ANZCA
FPM

PS64BP Position statement on environmental sustainability in anaesthesia and pain medicine practice Background Paper 2026

Short title: Environmental sustainability BP

1. Introduction

Climate change, environmental degradation and pollution are major threats to human health.[1] The Australian and New Zealand College of Anaesthetists (ANZCA)[1] has joined many leading global health organisations, including the World Organization of Family Doctors[2], to declare climate change a health emergency. As trusted leaders across scales, anaesthetists and pain medicine physicians have a vital role to play in influencing policy, regulation, industry, health services and individual practices to mitigate climate change, environmental degradation and pollution.

This Background Paper and corresponding Position Statement provide important updates to ANZCA's initial PS64 *Position Statement on environmental sustainability in anaesthesia and pain medicine* published in 2019.[3] Relevant evidence, knowledge, policies and practices have changed considerably since 2019 and as such this Background Paper aims to guide ANZCA and its fellows to continue leadership and actions to minimise the adverse climate and environmental impact of both the wider health system and individual practices through education, collaboration, advocacy and research. The carbon footprints of Australian and New Zealand healthcare systems are substantial, estimated at 5-7%[4, 5] and 3-4%[6] of total national carbon footprints respectively, and globally if the healthcare sector was a nation it would be the fifth largest national carbon emitter.[7] Uniquely as a medical specialty our daily work practices can directly influence environmental pollution and greenhouse gas emissions, whether it is the products we use, our choice of anaesthetic agent or the protocols and governance structures we are part of.

Noteworthy ANZCA advocacy and leadership since 2019 has included endorsement of the joint statement *'Working together to achieve sustainable high-quality health care in a changing* climate'[8] led by the federal Department of Health and Aged Care and Interim Centre for Disease Control; the multi-college '*Healthy Climate Futures* Campaign'[9]; and the *'Green College Guidelines'*.[10] These are in addition to published Statements on Desflurane[11] and the Decommissioning of Nitrous Oxide Medical Gas Pipeline Infrastructure[12] (the latter in conjunction with both the Australian and New Zealand Societies of Anaesthetists) and numerous other activities, resources and education events[13] supported by ANZCA's Environmental Sustainability Network (ESN).[14]

Importantly, improving health system sustainability is strongly linked to evidence based, effective, efficient health care, and is an opportunity to improve the quality of healthcare we provide. Australia's first Health and Climate Strategy's vision is to create 'Healthy, climate-resilient communities, and a sustainable, resilient, high-quality, net zero health system'[15] and the Australian Commission on Safety and Quality in Health Care (ACSQHC) now has a *Healthcare Sustainability and Resilience module* to guide integration of environmental sustainability and climate resilience into safety and quality standards.[16] The recognition of related education for present and future fellows has advanced also, with the Australian Medical Council (AMC) introducing requirements for sustainable healthcare and environmental health principles into both medical student and pre-vocational curriculums[17], and requirements for medical specialty programs expected soon.[18]

2. Review of issues

2.1 Planetary Boundaries

Australian and New Zealand College of Anaesthetists & the Faculty of Pain Medicine

Planetary health is the concept that human health and wellbeing depend on the health of the earth's natural systems. Significant changes to the Earth's environment, driven by human activity, are threatening to destabilize planetary health. A framework, first proposed in 2009, which defines nine Earth life support systems (planetary systems) and the boundaries for each that is necessary to maintain a "safe operating space" for humans. Earth life support systems are the natural systems and processes that make the planet habitable for humans and other life.

The framework developed out of the scientific understanding of the essential need to measure and maintain the Earth's natural limits to support human growth and wellbeing and the biophysical constraints of the growth economy. It combines input from many fields of global environmental change research, sustainability science, and research into the resilience and self-regulation of living systems.

The 2025 Planetary Health Check revealed seven of the nine boundaries have been breached: Climate Change, Biosphere Integrity, Land System Change, Freshwater Use, Biogeochemical Flows (human driven cycles of nitrogen and phosphorus), Novel Entities (synthetic chemicals, plastics and other human-made materials), and Ocean Acidification. Only two systems – Ozone Depletion and Aerosol Loading – remain in the safe operating space.

Healthcare providers should aim to deliver high quality, high value healthcare within the boundaries of all nine of Earth's planetary life support systems to support human and planetary health.

2.2 Medications

2.2.1 Assessing the global warming effects of inhalational anaesthetic agents

There are a few broad concepts that provide useful background when considering anaesthetic agents and their environmental impact. Since the last background paper, there has been considerable discussion regarding the subtleties of how we interpret climate science, as well as the lasting environmental pollution by Waste Anaesthetic Gas (WAG) breakdown products. These areas are therefore explored in some detail in this background paper.

For volatile agents, concepts related to effects on radiation and what is meant by the term "greenhouse gas" are relevant. An understanding of the impact of N_2O also requires consideration of potential impacts on the ozone (O_3) layer.

2.2.1.1 Ozone Layer Effects

The potential for compounds to be associated with ozone depletion is measured by the ozone depletion potential (ODP) of the agent in question. Halogenated agents that contain chlorine such as isoflurane could potentially be associated with catalytic destruction of O_3 in the atmosphere.[19] However, isoflurane and methoxyflurane are typically photocatalysed at lower altitudes, minimising their impact, and atmospheric oxidation of desflurane and sevoflurane seem not to result in ozone depletion since they are purely fluorinated ethers.

N_2O, however, persists in the environment for over 100 years, allowing accumulation in the stratosphere. Here it is broken down by UV to release reactive nitrogen species (NO and NO_2) which catalyse the depletion of O_3. N_2O is therefore a significant ozone-depleting gas.

2.2.1.2 Concepts of the earth's "energy budget", radiative forcing and global warming potential:

The concept of the Earth's "energy budget" refers to the balance of energy the earth receives from the sun and the energy it then radiates back into space.[20] The balance between these maintains enough energy to maintain the habitable conditions that we exist in, whilst allowing enough heat to escape to prevent runaway thermal rise. The incoming energy is largely short wavelength solar radiation (because the sun is at a very high temperature) and escapes as longer wavelength infrared radiation (because the earth is cooler).

Compounds with atomic bonds manifesting a dipole moment absorb and re-emit infra-red (IR) radiation in characteristic spectrums dependent on vibrational resonance in their chemical bonding structure. This is as relevant for climate change as it is for anaesthesia monitoring devices, as these compounds will absorb and then re-radiate this energy back towards the earth from high altitude, trapping the energy in the atmosphere (radiative forcing). Symmetrical diatomic molecules such as oxygen (O_2) and nitrogen (N_2) do not absorb IR in this manner, allowing the earth to radiate energy to space in the IR band as the atmosphere is predominantly O_2 and N_2. This prevents excessive buildup of heat in our environment. There are natural IR absorbers (CO_2, O_3, methane and water vapour) which allow sufficient insulation to maintain the climate temperature that we are adapted to. Of note: the natural absorbers do not absorb across the full IR spectrum, allowing an “atmospheric window” for radiative loss. It is the addition of extra persistent radiative forcing compounds in the atmosphere which increases the climate insulation and thus results in global warming.

