Royal College of Anaesthetists

e-LA
e-Learning Anaesthesia

Sustainability: Background science

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Dr Jennifer Hawkins
Dr Natasha Parrott

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Atmosphere structure and science

Structure

The Earth's atmosphere is divided into the troposphere (up to 10,000m), the stratosphere (10,000-50,000m) and the mesosphere (50,000m +). The so-called 'ozone layer' is within the stratosphere between 20,000 – 30,000m. The purpose of the ozone layer is to protect us from harmful amounts of ultraviolet (UV) light.

If you were to ascend through the troposphere, the temperature decreases to -50°C (as you experience on an aeroplane), however, it then stabilises and increases through the stratosphere.

There is a boundary between the tropopause and the stratosphere, which is called the tropopause. The tropopause is at an altitude of 8000m at the North and South Pole and approx. 18,000m at the equator. The variation in height is due to the change in temperature with latitude.[1] See figure 1.

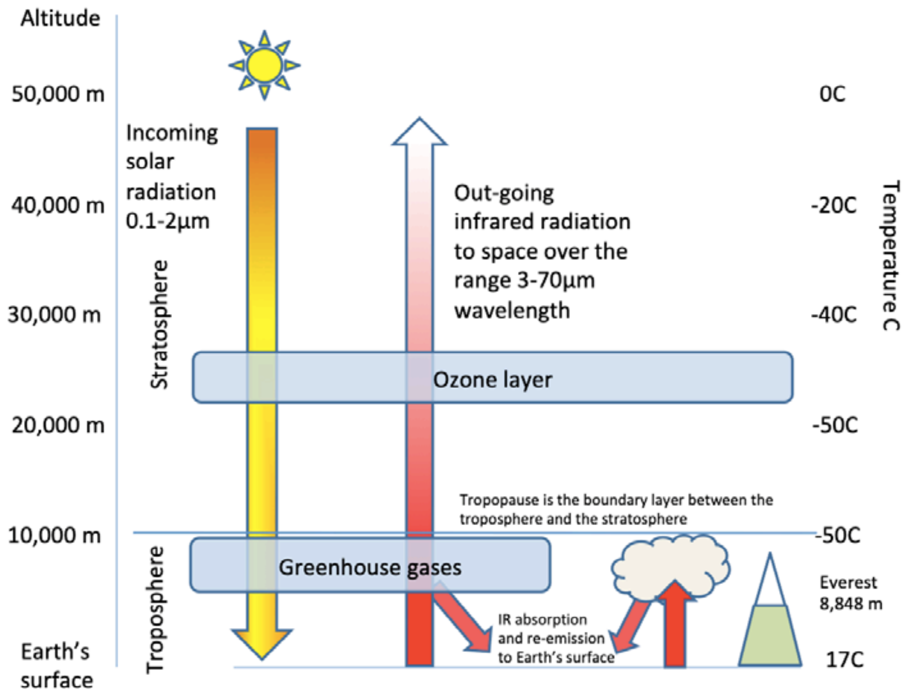

Figure 1: *A simplified diagram of the atmosphere. The first 10,000m or so is the troposphere containing most of the mass of the atmosphere and almost all of the water. This is where greenhouse gases have their effect. The next 40,000 m is the stratosphere and is where ozone exerts its UV protective effect.*
The degree of radiative forcing is calculated at the boundary layer between the troposphere and the stratosphere, the tropopause. In 2018 this was +3.101 Wm^{-2}.
Image from Tom Pierce with permission

Science

The sun's surface emits radiation mainly in the visible spectrum, this is transmitted to Earth and warms the atmosphere. The Earth emits mainly thermal infrared radiation (IR), the peak wavelength of which is around 10 µm. Diatomic molecules such as oxygen and nitrogen absorb very little outgoing infrared radiation.

A relatively transparent 'atmospheric window' exists between the wavelengths of 8 and 14 µm where little IR absorption by greenhouse gases (GHG) occurs. Outside these wavelengths, the presence of GHG absorb outgoing IR and re-emit it, some of which will return to Earth and swing the energy balance to net energy gain[1] (see figure 2 below).

Greenhouse gases can be natural or anthropogenic i.e. gases that result from or are produced by humans and their activities. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the primary (natural) GHG in the Earth's atmosphere. There are a number of entirely human-made GHG in the atmosphere, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and perfluorinatedcarbons (PFCs).[2] All of these molecules have a loosely bound structure (containing 3 or more atoms) which makes them efficient absorbers of the long wave radiation bouncing back from the planet's surface. When they re-emit this long-wave radiation back towards Earth, this results in warming.[3]

