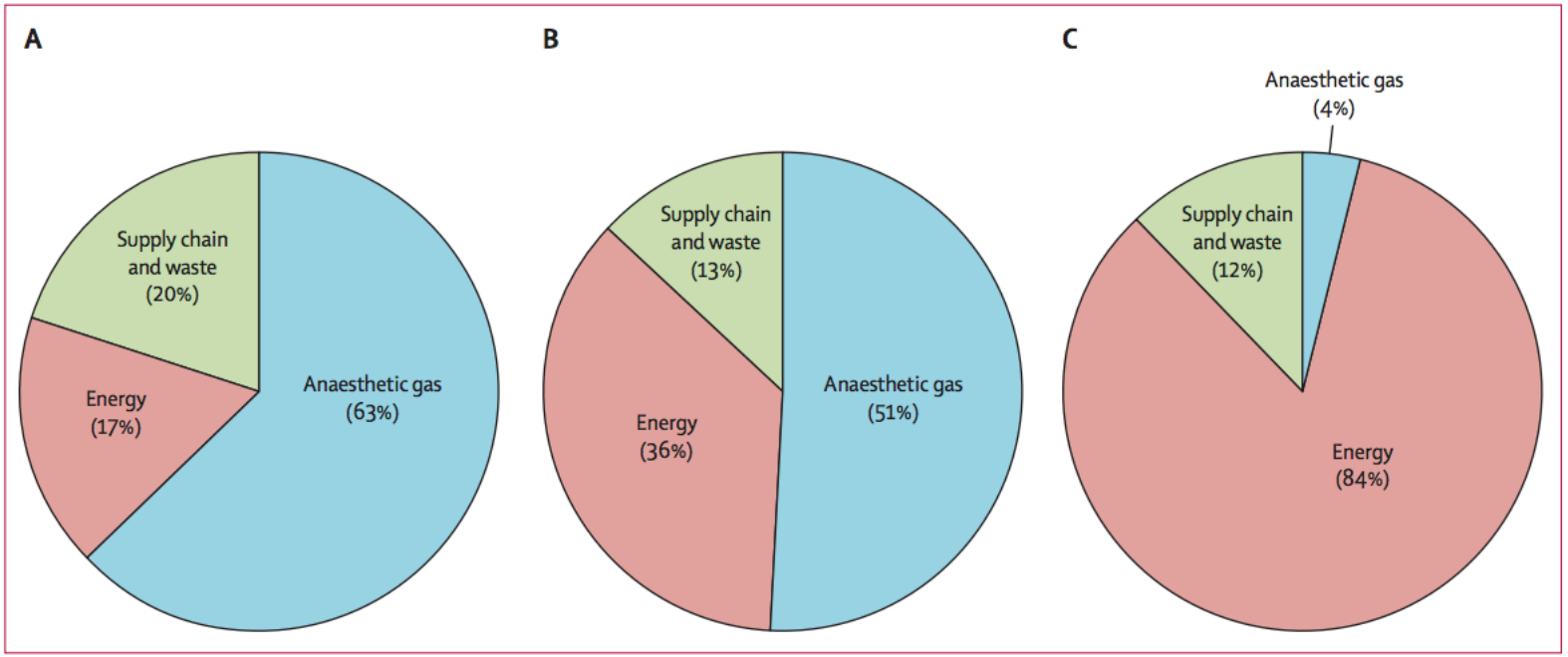


Figure 2: **Relative contribution of scopes 1, 2, and 3 to the carbon footprint of operating theatres at (A) Vancouver General Hospital, (B) University of Minnesota Medical Center, and (C) John Radcliffe Hospital**

Anaesthetic gas=scope 1. Energy=scope 2. Supply chain and waste=scope 3.

MacNeill AJ, et al., Lancet Planetary Health 2017

Do we need desflurane?