The magnitude of this effect is proportional to:

1. Amount of energy absorbed/re-radiated by the agent.
2. The wavelengths absorbed (e.g. within the atmospheric IR window / overlap with already maximally influenced spectra).
3. Mass of the agent accumulating in the troposphere.
4. Duration of that radiative forcing agent (and breakdown products) in the troposphere.

Each WAG, and their photochemical breakdown products, absorb IR over a unique range of wavelengths and to varying intensities depending on their chemical structure. This can be assessed by the integrated absorption cross-section which measures how efficiently the gas in question may affect the balance of radiation entering and leaving the Earth’s atmosphere.[21] Where a particular substance has the effect of pushing the balance between incoming and outgoing radiation energy to favour warming, this is referred to as positive *radiative forcing* (expressed in watts per square meter (W/m^2)). This value depends on the concentration of the compound in the stratosphere, so the value of *radiative efficiency* is used to indicate the “strength” of warming as parts per billion (W/m^2/ppb). Even though N_2O has a lower radiative efficiency than the halogenated ether volatiles, it’s accumulated concentration in the stratosphere is much higher, so that it contributes more radiative forcing. By combining the known lifetime of an agent in the atmosphere and its radiative efficiency, it is possible to calculate the *Global Warming Potential* (GWP) normalised to the reference gas CO_2.[22-24] This allows us to account for the effect of agents of varying radiative forcing intensity as well as their persistence in the environment. It is typically expressed as a multiple of CO_2 effect and correlated with a time period (eg: GWP20, GWP100) to account for the duration in the atmosphere. It is important to note that for a WAG to exert its climate forcing effect it must persist long enough to mix and accumulate in the troposphere which requires at least 1 year.

2.2.2 Nitrous oxide

N_2O is a long-lived greenhouse gas with a global warming potential 273 times that of CO_2 over 100 years, and it also depletes the O_3 layer.[25] Although medical use only accounts for 1-3% of N_2O emissions, it is estimated to account for 20% of the Australian healthcare sector's direct (scope 1) emissions.

N_2O leaks in considerable amounts from the centralised pressurised medical gas pipeline systems (N_2O MGPS; commonly known as reticulated systems in Australia and NZ), accounting for 47-100% of procured N_2O. In addition, though it is a lesser source of emissions, cylinders returned to suppliers have their residual volumes vented to the atmosphere.

Efforts to reduce emissions include avoiding installation of new N_2O MGPS, decommissioning existing N_2O MGPS, utilising point of care cylinder supply where clinical use is indicated, and fully utilising cylinder contents. This is formally endorsed by ANZCA, United Kingdom and Irish Anaesthetic societies (RCoA/AoA/CAI/APAGBI/OAA)[26], the American Society of Anaesthesiologists[27], and the World Health Organisation.[28] The Australasian Health Facilities Guidelines were amended in 2025 with ANZCA's support to state that N_2O MGPS are no longer mandatory for any service.[29]

Change to cylinder supply at the point of care in the operating theatre and remote clinical areas requires advocacy and engagement with anaesthetic clinicians, non-anaesthetic clinicians, and non-clinical staff. It is not always feasible to immediately decommission N_2O MGPS; in these situations, investigations for leaks should be carried out in accordance with Australian Government Guidelines while preparing to decommission part or all of the MGPS in future.[30]

The use of N_2O can represent the vast majority of the emissions of an anaesthetic. Consequently, there is a growing body of opinion advocating for the avoidance of its use in anaesthesia to reduce the GHG impact of an anaesthetic.

Other strategies to reduce N_2O related emissions include reducing the FGF and using it for the lowest possible duration.[31, 32] Technologies that can capture and destroy N_2O to avoid its environmental impact are emerging, although they cannot be used in the presence of inhaled anaesthetic agents, which limits their use in the operating theatre. Its use may be beneficial in birthing suites and where N_2O is used as a sole agent for sedation, though evidence of efficacy is lacking.[33]

Despite these technological advancements, the most impactful strategies to reduce the environmental impact of N_2O are to decommission and avoid installation of N_2O MGPS, and to reduce its clinical use.

2.2.3 Inhalational anaesthesia agents

Modern volatile anaesthetics such as desflurane and sevoflurane have lower toxicity than older agents due to minimal hepatic metabolism, but their strong carbon–fluorine (C–F) bonds make them resistant to atmospheric breakdown, allowing persistence in the troposphere. Desflurane, with a much higher GWP100, and lower potency than sevoflurane, has a disproportionately greater climate impact per unit of anaesthesia delivered. Replacing desflurane with sevoflurane reduces CO_2-equivalent emissions by approximately 10-fold at a fresh gas flow of 0.5 L/min and 39-fold at 2 L/min.

Volatile Agent	*Atmospheric Lifetime* *(years)*	*GWP 100*[23, 24, 34] *(range of calculations)*	*Radiative Efficiency* *(W/m²/ppb)*	*Effective Radiative Forcing (W/m²)*
Sevoflurane	1.41 - 1.9	140 - 205	0.31	0.00003
Isoflurane	3.5	536 - 565	0.43	0.00006
Desflurane	13.7 - 14.1	2530 - 2720	0.46	0.00017
N_2O	120	273	0.0032[35]	0.21

Although the rapid onset/offset characteristics of desflurane with postulated advantages in neurosurgical and bariatric cases has been heavily discussed in previous years, the real-world clinical advantages have been questioned with only small changes in technique accounting for wakeup speed variation.[36] It is increasingly common in Australasia and worldwide, to see anaesthesia departments who have completely ceased or significantly reduced using desflurane. Calls for desflurane to be withdrawn from use due to its environmental harm are common. Of note, desflurane was removed from routine clinical use in England and Wales in 2024, excepting a small number of clinical situations. However, the global market continues to expand and, in some nations, continued high FGF techniques continue to be employed.

2.2.3.1 Considerations in assessing the impact of volatile anaesthesia over time epochs.

In recent years, counter arguments have been provided that the environmental impacts of volatile anaesthetics have been overstated by focusing on a purely GWP metric and of limited significance to global CO_2 release.[37-39] When compared with CO_2, WAGs (except N_2O) have a comparatively short atmospheric lifetime which limits their accumulation in the troposphere where they must accumulate to exert their effect. As CO_2 has such a prolonged impact on radiative forcing, and is released in much larger quantities, it is argued that the total impact on global mean surface temperature by atmospheric waste anaesthesia gases is small and short lived compared with other sources of greenhouse gases. This has been taken by some as a reason to minimise or ignore the environmental recommendations within anaesthesia.