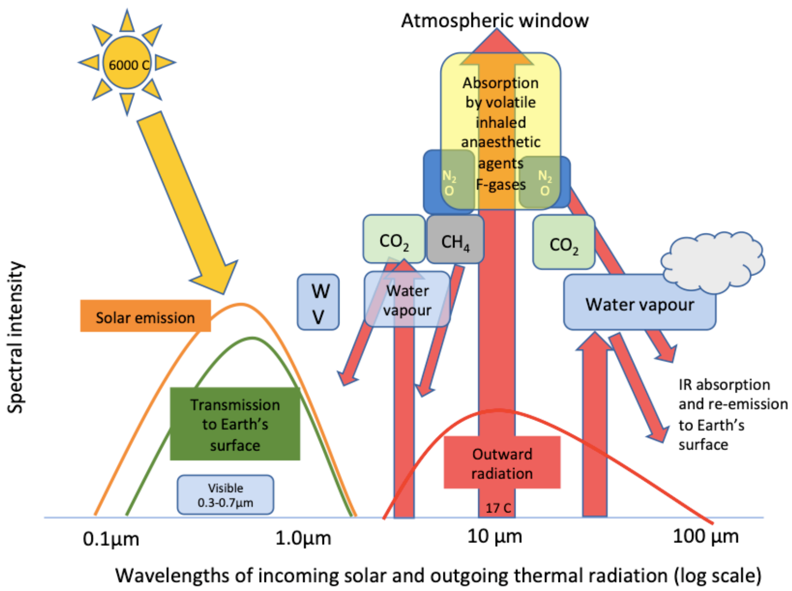

Figure 2: Simplified diagram to illustrate the incoming solar radiation and the out-going infrared radiation. The peak solar radiation to reach Earth's surface occurs at 480nm wavelength and the peak out-going is at 10µm wavelength at which little natural atmospheric IR absorption occurs (the atmospheric window). Volatile anaesthetic agent and F-gasses have their peak absorption at this wavelength and so despite their very low concentration they comprise about 10% of the total warming. The F gases include: HFC, Hydroflourocarbons; HCFC Hydrochloroflourocarbons; PFC Perflurocarbons. Image from Tom Pierce with permission

The so-called ‘Greenhouse effect’ is defined as the infrared radiative effect of all infrared-absorbing constituents in the atmosphere. GHG, clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth’s surface and elsewhere in the atmosphere. These substances emit IR in all directions, but, as everything else is equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers. This is because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of GHG increases the magnitude of this effect; the difference is sometimes called the “enhanced greenhouse effect”. The change in a GHG concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing. Surface and troposphere temperature increase in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.[2]

International committees, organisations and conferences

Intergovernmental Panel on Climate Change (IPCC)

The IPCC is the United Nations body for assessing science related to climate change, which it then communicates to policymakers. They present information on the potential implications and future risks of climate change, as well as possible adaptations to mitigate them in order to assist the development of climate change policies. Created by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) in 1988, the IPCC has 195 Member countries.

The IPCC does not perform its own research, but many thousands of scientists volunteer their time to review up to date papers and studies to provide thorough summaries of the current state of affairs. Areas that require further research are identified, as well as those that have strong scientific backing. The processes are designed to be transparent, involving experts and governments worldwide, in order to gain accurate and comprehensive data.

The IPCC is divided into three Working Groups and a Task Force:

- Working Group I - "The Physical Science Basis of Climate Change"
- Working Group II – "Climate Change Impacts, Adaptation and Vulnerability"
- Working Group III – "Mitigation of Climate Change"
- Task Force on National Greenhouse Gas Inventories - aims to develop and refine a methodology for the calculation and reporting of national greenhouse gas emissions and removals.[4]

More information can be found on the website: ipcc.ch/about/

World Meteorological Organisation (WMO)

Mandate: "As weather, climate and the water cycle know no national boundaries, international cooperation at a global scale is essential for the development of meteorology, climatology and operational hydrology as well as to reap the benefits from their application. WMO provides the framework for such international cooperation."

The WMO is an agency of the United Nations that is focussed on coordinating global cooperation in all aspects of the environment, climate and weather, and the resulting water resources. They have a variety of programmes that are involved in data collection and communication, as well as maintaining the necessary worldwide standards in these areas. They also facilitate research in meteorology and activities in operational hydrology, particularly in relation to areas such as aviation, agriculture, transport and water resource management.

Service areas include:

- National Meteorological and Hydrological Services
- Technical Commissions and Research Board
- Regional Offices [5]

Further details of their programmes, projects and focus areas can be found on their website public.wmo.int/en

Climate Change Summits (COP)

The United Nations (UN) host annual climate change conferences. They are the formal meetings of the UNFCCC (United Nations Framework Convention on Climate Change). They started in 1995 and it is here where the Kyoto Protocol, amongst others, was established. The Conference of the Parties (COP) is the supreme decision-making body of the convention. They review the national communications and emission inventories submitted by Parties. Based on this information, the COP assesses the effects of the measures taken by Parties and the progress made in achieving the ultimate objective of the Convention.[6]

Some of the key protocols include:
The Montreal Protocol, which universally banned the use of chloroflurocarbons (CFCs).
The Kyoto Protocol, which aims to limit CO_2, N_2O and CH_4, as well as the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).[2] See "*International Agreements*" e-module for more information.

Climate Change and Global Warming

The following section will cover some of the terms and concepts commonly used when discussing climate change and global warming.