- Faster wake times for surgeries < 90”
- Surgeries > 110”, comparable wake up times (85% MAC decrement in VRG)
- <u>Researchers kept at 1-MAC until very end of surgery</u>
- Faster wake up →more $??
  - Patient payer mix
  - Patient volume
  - Staff compensation system

- Eger, et al, *Tutorial: Context-Sensitive Decrement Times for Inhaled Anesthetics*, A&A 2005
- *Dexter, et al, Statistical Modeling of Average and Variability of Time to Extubation for Meta-Analysis Comparing Desflurane to Sevoflurane*, Dexter, A&A 2010

Yale-New Haven Health System

- Eliminated Desflurane from formulary, 2013
- Saved approximately
  - 186,690 kg CO_{2e}/year
  - 456,455 passenger vehicle miles driven/year
- Sevoflurane use up slightly, isoflurane no difference; assumed no difference in TIVA/regional
- Saved $1.2 million across health system/year by eliminating desflurane drug and vaporizers

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

University of Utah

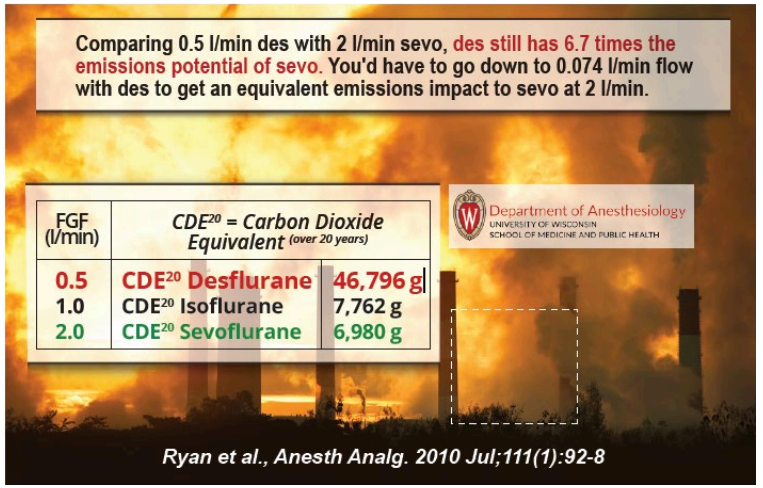
- Cash challenge: electively cut desflurane use by 50%
- Reduced inhaled anesthetic acquisition costs by $308,000
- saved WAG GHG equivalent of 5.4 million miles driven
  - without increasing their turnover times
  - without increasing PACU discharge times
  - Propofol usage did not increase
  - Isoflurane use did increase
  - Sevoflurane use stayed the same
- **Behavior change gone within one year**