A counter argument to this is that this diminishes personal responsibility.[40] Individuals in the anaesthesia community have a disproportionate climate impact compared with others, and these are small changes in our practice that can minimise one's personal carbon footprint and reduce the environmental harm caused by our specialty. It is also a practice change that will see benefits in a smaller time frame. Others have noted that the GWP concept, whilst not telling the entire story, does account for a shorter-lived molecule's impact over time and that the existing arguments based on GWP assessments in minimising WAG release continue to be valid.[41]

However, it does highlight that we should consider the reduction in genuine CO_2 emissions associated with health care due to the persistence of CO_2 in the environment once released. For WAGs this implies that we should be additionally considering the life cycle carbon footprint of production and supply as well as simple GWP dynamics when comparing with other anaesthesia techniques. This does continue to be a valid argument for utilising propofol infusions and regional anaesthesia over volatile anaesthetic techniques[42], although employing low FGF approaches and capture/recycling technologies may narrow this gap.

2.2.3.2 Volatile anaesthetic relevance regarding per- and polyfluoroalkyl substances (PFAS)

Volatile anaesthesia agents comprising Tri-fluorinated methyl groups ($-CF_3$) are classified as Per- and Polyfluoroalkyl Substances (PFAS). Due to the strength of their C-F bond and lack of environmental pathways of degradation these are colloquially known as “forever chemicals”. PFAS are pervasive in environmental water worldwide with Australia being one of the mapped “hotspots” (although this may represent sampling bias).[43] PFAS exposure has been linked to multiple cancers, thyroid dysfunction, dyslipidaemia, changes in cholesterol, and decreased infant and foetal growth, increased risk of pregnancy-induced hypertension and ulcerative colitis.[44] There has been an increasing body of literature in recent years concerning the impact of WAG in this area.[34, 45] The highly soluble hepatic and photochemical breakdown products fall within the definition of PFAS and accumulate in aqueous environments. Whilst concerns about propofol’s environmental impact has been previously considered, it is only recently that it has become clear that sevoflurane might represent a 20 to 120 times greater environmental burden and desflurane threefold higher than sevoflurane.[45]

The degradation products of sevoflurane and desflurane yield hexafluorisopropanol (HFIP) and trifluoroacetic acid (TFA) which introduce PFAS to the environment through urinary excretion and wet deposition (rain/fog/snow) into aquatic ecosystems. As well as WAG release, they are introduced through fluorochemical pesticides, refrigerant gases and catalysed breakdown of PFAS molecules. As they are renally excretable, they do not bioaccumulate in animals, and these short chain PFAS compounds are currently considered low-moderate toxicity. However, they are observed to be accumulating at orders of magnitude higher than longer chain PFAS compounds.[46] The EU Drinking Water Directive sets a limit of 0.5 µg/L (500 nanograms per litre) for total PFAS.[47] Australia and New Zealand limits concentrate on individual chemicals at comparable levels, with Australia currently reducing its tolerated levels considerably in 2025.[48, 49] However, a recent report measuring TFA in European surface water and ground water recorded an exceedance of the 0.5 µg/L threshold in 79% of samples, with more than 98% of the detected mass of total PFAS being TFA. TFA is often excluded from PFAS accounting due to its lower observed toxicity and lack of mammalian bioaccumulation, but questions regarding this and plant accumulation remain. What is unquestioned is that the concentrations of TFA are accumulating in the environment with no clear biological mechanisms for breakdown.[50, 51]

Because of the amount of TFA/HFIP produced by volatile anaesthetics, they are potentially a significant contributor to this environmental pollution. Each hour of maintenance anaesthesia in one patient results in 240 mg of HFIP excreted via urine into the local water system, contaminating 480,000 L of water when diluted to the threshold limit of 0.5 µg/L. Including atmospheric breakdown; the global consumption of 8 million bottles of sevoflurane in 2022 would, if diluted to the EU limit, require 3.5×10^{15} L of water, or 3,500 cubic kilometres.[45]

2.2.3.3 Volatile capture technologies

Examples of WAG capture systems are commercially available in Europe and Canada that filter WAG in gas scavenging systems to reduce environmental release[52]. Smaller examples of these technologies are commonly available for malignant hyperthermia mitigation. The filter materials are effective in binding WAGs but clinical application can impact their efficiency.[34, 42, 53] There currently are complexities in recycling these compounds for re-use in the context of circular economic principals which may be mitigated in the future and commercial degradation technologies are a potential approach. At present, no system is available in the Australasian market.

2.2.4 Intravenous agents

For intravenous agents, issues of direct contributions to climate change through their chemical properties are not the most significant issue. The more substantial issue with intravenous agents may relate to the entire procurement chain, which accounts for up to 60% of the healthcare-related climate impact, of which at least half is derived from pharmaceuticals and medical equipment.[54] In considering the impact of a drug over its entire life cycle, it is necessary to consider methods of manufacture, packaging, transport to the hospital, energy and materials required for drug delivery, whether it re-enters the environment in an unmetabolised form and waste production and management of unused drugs. Correct disposal of excess medications is essential to minimise their wider environmental impact, and medications should never be disposed of via the common sewage pathways.

The greenhouse gas emissions related to propofol was found in a LCA published in 2012[55] to be nearly four orders of magnitude lower than desflurane or nitrous oxide, and significantly lower than sevoflurane or isoflurane. This study assumes a 50% wastage of propofol, and takes into account the plastic disposables required to deliver the drug. The main greenhouse gas emissions attributed to propofol result from the energy requirements to operate syringe pumps, with minor contributions from manufacturing and waste.[56-60]

Optimal fresh gas flow for use with TIVA is determined by many factors including clinical and environmental considerations.[61] Higher flows are required for laparoscopic surgery. Optimisation for the environment is determined by local grid emission factors and the method of carbon dioxide absorbent disposal, as well as the patient's minute ventilation. This can be calculated when these variables are known. FiO2 should also be kept to a clinically appropriate minimum to reduce unnecessary emissions related to the manufacture and transport of medical oxygen.