Definitions

- **Radiative forcing**
  - A measure of the influence a given climatic factor has on the amount of downward-directed radiant energy imposing upon the Earth's surface.
  - Climatic factors may either be caused by:
    - Human activity e.g. greenhouse gas and aerosol emissions
    - Natural forces e.g. solar irradiance
  - For each factor, so-called forcing values are calculated for the time period between 1750 and the present day.
  - "Positive forcing" is exerted by climatic factors that contribute to the *warming* of Earth's surface, whereas "negative forcing" is exerted by factors that *cool* Earth's surface.[7]
  - Current values for radiative forcing are between +2.3 to 3.3W/m^2 as of 2018.[8]

- **Global Warming Potential (GWP)**
  - "The cumulative radiative forcing, both direct and indirect effects, over a specified time horizon resulting from the emission of a unit of mass of gas related to some reference gas"
  - GWP has been developed as a metric to compare (relative to another gas) the ability of each greenhouse gas to trap heat in the atmosphere, and is generally taken over 100 years (GWP_{100})
  - CO_2 was chosen as the reference gas to be in line with guidelines from the IPCC, which by definition has a GWP of 1.[2]

- **Carbon Dioxide Equivalents (CO_2e)**
  - Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential, and allows them to be described in a common unit, i.e. it puts everything in the same scale.
  - For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 that would have the equivalent global warming impact.[2]
  - For example, the global warming potential for methane over 100 years is 21. This means that an emission of 1 metric ton of methane is equivalent to emissions of 21 metric tons of carbon dioxide.
  - Of note, the CO_2e of the NHS in England is calculated to be around 21MTCO_2e.[9]

- **Ozone Depleting Potential (ODP)**
  - Widely used as a measure of the effectiveness of a given compound in removing ozone, relative to a standard compound, which is taken to be Trichloroflurometh ane (CFC-11).
  - By definition, CFC-11 has an ODP of 1.
  - The ODP of a compound is normally defined as the ratio of the global loss of ozone (i.e. integrated over latitude, altitude, and time) from that compound at steady state per unit mass emitted, relative to the loss of ozone due to emission of unit mass of the reference compound.
  - The ODP thus provides a relative measure of the *overall* impact of a compound on ozone destruction over the long term.[10-11]
  - Note: ODP is related to a substance's ability to destroy the stratosphere, vs GWP which is related to its ability to warm the earth. Many (though not all) GHGs will do both, though the extent of this varies between agents.
  - Aside from nitrous oxide, anaesthetic agents have negligible ODP (but high GWP). In contrast many ODP CFCs also have high GWP i.e. do both.

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Sustainability: Health and climate change

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Dr Jonathan Groome
Dr Natasha Palipane

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Module Learning Outcomes

- Health implications of climate change and global warming.
- Air pollution and cardiorespiratory disease.
- The role of public health and population-based health.
- Social sustainability, social inequalities, and civility in healthcare.
- Healthcare within international agreements.

Health implications of climate change and global warming

Populations of all animal species depend on supplies of food and water, freedom from excess infectious disease, and the physical safety and comfort conferred by climatic stability. The world's climate system is fundamental to this life-support. (WHO 2003).

Our climate is changing, and our ecosystems are now suffering the effects of a warmer planet. Humans are not immune to these changes. Climate change significantly influences the social and environmental determinants of health – safe food and water, security, and clean air. In addition to this we are now seeing the direct health impacts of our changing climate. In this section we will explore these further.

The relationship between climate change and its effects on health is complex and often modulated by interactions with other ecological processes, social conditions, and adaptive policies and behaviours. In simple terms the effects of climate change on health can be direct or consequential, secondary to environmental and ecological disruption.

Direct Effects

A Warmer Planet

Our planet is warming, and left unchecked the predictions indicate that in the UK annual mean temperatures will be 2 and possibly as much as 8°C higher by 2080, with an increased incidence of heatwaves, dryer summers and wetter winters.[1] This in turn will lead to an increased rate of morbidity and mortality associated with cardiac, respiratory and allergen-induced conditions. In the UK, heat related mortality currently accounts for around 2000 excess deaths per year. This is predicted to increase by around 540% in the 2080s.[1]

Globally, 30% of the world population spend 20 days exposed to lethal heat events.[2] If we continue along the current trend this could increase to 74% by 2100.[2] Heat related morbidity and mortality primarily affects the elderly and with an aging population this will lead to an increased demand on health systems.

Extreme Weather Events and Natural Disasters

Since the 1960s the number of weather-related natural disasters has more than tripled, resulting in over 60,000 deaths per year globally.[3] The morbidity and mortality from such disasters can be immediate (trauma, burns or drowning) or delayed in the form of mental health problems, waterborne disease and malnutrition. With more than half of the world's population living within 60km of the sea we can expect the effects of rising sea levels to further impact this.

Indirect Effects

Water and Food Supply Impacts

Be it from fires, floods or drought the impact on safe drinking water and nutrition can be profound. As things stand, 1 in 10 people do not have access to clean water.[3] This leads to an increased rate of waterborne and diarrhoeal disease which currently kills over 500,000 children under 5 each year.[3] Unfortunately, the rates continue to rise, and we are currently seeing Yemen face the worst cholera outbreak in history with over 2.2million people being affected since it began in 2016.[4]

The relationship between food and climate is complex. Intensive agricultural methods have been shown to significantly impact our climate and soil quality yet, despite the increase in food production, more than 10 percent of the world's population are undernourished.[4] Failing to keep surface temperatures below 1.5°C, as recommended by the IPCC, will lead to droughts occurring 5-10 times more often.[4] Rising temperatures, variable precipitation and extreme weather events will likely lead to food scarcity in the poorest areas increasing the prevalence of malnutrition related deaths which currently stands at 3.1 million per year.[3]

Conflict and Migration

It is unsurprising that once environmental degradation results in uninhabitable conditions populations migrate to survive. Analysts predict that by 2050 the number of climate migrants will be between 200 million and 1 billion.[5] What leads to climate migration?