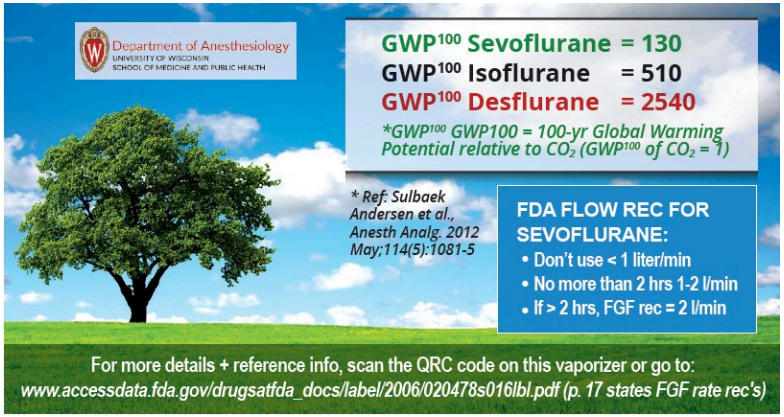
Courtesy H. Hopf, U. Utah

LEARN MORE

University of Wisconsin

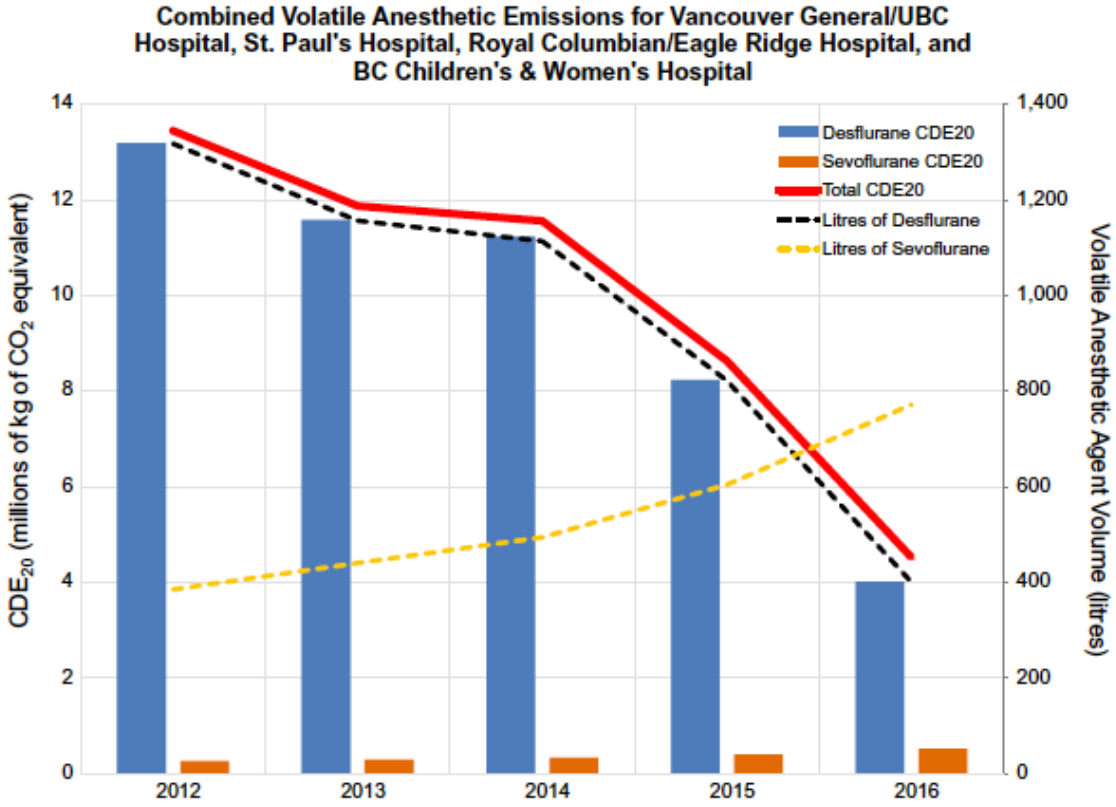
- Educational campaign
- Info stickers on vaporizers (point of decision-making)
- Saved approximately:
  - 2,865,430 kg CO_{2e}/year
    - ↓ Desflurane
    - ↓ N2O
  - 7,005,941 passenger vehicle miles driven/year
  - $300,000 in inhaled drug purchase costs/year
- Behavior change sticking





Zuegge, et al, A&A 2019

Changes in use of desflurane and sevoflurane and carbon emissions University of British Columbia 7 hospitals