2.2.5 Sustainable prescribing practices

Pharmaceuticals contribute to environmental harm across their life cycle, including resource-intensive manufacturing, greenhouse gas emissions, inappropriate prescribing, and the release of active pharmaceutical ingredients into ecosystems through excretion and improper disposal.[56, 57]

The Environmental Pain Approach advocates for multimodal pain management strategies that minimise reliance on long-term pharmacotherapy, particularly opioids and other high-impact medications, thereby reducing environmental burden while improving patient outcomes.[59] These strategies are endorsed by programs such as The Opioid Analgesic Stewardship in Acute Pain Clinical Care Standard, the Low Back Pain Clinical Care Standard, The Osteoarthritis of the Knee Clinical Care Standard (Australian Commission on Safety and Quality in Health Care).

Reducing the size of drug vials available can reduce drug wastage, as shown in an audit of propofol use, which showed that limiting the availability of propofol vials to the smallest available size (20mL) reduced the amount of propofol wasted from 29.2mL/day/bin wasted to 2.8mL/day/bin.

2.3 Waste

Effective reduction of waste in healthcare requires solutions which make full use of the value of products which are used, according to circular economy principles. This includes strategies such as rethinking systems, reducing the number of products opened, and reusing products as well as optimising recycling streams for waste generated. This kind of system transformation requires change at macro (government policy), meso (hospital) and micro (individual attitudes and behaviours) levels.

2.3.1 Circular economy[62]

A linear economy is an economic model where resources are extracted to make products that eventually end up as waste and are thrown away. Products and materials are generally not used to their full potential in a linear economy, and the result is an unsustainable system which degrades natural systems and drives climate change and biodiversity loss.

By contrast, in a *circular economy*, products and materials are kept in circulation for as long as possible through processes such as reuse, refurbishment, remanufacture and recycling. The circular economy is based on three principles:

1. Eliminate waste and pollution
2. Circulate products and materials (at their highest value)
3. Regenerate nature

This strategy enhances the value and lifecycle of the products, materials and resources, and by doing so reduces our reliance on raw materials, protecting finite resources. A circular economy framework improves the sustainability of a system and promotes a better balance between society, environment and the economy.

Circular economy principles can be applied to healthcare systems by examining the ladder of "R strategies"[63] (see figure below). This ladder highlights the greater benefit of actions which drive more circularity (such as refusing, rethinking and reducing use) compared to actions lower on the ladder. All strategies which improve circularity should be considered in system design.

Figure 1: R Strategies for a circular economy*

MORE CIRCULAR

Design products and services differently for smarter use of materials		Health system examples
R0 REFUSE	Prevent use of products and raw materials while providing the same or better functionality or outcome through a different approach.	Social prescribing, redesigned theatre packs, sustainable building design
R1 RETHINK	Make product use more intensive (e.g by sharing products or services).	Precinct level partnerships to share resources (e.g sharing electric vehicle infrastructure), integrated models of care, leasing arrangements for high cost medical devices
R2 REDUCE	Increase efficiency in product use and/or manufacture by consuming fewer natural resources and materials.	Increased in-patient food choices, less use of packaging, medicines optimisation
Extend lifespan of products and their parts		
R3 REUSE	Reuse products that are in good condition and fulfill their original function including by reprocessing medical devices designed to be re-used and remanufacturing medical devices designated single-use (per TGA regulations).	Reuse of medical equipment (e.g crutches), instruments, scrubs, reusable cups
R4 REPAIR	Maintain and repair of products so that they can be used with their original function.	Regular maintenance and repair of equipment and furnishings
R5 REFURBISH	Restore old products and bring them up to date.	Refurbishing of medical and electronic equipment (e.g mobile phones) for re-sale or donation
R6 REMANUFACTURE	Reuse parts of discarded products in new products with the same function.	Reuse of equipment parts in new equipment
Useful application of materials		
R7 REPURPOSE	Use discarded products or their parts in a new product with a different function.	Reuse of medical equipment for educational purposes, donation of towels for animal shelter bedding
R8 RECYCLE	Process products at end of life to obtain materials for use in new products.	Recycling paper, plastics, metals and organic waste for compost
R9 RECOVER	Process or incinerate materials at end of life with energy recovery.	Onsite waste to energy systems using food waste

MORE LINEAR

**'R Strategies for a circular economy' from Accelerating towards net zero: A guide for the Australian health system[63] (Adapted from: Sustainability Victoria Strategic Plan 2024-2027[64], and Outline of the circular economy[65])*

2.3.2 Green procurement principles

Procurement and supply chain activities account for up to 70 per cent of healthcare emissions. The supply chain is the complete network of activities and resources used in the creation and delivery of products, from the initial sourcing of the raw materials to delivery of the final product to the anaesthetist. For example, virgin plastic is extracted from petrochemicals to produce laryngeal masks, energy intensive stainless steel produced from mined iron ore is required for cannulas and sea, air and/or road freight are required to deliver all products. Decarbonisation of these supply chains is crucial for achieving sustainable healthcare. [66]

Healthcare procurement processes are generally based on commercial arrangements without adequate environmental considerations. Embedding sustainability into procurement processes requires system change, and anaesthetists can contribute to this transformation through participation in hospital procurement committees, as well as through research, education, leadership and advocacy.

Robust evidence which considers the manufacture, transport and waste management of products should be utilised in procurement decisions. When comparing reusable with single use disposable alternatives, and when comparing alternative “green” single use items, manufacturer claims of reduced cost, infection risk, and environmental impact should be scrutinized using sound evidence-based methods.

2.3.2.1 Case example: greenwashing

‘Natural fibre’ anaesthetic drug trays are often promoted as an environmentally friendly alternative to single-use plastic trays because they can be composted. However, an Australian LCA conducted by Lightfoot and colleagues[67] found that small polystyrene trays actually had lower associated carbon emissions, largely due to their reduced mass and lower water use, particulate matter formation, and mineral resource depletion.

The study also noted that the claimed composting benefits of natural fibre trays were not consistently achieved in real-world settings, highlighting the need to critically evaluate manufacturers’ sustainability claims. Overall, the analysis strongly recommended reconsidering the routine use of single-use drug trays for every procedure in favour of reusable plastic drug trays.

Further information on green procurement can be found in the Sustainable Procurement in Healthcare Guide published by Practice Greenhealth, Healthcare Without Harm, and Global Green and Healthy Hospitals. [68]

2.3.3 Reducing material waste

In addition to the recommendations in the Position Statement, the following examples illustrate further practical ways anaesthetists can reduce the environmental harm we cause while providing high quality care to patients.