- Climate processes – rising sea levels, salinization of agricultural land, desertification and water scarcity.
- Climate events – Flooding, fires and storms.
- Non-climate drivers – government policy, population growth and community resilience to the effects of climate change.

Stresses on natural resource and mobile populations lead to an increased risk of geopolitical instability. Such impacts have already led to increased tensions in areas such as the Middle East and Africa. Dwindling fish stocks and a melting arctic are now also exposing new political and economic battle grounds.

Infectious Disease

The relationship between infectious disease and a changing climate is multifaceted and complex. There are four main types of disease transmission.

Anthroponoses (Human Source)

- Direct – HIV, Tuberculosis or leprosy.
- Indirect, via vector host / contaminated water – Malaria, Dengue or Cholera.

Zoonoses (Animal Source)

- Direct – Rabies, Avian Influenza or Ebola.
- Indirect, via vector host / contaminated water – Lyme disease, Bubonic Plague or West Nile Virus.

We have already touched on the effects of water scarcity and malnutrition and how they can lead to increased infectious disease. Mass migration also significantly impacts the transmission of infectious disease by many means such as disrupting health services and vaccination efforts, and overcrowded housing.

Variable rainfall, longer monsoons and warmer temperatures lead to significant changes in the prevalence and geography of vector borne diseases. It is predicted that global temperature rise of 2-3°C will increase the number of people at risk of malaria by several hundred million, whilst the seasonal duration of the disease would increase in many endemic countries.[6] Vector borne diseases are extending their area of prevalence. For example, Dengue Fever in Southern Europe and in August 2019 the first cases of native Zika virus were described in Southern France.[6]

Changes in infectious disease transmission are very likely to continue with a changing climate, and it is essential that we learn more about their complex causal relationships.

Summary

The ways in which climate change will influence the health of our populations is complicated and at times overwhelming. Figure 1 summarises the impact of climate change in human health and how it exacerbates existing inequalities.

Within healthcare systems it is essential that we assess risk locally and adopt adaptive management strategies to ensure resilience and preventative strategies.

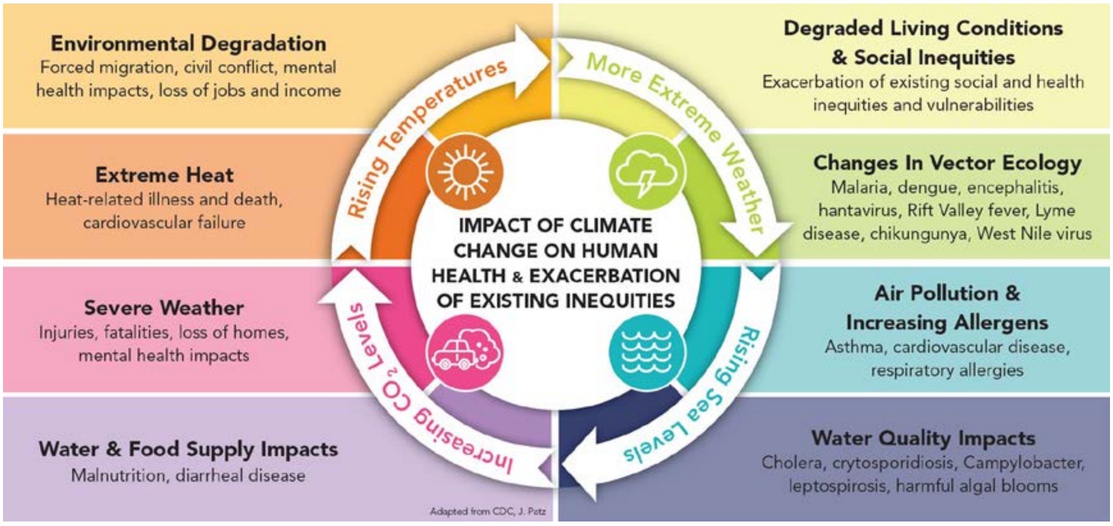


Figure 1: Impact of Climate Change on Human Health & Exacerbation of Existing inequalities.[7]

Air Pollution and Cardiorespiratory Disease

Air pollution is the biggest environmental threat to the UK's health. Exposure is linked to chronic health conditions and to a reduced life expectancy. Long term exposure is estimated to result in 28,000-36,000 deaths a year.[8]

What is meant by air pollution?

Air pollution is a mixture of both natural and man-made components (figure 2). Most urban air pollution consists of nitrogen dioxide and particulate matter (particles of various sizes and compositions depending on factors such as emission sources and location). The size of the particulate matter determines potential health effects whereby, the strongest evidence for effects is associated with fine particles. Other common pollutants include ammonia, ozone and sulphur dioxide.

Although the focus of this module is on the effects of outdoor pollution, it is important to remember that there several indoor sources of pollutants that can have adverse health effects. These include gases and particulate matter from domestic appliances (cooking, heating), tobacco smoke and compounds from cleaning products.