Between 2012-2018, saved 8.9 million kg (66% reduction) = 1,700 cars on the road

Alexander, et al. CJA 2018

Oregon: 8 hospitals

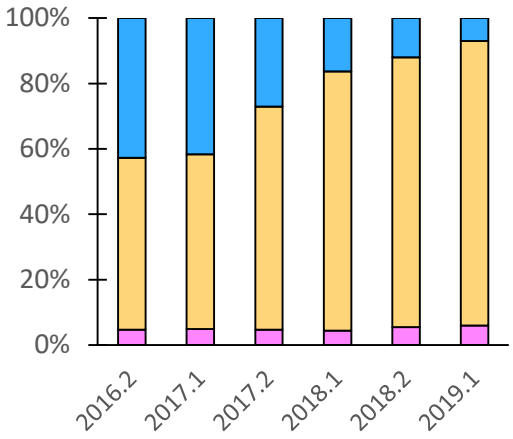
Provider performance reports

2016-2018, saved 4,996,172 kg CO2e = 12,156,135 passenger vehicle miles driven

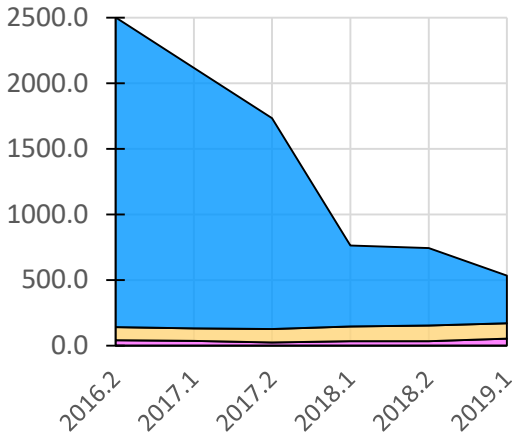
$636,000 per year saved

No difference in out of room time or PACU time

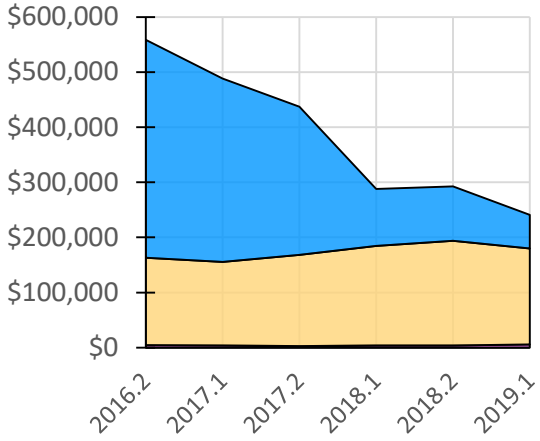
Agent Selection (%)



GHG emissions ($mtCO_2e$)



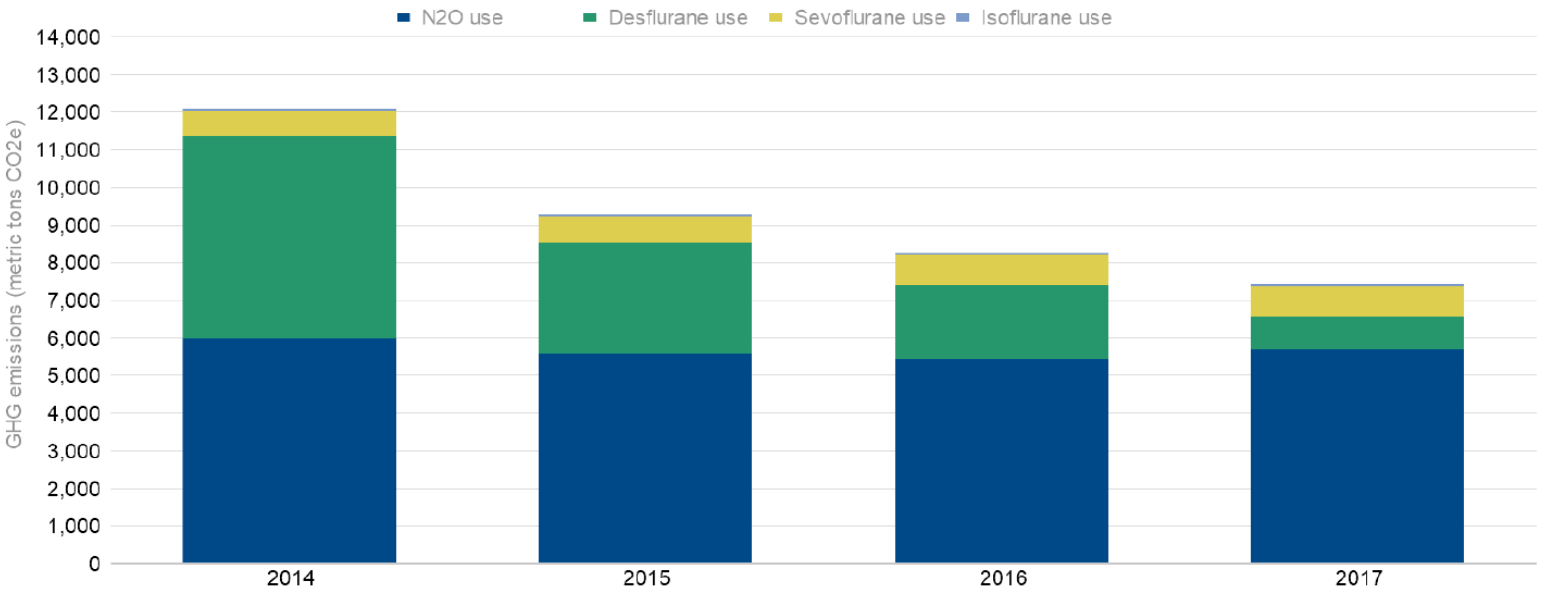
Cost ($)