Hospitals should employ effective water conservation strategies, including the use of water aerators to reduce the amount of water used for the same apparent volume, fixing leaking plumbing, motion-sensitive automatic surgical taps, and ensuring maximum capacity of washers (both in equipment and laundry cleaning).[69]

Surgical scrubbing with alcohol-based hand rub reduces water use, has secondary benefits of reducing waste from ancillary items such as towels, scrub brushes and nail picks, and has been demonstrated to have equivalent efficacy to scrubbing with water. Mastracci *et al* (2024) summarise the available evidence estimate that switching to alcohol-based hand rub would save up to 16L of water per 2-minute surgical scrub.[70-72]

Paper products should be avoided where possible.[69] Methods for achieving this are through the use of electronic records (being mindful that there is an environmental impact to this alternative), avoiding printing or printing double-sided where needed. The use of recycled paper diverts paper waste from landfill which is a significant contributor of greenhouse gases.[69]

2.3.4 Reuse

2.3.4.1 Reusable anaesthetic equipment

Single use disposable medical devices in healthcare have increased at a rapid rate over the past three decades, with a resulting increase in ecosystem destruction related to natural resource extraction, fossil fuel combustion during manufacture and transport, and waste disposal. While reuse is unsuitable for items that are difficult to decontaminate with current technologies, such as needles and intravenous tubing, evidence from surgical and broader healthcare settings consistently shows that reusable equipment has a lower environmental impact than single-use alternatives. Studies report average reductions in carbon footprint of 38–56% when switching from disposable to reusable products[73-75], with the benefits being greatest when the local energy source is from renewable electricity. In areas (such as Victoria) that have traditionally been reliant on coal for electricity generation, the introduction of close to 100% renewable electricity for public hospitals in 2025 reduced the carbon footprint of reusable equipment to less than 10% of single use variants.[76]

Switching to reusable anaesthetic equipment can save money as well as reducing waste and environmental harm. In a comparison in 2017 between two Australian hospitals, one hospital used reusables, the other used mainly disposables. For the six-theatre operating suite it was found that using reusable equipment saved $A30,000 per annum (inclusive of all labour/non-labour costs).

Work is being done to better understand and reduce system barriers to switching from disposable to reusable equipment in healthcare. For further information, readers are directed to the following resources: “Green Surgery: Reducing the environmental impact of surgical care”, and “Catalysing action on single use items in healthcare”.[75, 77]

2.3.5 Remanufacture

In Australia and New Zealand, the correct use of the terms remanufacturing and reprocessing are important, as they carry legal and regulatory implications (see definitions in glossary).

Medical devices may be labelled single-use because the manufacturer chooses not to validate or distribute cleaning instructions to hospitals. Remanufacturing of these medical devices by external companies allows the product to meet clinical and safety standards for reuse. Remanufacturing companies are responsible for carrying out the necessary studies and validation to ensure the safe return of each device back into the market to meet regulatory requirements.

Remanufacturing offers clear environmental and some economic benefits. Remanufacturing to allow reuse of a number of single use products, including calf compression devices, Hovermats, and intravenous tourniquets, has been successfully implemented in Australia and New Zealand. Anaesthetists can advocate for their hospitals to engage with accredited companies to remanufacture medical devices that would otherwise go to landfill.

Engaging suppliers that offer take-back or remanufacturing schemes and prioritising products designed for longevity can further enhance circularity. By collecting data on equipment use and maintenance, and promoting awareness of sustainability principles among colleagues, anaesthetists can drive both environmental and financial benefits within their hospitals.[4, 55, 78-84]

2.3.6 Recycling

Recycling has many economic and environmental benefits, though it should be noted that compared to reducing waste production and reusing items, it is less energy efficient and can create secondary issues associated with re-processing of materials such as toxin release.[69, 85-87] Recycling allows the diversion of waste from landfill to other products whether it be reprocessing into the same product (e.g. paper recycling), or reproduction into new products through the waste product being used as raw materials. Manufacturing goods using recycled products as raw materials uses less fossil fuels and so has a smaller contribution to the production of greenhouse gases and climate change. It also means less deforestation for the production of paper production, less mining for metals and reduced need for oil for plastics production.[85]

The biodegradation of landfill generates methane which is a greenhouse gas.[86-88] Diverting recyclables away from landfill reduces leachate and potential groundwater contamination which can occur at landfill sites.[86]

Recycling also saves money.[69, 87, 89] An audit conducted in a US hospital revealed savings of $4672.88 over their six-month audit period from the addition of single-stream recycling (recyclables segregated at the recovery facility).[87] Compared to landfill disposal, recycling has an economic advantage of job creation through its labour intensive processing, the transport of recyclable waste, sorting and transformation of materials.[90] Any potential costs of transporting and disposal of recyclable waste may be mitigated (depending on the area) by on-selling these potential raw materials to recycling facilities.[89]

Barriers to recycling include a lack of knowledge, convenience, absence of recycling facilities, lack of management support, leadership or encouragement in this area and concerns regarding infectious contamination. Supportive leadership, access to and education regarding waste streams available and appropriate waste segregation assists in mitigating these issues.[91, 92]

It is important to ensure that waste which is destined for recycling is not contaminated as it will not be accepted by the recycling facilities and that entire waste haul is then treated according to the highest level of risk.[93] This then becomes a costly exercise both environmentally and financially and may hinder recycling facility relationships.

2.3.7 Optimising waste management

Around 100,000 tonnes of clinical and pharmaceutical waste was produced in Australia in 2023-24, according to the Hazardous Waste in Australia Report 2025.[94]

Disposal of clinical waste is more expensive and more environmentally harmful than general waste. Hospital audits have found that large volumes of general waste may be discarded inappropriately into the clinical waste stream. Princess Alexandra Hospital in Brisbane demonstrated that appropriate segregation of clinical waste from general waste can result in a 60% reduction of waste disposal costs.[95] Educating theatre staff on the correct use of clinical waste bins, and provision of adequate general waste bins in clinical areas is recommended.

The management of sharps waste is financially and environmentally costly due to the processing required (maceration/autoclaving). By ensuring that only sharps are disposed of in sharps bins (needles and easily broken glass medication vials) reduces the volume of waste requiring energy-intensive processing.

2.3.8 Pharmaceutical waste impacts

Drugs can contribute to water table contamination and ecotoxicity if incorrectly disposed.[96-98] This is a particular problem with propofol, as it is poorly biodegradable, accumulates in fat and is toxic to aquatic life if leaching into water occurs. Propofol can only be destroyed by incineration[99], so it should not be disposed of in general waste, into the sink, or into sharps bins which do not undergo incineration (local hospital processes will vary and should be consulted). Deactivation systems do not destroy propofol but may be a feasible alternative to preventing environmental contamination via incorrect disposal into sinks or clinical waste, providing their contents are incinerated. Ephedrine is also toxic to fish and aquatic invertebrates though no recommendations have been made for its disposal.

Table 1 Persistence, bioaccumulation and toxicity of drugs used in anaesthesia and intensive care.