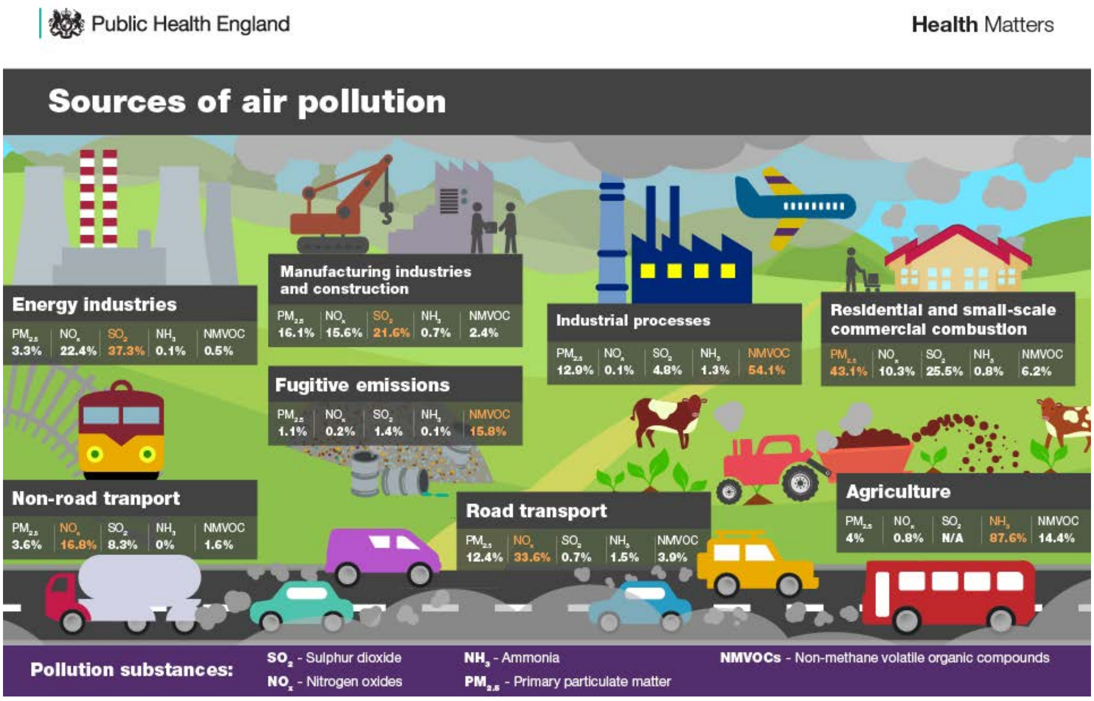


Figure 2: Sources of Air Pollution [8]

It is worth noting that there are over 9.5 billion NHS related road miles per year, which is around 3.5% of all road travel in England. This is from staff and patient travel and logistics.[9]

Health effects of air pollution

Studies have shown that both short-term and long-term exposure to air pollution can have adverse impacts on multiple organ systems such as:

- **Lungs**
  - Asthma: causation and exacerbation
  - Accelerated decline in lung function for adults and older people
  - Chronic obstructive pulmonary disease
  - Lung cancer
- **Cardiovascular system**
  - Coronary heart disease
  - Increased risk of heart failure, myocardial infarction and arrhythmias
- **Central Nervous System**
  - Stroke
  - Dementia

The impacts of exposure to poor air quality affect people across their life course[10] from pre-conception to old age (Figure 3). It also disproportionately impacts on the most vulnerable groups of people such as older persons, children, pregnant women and those with pre-existing health conditions.[10]

These health impacts result in increased hospital admissions and premature deaths. Studies have shown particulate matter to cause increased hospital admissions and deaths on high pollution days.[8]

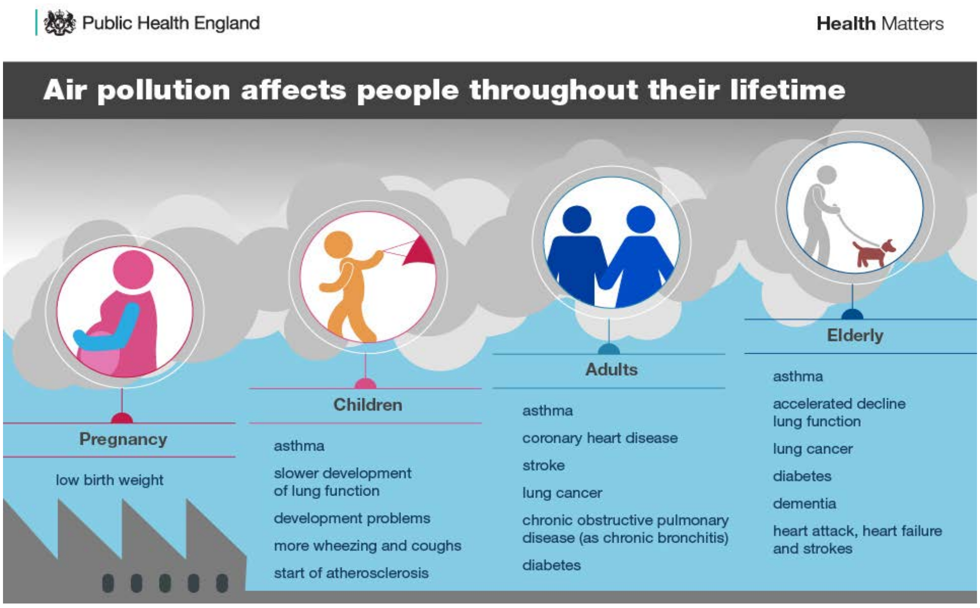


Figure 3: How air pollution affects people throughout their lifetime [8]

The scale of the problem extends beyond public health to socioeconomic costs. A 2010 report from the European Audit Committee suggested the cost of air pollution to be in excess of £8-20billion.[8] Another report from 2012 suggested the cost to economy to be £2.7 billion in lost productivity alone.[8]

Social sustainability, social inequalities and civility in healthcare

What are health inequalities?