Desflurane Sevoflurane Isoflurane

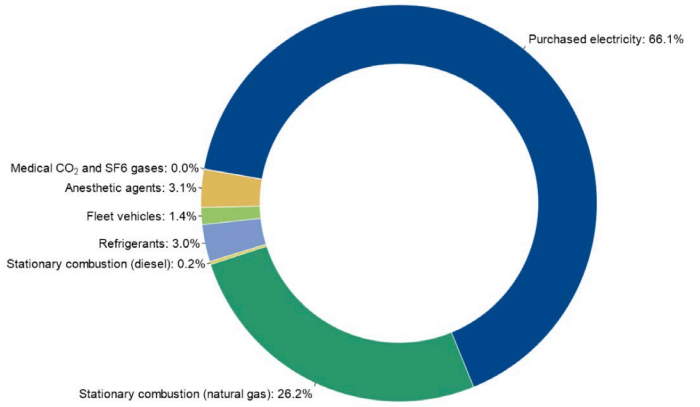
Courtesy Brian Chesebro, MD

Annual GHG emissions associated with anesthetic usage in Kaiser Permanente's Northern California facilities



Between 2014 and 2017, Kaiser Permanente's Northern California region achieved a 39% reduction in GHG emissions associated with its use of anesthetic agents, thanks mainly to replacing desflurane with anesthetics that have lower Global Warming Potential.

Sources of Kaiser Permanente's greenhouse gas emissions in 2016 (operations only)



Scaling Up Inhaled Anesthetic Practice Improvement: The Role of Environmental Sustainability Metrics

- Removing environmentally offensive options
- Creating barriers, e.g. locking up vaporizers
- Financial incentives
- Educational campaigns
- Point-of-care information: $$, GHG
- Feedback reports
- Financial penalties, e.g. pay-for-performance, carbon taxes

Sherman and Berkow, A&A 2019

SUS 01: FGFs

- Percentage of cases with mean FGF ≤ 3 L/min, during admin of inhaled anesthetics
- Inclusion: inhaled anesthetic ≥ 30 min. from placement of airway device to its removal
- Exclusion:
  - Cases in which inhaled anesthetics not used
  - Cases with maintenance period < 30 min
  - Cases where > 20% of FGF values manually entered