Drugs	Persistence	Bioaccumulation	Toxicity	Additional notes
Propofol	High; also accumulates on land in biosolid waste	Potential; because of high lipid solubility	Multiple effects, including algae growth inhibition and acute toxicity in small crustaceans and freshwater fish	Falås and colleagues showed higher levels of propofol *leaving* wastewater treatment plants than *entering*, possibly because of deglucuronidation.[23] As 60 times more propofol is excreted in the glucuronidated form, currently measured levels are likely hugely underestimating the environmental risk.
Opioids	High	Potential	Cause genetic damage to bivalves and water fleas	Few studies into remifentanil but has low persistence and bioaccumulation and likely low toxicity
Antibiotics	Macrolides and quinolones: high; overall, antibiotics exhibit pseudo-persistence	Some have high bioaccumulation.	Multiple antibiotics with toxicity to fish and amphibians; beta-lactams generally less toxic	Macrolides are toxic to zebrafish, affecting yolk sac and swim bladder. Tetracyclines toxic to amphibians.
Lidocaine	Monoethylglycinexylidide (MEGX), a major metabolite, is highly stable at room temperature	Low because of low lipid solubility	Possible; MEGX metabolises to 2,6-dimethylaniline, a likely carcinogen	~10% of lidocaine given is excreted unchanged in the urine
Bupivacaine	High	Little evidence, but likely low at pH 7.4	Low; little data on ecotoxicity of metabolites	Metabolised in liver, excreted in urine and <10% unchanged.
Sugammadex	Lack of literature currently	Lack of literature currently	Binds to oestrogen and progesterone, so concern with endocrine disruptor for aquatic life	Eliminated unchanged by the kidneys.
Paracetamol	<15 days in the environment, but pseudo-persistence	Effluent release areas constantly exposed, leading to chronic exposure	Highly toxic to bacteria and algae; neurotoxic to crustaceans and planarians at low doses	Some degradation products may be more toxic than paracetamol itself, adding to the total environmental impact.

Table 1 Persistence, bioaccumulation and toxicity of drugs used in anaesthesia and intensive care *(from: Sustainability in anaesthesia and critical care: beyond carbon[100])*

There are significant differences in pharmaceutical waste streams available between Australia and New Zealand highlighting the importance of responsible drug handling and use to minimise waste. No separate high-temperature incineration waste stream for pharmaceutical waste exists in New Zealand except for cytotoxic waste, which is transported out of the country for processing. All other pharmaceutical waste is disposed of within clinical or sharps waste streams and enters landfills after autoclaving. Autoclaving only makes pharmaceutical agents safe to handle, however does not denature the majority of them. Terminal leachates therefore can enter the water table.

2.3.9 Compostable items

Compostable/organic waste streams reduce the amount of waste sent to landfill or processed in other waste streams, and reduce emissions of methane and carbon dioxide. Paper, compostable plastics and hospital food waste are compostable in either industrial or ‘home’ (municipal) composting depending on their composition and classification under the Australian Standards.[101]

However, due to the lack of available healthcare industrial composting streams a large majority of healthcare-associated waste across Australia and New Zealand that may be appropriate for this stream is directed to landfill and thus is not composted. The availability and accessibility of these services should be assessed before adopting the use of items that are intended for this waste stream, as they are likely to be disposed of in landfill conditions which often result in higher associated emissions when products require industrial composting.

2.4 Beneficial care

2.4.1 Rational use of diagnostic tests[102-105]

Rational use of diagnostic tests can reduce our environmental footprint through increasing workplace efficiency. This will result in better health outcomes for patients both directly and indirectly. The Quality Use of Diagnostics, Therapeutics and Pathology program overseen by the Australian Commission on Safety and Quality in Healthcare includes the goal of improving pathology testing which is also incorporated in the Healthcare Sustainability and Resilience Module (2025).[16]

Diagnostic tests account for approximately 2% of a hospitals carbon footprint.[106] Of this, 10-40% of preoperative tests are likely unnecessary and don't improve patient care.[107, 108] Preoperative investigations should therefore be targeted to guide perioperative management and performed only when results are likely to alter patient care.

Routine laboratory blood testing is not recommended for asymptomatic patients having low-risk surgery.[109] Test selection should be based on the patient's clinical history, examination findings, and the nature of the planned procedure.[110]

In most cases, functional, asymptomatic patients may proceed with planned non-cardiac surgery without further cardiovascular testing including electrocardiograms, spirometry, chest radiographs, transthoracic echocardiogram or other advanced cardiac investigations.[111]

2.5 Infection prevention and control

Heating, ventilation and air conditioning (HVAC) is mentioned in PG28 but some more detailed guidance pertaining to sustainability is outlined below.

HVAC accounts for 50-90% of operating theatre energy consumption. Setbacks when elective theatres are not in use can significantly reduce the energy consumed. It is important to consider local policy but considerations in relation to setbacks include:

- Reduced air exchange rates in unoccupied areas with the possibility of limiting to 8 air exchanges per hour (ACH) in operating theatres and 4 ACH in operating scrub rooms and anaesthetic rooms.
- Temporary shut down of anaesthetic gas scavenging pumps.
- Temperature optimisation for energy efficiency (the humidity should remain in the range of 30-60% for microbial control).
- Ability to achieve normal operating conditions within 30 minutes when returned to standard ventilation.
- Minimising unnecessary door openings also reduces airborne contamination and conserves HVAC energy.

2.6 Building design and Infrastructure

Infrastructure decisions, whether for new builds or retrofits, represent a major opportunity to reduce emissions, improve resource efficiency, and enhance staff and patient wellbeing. Sustainable infrastructure also reduces operational costs, builds resilience to climate change, and supports continuity of care during extreme weather events.

Planning of future healthcare facilities should adopt an integrated, whole-of-life design approach, consistent with sustainable design frameworks.

There is evidence that good architectural healthcare design can improve patient well-being and staff satisfaction. Common findings are that quiet surroundings, natural lighting, and views or contact with nature improve patient recovery. The costs of constructing a quality indoor healthcare environment may be more than offset by increased productivity from happy and healthy staff.[112] Efficient buildings can reduce cost to the community, are gentler on the environment and may be designed for improved health of patients and productivity of staff.