The Kings Fund describes health inequalities as "avoidable, unfair and systematic differences in health between different groups of people".[11] Essentially, this means that factors such as socioeconomic status, gender, ethnicity and social exclusion are correlated with poorer health outcomes.

An example of this is difference in healthy life expectancy across socio-economic strata. In figure 4 the dark green dots look at life expectancy compared to income, whilst the light green dots represent disability-free life expectancy. The more deprived you are, the shorter your life is and the greater proportion of it is spent in ill health. People in the most deprived parts of England live, on average, 19 years less in good health compared to the least deprived parts.[11]

This relationship, known as the social gradient in health, exists across the whole population and is not exclusive to the extremes of deprivation. Health inequalities are therefore experienced by everyone. This relationship was described in Sir Michael Marmot's report "Fair society, healthy lives" and can be used to demonstrate other measures of deprivation such as education, access to green spaces and exposure to air pollution.[12]

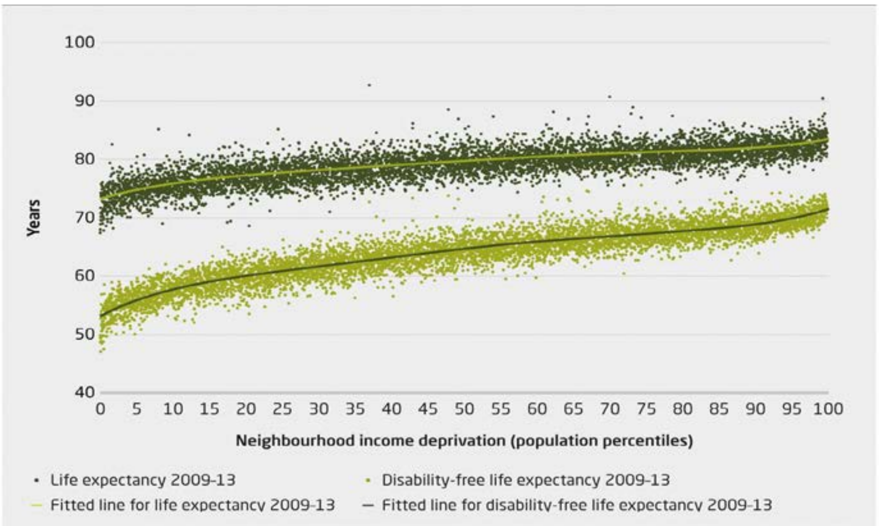


Figure 4: Inequalities in male life expectancy and disability-free life expectancy by neighbourhood deprivation 2009 – 13 [11]

Health inequalities and climate change

Health inequalities can be observed in the consequences of climate change on a national and global scale. For instance, heat-related mortality is more likely to affect older people, those with pre-existing medical conditions and those living in urban settlements. Similarly, climate change can lead to emerging infections and flooding, the impacts of which are over-represented in disadvantaged areas.

Although poor air quality affects everyone in the UK, the distribution of adverse health effects is shown to disproportionately impact on socio-economically deprived communities.[13] This could be linked to:

- higher rates of pre-existing morbidity associated with deprivation
- reduced access to health care, employment and decent housing
- increased likelihood of living in unhealthy environments such as clustering of disadvantaged communities around busy roads.

The role of public health in climate change

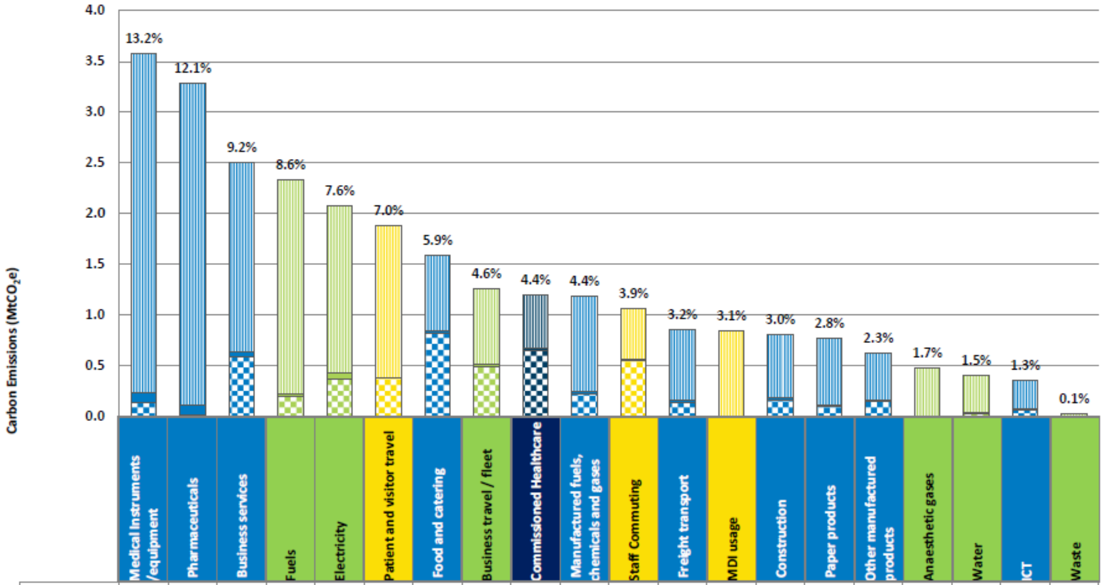
Given the wide-reaching consequences of climate change, there is a clear role for public health authorities in focusing on whole populations and on the wider determinants of health to reduce the inequalities in associated health impacts. Examples include:

- Response plans to emergencies such as heatwaves and flooding
- Health promotion interventions to improve health and wellbeing and reduce the prevalence of non-communicable diseases
- Local-based interventions to improve population health whilst reducing inequalities such as encouraging active travel to increase physical activity. This will also reduce congestion and pollution
- Surveillance of vector-borne diseases as climate-associated changes occur in the transmission and distribution

Healthcare within international agreements

This module has primarily considered the effects of the climate crisis and how the health sector and healthcare professionals need to mitigate against them. Whilst climate resilience is essential in dealing with the fallout, the sector needs to look at how it is contributing to the problem. A brief review is provided below but for more detail please read the e-modules within this series entitled '*Sustainable Healthcare' and 'International agreements'.*

Globally the health sector contributes to 4.4% of net emissions.[14] If the health sector were a country it would be the fifth largest emitter on the planet. On-the-whole this is linked to healthcare spending; those who spend more, emit more. In the UK the health sector makes up 5.4% of net carbon emissions.[14] The Sustainable Development Unit[15] described the carbon hotspots in the health and social care system within England (figure 5). Anaesthesia activity contributes to the majority of these components.



	Medical Instruments /equipment	Pharmaceuticals	Business services	Fuels	Electricity	Patient and visitor travel	Food and catering	Business travel / fleet	Commissioned Healthcare	Manufactured fuels, chemicals and gases	Staff Commuting	Freight transport	MDI usage	Construction	Paper products	Other manufactured products	Anaesthetic gases	Water	ICT	Waste
Total	3.57	3.29	2.50	2.33	2.07	1.89	1.59	1.25	1.20	1.19	1.07	0.86	0.85	0.81	0.77	0.62	0.47	0.40	0.36	0.03
%	13.2%	12.1%	9.2%	8.6%	7.6%	7.0%	5.9%	4.6%	4.4%	4.4%	3.9%	3.2%	3.1%	3.0%	2.8%	2.3%	1.7%	1.5%	1.3%	0.1%
NHS	3.34	3.18	1.86	2.11	1.64	1.51	0.74	0.74	0.53	0.94	0.50	0.70	0.85	0.63	0.66	0.46	0.47	0.37	0.28	0.03
Public Health	0.10	0.09	0.05	0.02	0.06		0.02	0.02	0.02	0.03	0.02	0.02		0.02	0.02	0.01		0.01	0.01	0.00
Social Care	0.14	0.02	0.58	0.20	0.37	0.38	0.83	0.49	0.65	0.22	0.55	0.14		0.16	0.09	0.15		0.03	0.07	0.00

Figure 5: Carbon Emissions from NHS, Public Health and Social Care in 2017.[15]

In line with international agreements the NHS recently published 'For a Greener NHS' with a commitment to reaching net zero.[16] It is essential that we work together to reduce the carbon footprint associated with how we work. When we look at non-maleficence it essential that we expand the scope of potential harm from the end of our needle to the wider populous when we make clinical decisions. We must resolve the potential conflicts between caring for our patients and ensuring we care for our planet.

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Sustainability: **International agreements**

Version 1.00 October 2020

Dr Katharine Elliott
Dr Sally Durdin

Contents

Module Learning Outcomes

- International agreements and protocols(Montreal, Kyoto, Kigali, Paris, Osaka, Glasgow 2021)
- Greenhouse gas protocol.
- Climate Change Act.
- Healthcare without harm
- Other government Acts and policies, as well as UK and global strategies for climate change

Climate change is increasingly being recognised as one of the biggest threats to the planet. International cooperation is fundamental to attenuate the impact of climate change on global health. Since the first Conference of the Human Environment in 1972, there have been multiple international climate change agreements (see figure 1 below), each identifying areas where improvements need to be made in order to prevent climate change and protect the world. In this module we will look at some of the international agreements and UK policies which may impact on the global issue of climate change and offer strategies to tackle it.