SUS 01: FGFs

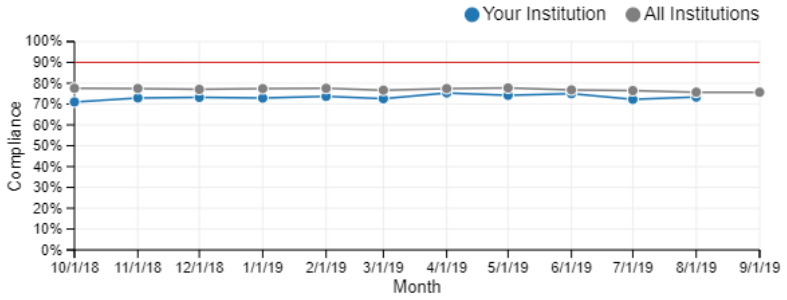
Overall Performance

✖ 73% Target 90%

Counts

SUS-01 Result	Count
Passed	21,696
Failed	7,902
Excluded	40,409
	70,007

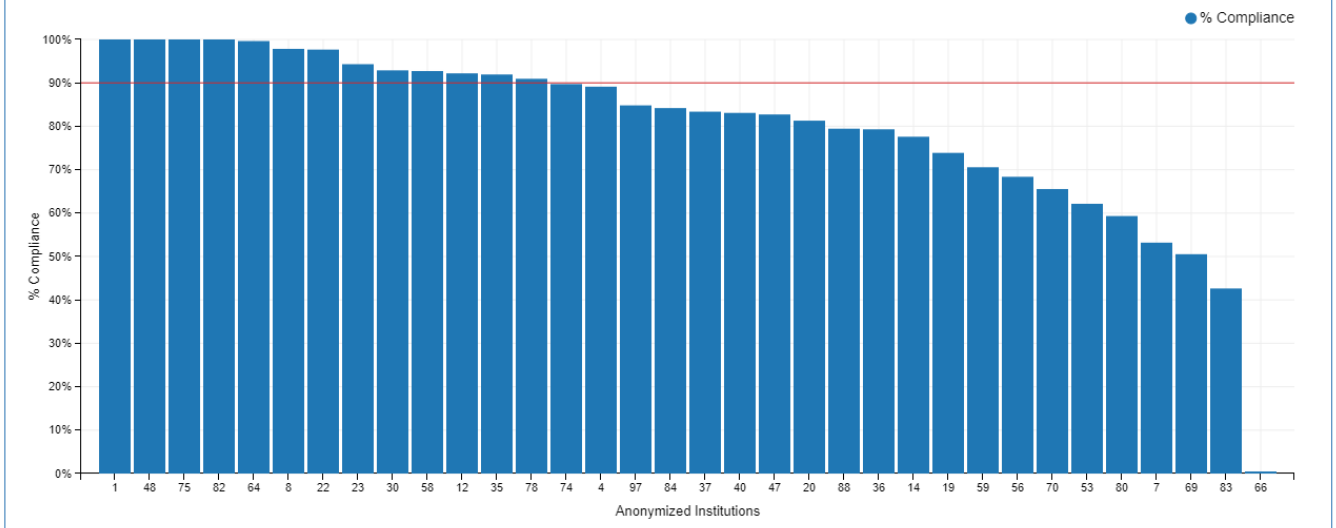
Trend



Breakdown of Primary Cause

SUS-01 Result	SUS-01 Result Reason	Case Count
Excluded	Total Duration of Gas Flow/Agent Ove...	20,945
Excluded	Duration of Maintenance Period (>= 3...	16,625
Excluded	Is Valid Case	2,205
Excluded	Incidence of Manually Entered Gases...	634
Failed	Mean Fresh Gas Flow (<= 3.0 l/min)	7,902
Passed	Mean Fresh Gas Flow (<= 3.0 l/min)	21,696
		70,007

Compliance by Institution



MPOG MULTICENTER PERIOPERATIVE OUTCOMES GROUP

Courtesy Nirav Shah and Kathryn Buehler

Real-time decision support: AIMS alerts

- if FGFs exceed 1 L/min
- If Sevo, after 2 MAC-hours (between 1-2 L/min, then alert changes to 2 L/min
- Mean FGF reduction from 2.10 L/min to 1.59 L/min) (note: unclear inclusion/exclusion)
- Saved $105,000 in 2010

Nair, et al. Anesthesiology, 2013;118:874-884

- What's next for sustainability metrics?
  - Real-time FGF alerts
  - GHG emissions for inhaled anesthetics
  - GHG emissions for other drugs
  - Non-GHG emissions
  - Drug waste
  - Overdosing
- CMS pay-for-performance, accountability

WAG Treatment: don't vent to the atmosphere!

- Charcoal: ultra short-term
  - ↓ Occupational exposure
  - Absorb and release
- Gas-capturing systems
  - Absorb and store
  - Potential reuse, storage issue
  - Volatiles only
- Gas destruction
  - N2O only
- ?? Efficiency
  - Only treat what is exhaled through circuit
  - ⇧FGF= ⇩efficiency

2020 Challenge! Reduce your facility inhaled anesthetic greenhouse gas emissions by 50%

1. Utilize low fresh gas flows
2. Avoid high impact inhaled anesthetics:
   - ⬇ Desflurane and Nitrous Oxide
3. Consider intravenous and regional techniques
4. Invest in WAG trapping or WAG destruction technology

https://publichealth.yale.edu/climate/research/conferences/challenge/

American Society of Anesthesiologists™
Environmental Task Force

Inhaled Anesthesia Climate Initiative

https://publichealth.yale.edu/climate/research/conferences/challenge/

"Health professionals have a duty to care for current and future generations."

World Health Organization

ASA Mission: "Advancing the Practice and Securing the Future"

American Society of Anesthesiologists

Thank you! Jodi.sherman@yale.edu