Strategies and objectives for such healthcare design would include:

- Improving patient safety. Hospital design with respect to non-slip flooring, proximity between beds and bathrooms, airflow and ability to clean surfaces makes for lower patient injury and infection rates.
- Improving patient outcomes. Design should increase opportunities for staff to observe and interact with patients. Hospital construction that minimises movement of patients with changing acuity reduces handover, and reduces complications.[113] Workflow patterns should inform the design, not the other way around.
- Increasing the satisfaction of patient, family and staff. Sound attenuation and design that separates corridors and lifts for staff and visitors creates a healing environment. Rooms with space for family, and provision for individual patient control of temperature and lighting create patient satisfaction.
- Connection with nature. Unobstructed natural views and sunlight have positive effects on pain, mood, and hospital stay, and natural scenery and vegetation have positive effects on staff and patients.
- Meeting expectations of staff and patients, and audit processes of preferences, expectations and satisfaction allows for continuous quality improvement.
- Improving effectiveness and efficiency of staff through standardisation, time in motion data, and design elements.

Flexible elements of design may allow for future growth, or changes in configuration consistent with newer clinical requirements. For example, central surgical sterilising departments should be designed to anticipate an increase in capability as hospitals move to purchasing more reusable equipment, in line with circular economy principles.

Active design, a term derived from New York City's Active Design guidelines. Key features include: active transportation (walking, cycling, mass transit), active vertical circulation within buildings (encouraging stair climbing, discouraging lifts and escalators), and consumption of locally grown fruits and vegetables, and tap water. Active design methods promote environmental sustainability and universal accessibility, as well as increased activity.[114]

2.7 Travel

Delegate travel to medical conferences may amount to 0.5 - 2 tonnes CO_2e per person. Attending a single conference may therefore consume an individual's entire annual carbon budget (~2.1 tonnes CO_2e per person per year) required to limit global warming to 1.5ºC. Fellows are encouraged to estimate their carbon footprint using an online calculator, as this improves our understanding of the size of the carbon impact of travel and other activities.

Most published estimates are conservative, based on direct economy-class flights. Business and first-class travel generate 2.6-4.3 times the emissions of economy travel. Virtual and hybrid conferences can reduce emissions by up to 87%, while a hub-and-spoke model can achieve reductions of up to 59%.

Carbon offset should be used as a last resort, and offset programs should be selected carefully, ensuring they are certified under recognised international standards such as the Gold Standard.[10, 115-125]

2.8 Environmental sustainability knowledge

2.8.1 Quality improvement

Engaging in quality improvement (QI) enables anaesthetists to work with their colleagues to problem-solve, innovate, and take ownership of better care processes in healthcare settings. Participation in QI work can improve staff engagement and morale, while improving processes and patient outcomes. Trainees can participate in QI projects to develop important skills and build relationships with colleagues. Consultant anaesthetists can benefit from QI work by developing their leadership skills while addressing longstanding concerns about the way systems are delivered.

Sustainability is now considered a core domain of quality in healthcare, alongside efficiency, timeliness, effectiveness, equity, patient experience and safety.[126] The domain of sustainability must run through and moderate the other domains, as healthcare needs to be considered not only in terms of the patients of today, but also in terms of the population in general and the patients of the future.[126] The Sustainability in Quality Improvement (susQI) framework embeds sustainability into traditional QI theory and practice. The goal of susQI work is to maximize sustainable value in healthcare, by optimizing patient and population outcomes while minimizing environmental, social and financial cost.

In 2025 the Australian Commission on Quality and Safety in Healthcare published a Healthcare Sustainability and Resilience Module which promotes susQI work as central to a number of its action items. The module aims to support health service organisations in addressing healthcare impacts on the environment and the climate risks affecting human health, and includes actions in governance, leadership and culture, redesigning processes to provide high quality care that reduces climate impact, and embedding of sustainability in quality improvement activities.[16]

Anaesthetic departments should invest in resources which empower their staff to lead and participate in quality improvement projects as this work can improve patient outcomes, reduce waste, cost and inefficiency, and can improve staff morale and teamwork.

Hospitals should invest in learning health systems which allow clinicians to access and interpret data from electronic medical records to better inform and track improvement initiatives.

Definitions

The following definitions are specific to this document:

- **Reprocessing** refers to the process of cleaning, disinfecting, sterilizing, and testing medical devices or equipment that are intended for reuse.

  The goal is to make the equipment safe for another use on the same or another patient without compromising its function or safety. This process follows strict regulatory guidelines to prevent infection or contamination. In Australia and New Zealand, reprocessing must comply with standards such as AS/NZS 4187 (for cleaning and sterilization of reusable medical devices).

- **Remanufacturing** changes the original manufacturer's intended purpose for the medical device or significantly changes the safety or performance specifications of a finished device.

  Remanufactured equipment must meet all regulatory requirements for safety and performance. Remanufacturing companies are legally required to carry out the necessary studies and validation to ensure the safe return of each device back into the market.

See further below for Appendix 1. Life Cycle Assessments.

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Related ANZCA documents

PG07 Guideline on pre-anaesthesia consultation and patient preparation
PG28 Guideline on infection control in anaesthesia
PG51(A) Guideline for the safe management and use of medications in anaesthesia

Further reading

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ANZCA professional documents are reviewed from time to time, and it is the responsibility of each practitioner to ensure that he or she has obtained the current version which is available from the college website (www.anzca.edu.au). The professional documents have been prepared having regard to the information available at the time of their preparation, and practitioners should therefore take into account any information that may have been published or has become available subsequently.

While ANZCA endeavours to ensure that its professional documents are as current as possible at the time of their preparation, it takes no responsibility for matters arising from changed circumstances or information or material which may have become available subsequently.

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Appendix 1. Life Cycle Assessments

Life cycle assessment (LCA) is a scientific method to determine the entire 'cradle to grave' environmental and financial effects of processes and products. In 1991, the Society for Environmental Toxicology and Chemistry defined the components of an LCA of an item to be analysed; 1. raw material acquisition, 2. processing and manufacturing, 3. distribution and transportation, 4. use, reuse and maintenance, 5. recycling, and 6. waste management. Everything we use and do has a footprint, whether this be for any product or service (e.g. admission to hospital). LCA allows for rational product and medical practice choices that reflect true environmental and financial costs beyond short-term effects. LCAs have a 'system boundary', i.e. a limit to which one examines the environmental effects of a product or process. This system boundary is defined by local and international standards. For example, if we are examining a plastic syringe, the system boundary could be defined to include the manufacture of the plastic and ongoing maintenance of installed infrastructure, but not the actual manufacture of such installed infrastructure used in turn to make the syringe.

Environmental factors beyond CO_2 equivalent emissions (i.e. the carbon footprint) can be accounted for in an LCA, including water consumption, petrochemical use, air pollution, and release of toxic by-products. Comparisons between items may indicate relative advantages for one outcome (e.g. CO_2 emissions), which may be contrary to other outcomes (e.g. water use and contamination). In the late 1990s, standardization of how LCAs should be conducted was achieved when the International Organization for Standardization (ISO) released the ISO 14000 series.

LCAs make use of life cycle inventories (LCIs). An LCI is a catalogue of flows to and from nature; with inputs such as energy, water and raw materials, and outputs (releases) to air, land and water. There can be a large number of inventory flows numbering in the hundreds; for example, even a simple plastic syringe's LCI requires flows of petrochemical resource extraction, manufacture, transport and use. To examine all of these details de novo every time an LCA was undertaken would be exhaustive and expensive. So, whilst it is ideal to obtain as much primary data as possible (e.g. measurement of a hospital steriliser's direct energy and water use), secondary sources of information are usually required for LCAs (e.g. details of plastic manufacture). Large, national and international databases are the routine sources for such information, such as Gabi® and EcoInvent® which incorporate geographically specific average industry data. For example, the estimated CO_2 emission from burning coal from a defined region is obtained from such environmental databases. Such average industry data can have greater associated uncertainty than directly measured (primary) data. Care must then be taken to ensure that the secondary data indicates the local conditions of the LCA in question (e.g. local coal fired electricity versus gas fired electricity used for the secondary data).

Re-iterating, the LCI has inputs (such as electricity from coal) that are combined to form an output (e.g. a plastic syringe). Every input from secondary databases has a degree of uncertainty associated with it. This uncertainty routinely cannot be derived directly from the available information, so a standard procedure was developed to derive uncertainty factors from a qualitative assessment of the data, known as the Pedigree Matrix. The Pedigree Matrix is a commonly used qualitative scoring system derived from the secondary data's reliability, completeness, temporal and geographical proximity to the process or item being assessed, and further technological factors, with a score from 1 (good) to 5 (poor) for each factor.

The Pedigree Matrix relies upon expert judgement. For example, if the secondary data for CO_2 emissions per kWh of electricity produced was obtained recently from all local coal fired power stations this would have better reliability, completeness, and temporal and geographical proximity than secondary data from an overseas derived database which sampled one coal fired power station a decade ago. As the Pedigree Matrix is based upon expert opinion, it is open to a perception of irregularities. The Pedigree Matrix has been updated to incorporate some of these concerns with greater emphasis upon direct empirical values for each of the factors.

Similarly, there are also uncertainties associated with all LCA primary inputs that are directly measured. For example, in an LCA study of plastic drug trays required transport of such trays from China to Australia. There is little uncertainty associated with the CO_2 emissions from such shipping as the distance travelled is well known and the variability in fuel consumption of container ships is small. On the other hand, for the reprocessing of the reusable plastic drug trays, if we had measured the electricity use of the washer just once rather than over several days with different load types, the CO_2 emissions from such electricity use would have a greater associated uncertainty. As for secondary data from LCI databases, the Pedigree Matrix for primary input data is a qualitative scoring system.

For every LCA potentially hundreds of mostly secondary inputs contribute to output data, each with associated uncertainty distributions. The Pedigree Matrix for each of these inputs determines the degree of uncertainty. How does one then combine the values and frequency distributions of these hundreds of inputs to obtain outputs such as CO_2 emissions and water use? Monte Carlo methods are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. Monte Carlo methods are useful when there are large numbers of inputs and where it is not pragmatic to obtain data for each of these inputs de novo and are used routinely in LCA.

When there is a range of possible values for a result there are a number of approaches to how to determine the best estimate and the frequency distribution around this result. Monte Carlo methods take data points from within the frequency distributions for all inputs to develop a final output result, frequency distribution and the plausible range including the central tendency of the frequency distribution[i]. The greater the number of 'runs' by Monte Carlo analysis the better the estimate of the most likely value and the associated frequency distribution.

In industry, LCAs are common as they identify high energy and water use as well as waste production. Until recently comparatively few LCAs have occurred in healthcare, although these now number greater than 200. The healthcare LCA website (https://healthcarelca.com/) is a suitable introduction to the varied environmental footprinting efforts in healthcare.

There are several types of LCA of which two are particularly relevant to healthcare sustainability; economic input-output LCAs (EIO) and process based LCAs. EIO LCAs assign an environmental effect to an item, process or service via knowledge of a monetary value. National economies are divided into many sectors (e.g. pharmaceuticals) with at least 100 sectors in developed countries. Each sector receives inputs from many other sectors and conversely has outputs to many sectors. Each sector has a different 'intensity' of environmental effect per financial cost. Such intensities are developed by government departments. Briefly, for each sector, data are obtained of the monetary inputs from each financial sector, and likewise the monetary outputs (i.e. dollars produced) to each financial sector. Through calculations an environmental cost/$ for each sector can be developed.

Different sectors of the economy have different environmental impacts. Pharmaceutical production will have a different carbon intensity (CO_2 emissions) for every dollar spent on producing a drug compared with the CO_2 emissions of producing one dollar of foodstuffs or manufacturing plastics. For example, if a plastic syringe costs $0.20 there is a carbon, water etc. footprint associated with that syringe based upon the $0.20 that will be different to the environmental footprint of producing drugs.

When attributing an environmental cost to a sector, e.g. pharmaceuticals, areas such as research and development, lawyer fees, and fees and travel for drug representatives are all included. The advantages of EIO LCAs are that they are all encompassing ('broad brush') and relatively inexpensive to perform once the initial expensive data gathering has occurred. Thereafter one only has to find the financial cost of any item or process in order to arrive at an environmental cost.

Process based LCAs arrive at an environmental cost for an item or activity based upon measured inputs. Process based LCAs thus examine the immediate inputs, but not more distant inputs; that is, they have a smaller 'system boundary' than input output LCAs. For example, the aforementioned $0.20 plastic syringe has a weight and petrochemical composition that would be linked to environmental effects; but all of the associated effects resultant from petrochemical industry activity, such as research and development, and the manufacture of machinery for drilling and exploration, are not included. The environmental effects of process based LCAs are thus routinely less than EIO LCAs.

Process based LCAs do not encompass all of the effects of an item or process and are more expensive to perform than EIO LCAs. They do, however provide a detailed analysis of an individual item or activity and are useful when comparing two similar items/activities. Further, EIO LCAs are less precise for many products and processes in healthcare. Consider a drug, medical device or operation that costs twice as much as another: an EIO LCA would consider that the more expensive process has double the environmental effects, which could be unrealistic. On the contrary, it may be impossible to obtain details of pharmaceutical manufacturing for a process based LCA, leaving a questionable EIO LCA as the only manner in which to assess a drug's environmental effects. Hybrid LCAs (combinations of EIO LCAs and process based LCAs) are used infrequently to attempt to overcome any knowledge gaps, but should be used with care when comparing two products or processes as input-output data will overestimate environmental effects in distinction to process based data.

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