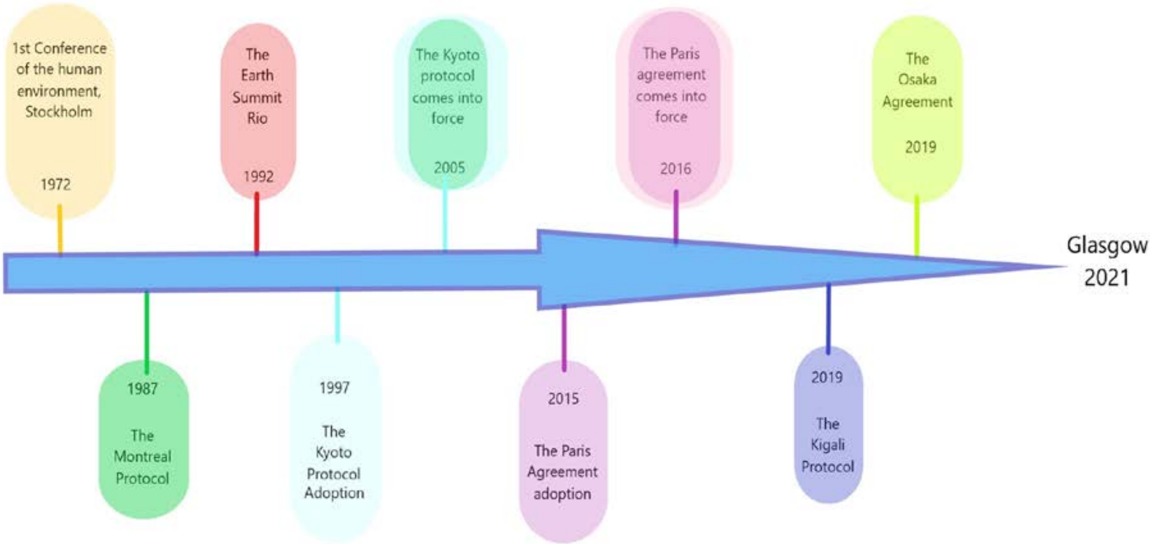

Figure 1: Timeline of international climate change agreements. Designed by authors.

International agreements and protocols

The Montreal Protocol (1987)[1]

At the Vienna Convention in 1985, scientific discoveries were discussed which exposed the effect of human activity on the integrity of the ozone layer. Holes in the ozone layer had been discovered over the Antarctic, and this prompted international action. Two years later, the Montreal Protocol was established and universally ratified. The agreement aimed to phase out substances found to be contributing to ozone depletion, such as chlorofluorocarbons (CFCs). It banned the production and use of CFCs and also exposed the scale of their illegal trade.[a]

The Montreal Protocol set out a timetable of targets for the phase out of 96 specific known ozone depleting substances (ODS).[1] It is reviewed regularly as further scientific knowledge becomes available and with technological advances[2]. Six amendments throughout the years have added to the substances controlled under this protocol. Since its implementation, the atmospheric concentrations of CFCs have not risen.

The Kyoto Protocol (1997-2005)[3]

This international agreement aimed to reduce the emissions of 6 main greenhouse gases (GHGs):[4]

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PCFs)
- Sulphur hexafluoride (SF_6)
- Nitrogen Trifluoride (NF_3)[b]

The Kyoto Protocol was adopted in Kyoto in December 1997, and became international law in February 2005. It recognised that developed countries were principally responsible for the majority of GHG emissions, and bound them to emission reduction targets. The aim was to reduce emissions by 5.2% below pre-industrial levels with a deadline of 2012. These emissions represented 29% of the world's total GHGs. Each nation had its own individual target to reach by this date. Unfortunately, the USA left this agreement in 2001, concerned it would harm the US economy, and Canada withdrew in 2011.

In 2012, delegates at the Doha conference chose to extend the Kyoto Protocol into a second commitment period, until 2020, and added nitrogen trifluoride (NF_3) to the list of GHGs covered in the agreement.

The Kyoto Protocol aimed to use natural carbon 'sinks', such as trees, to remove GHGs from the atmosphere. It also introduced the Clean Development Mechanism, whereby a country committed to an emission reduction could invest in countries and projects developing clean energy, sustainable infrastructure and technology. This would allow the committed country to gain carbon credits towards its targets, and developing countries to improve their sustainable footprint, mutually benefitting both countries. Penalties, such as economic and political sanctions, were introduced for countries which failed to meet their targets.

The Paris Agreement (2015-2016)[5]

The Paris Agreement was the first ever legally binding global climate change agreement, which replaced the Kyoto protocol. Its long term, holistic approach to climate change recognised wide-ranging goals:

- To prevent global temperatures from rising above 2°C higher than pre-industrial levels, while striving towards limiting the increase to 1.5%
- To pass peak emissions as soon as possible
- Net GHG neutrality within this century
- To have a 20% reduction in CO_2 emissions, a 20% increase in renewable energy and a 20% increase in energy efficiency by 2020
- Establishing binding commitments for Nationally Determined Contributions (NDCs) from each country, reviewed every 5 years
- Encouraging the use and preservation of natural carbon sinks and reservoirs
- Providing funds for developing parties to meet their commitments
- Developed countries to support and finance developing countries
- Long term sustainable technology development

It entered into force in 2016 and every 2 years, all countries must present their emissions inventories as a way of tracking progress towards their targets.

The Kigali Protocol (2019)[6]

The Kigali Protocol is an amendment of the Montreal Protocol, which aims to avoid the production of 70 billion tonnes of CO_2 equivalent emissions.[7] It focuses on the recovery and destruction of banks of hydrochlorofluorocarbons (HCFCs) used in refrigeration, hydrofluorocarbons (HFCs), used as refrigerants, insulation and aerosols, and ozone depleting substances (ODS) as well as tackling the illegal trade of HCFCs and HFCs. The phasedown of HFCs is expected to avoid up to 0.5°C of global temperature rise. Countries involved are expected to reduce their use of HFCs by 80-85% before the late 2040s. Medical HFCs (MDI propellants and inhalation anaesthetic agents) are excluded from this agreement.[c]

The Osaka Agreement (2019)[8]

This recognised the US withdrawing from the Paris agreement, and focused on investing in good quality infrastructure and providing access to health education and training. It discussed investment in sustainable growth and financing business innovation to help combat climate change.

The Greenhouse Gas Protocol

The GHG protocol is a standardised method for companies, governments and cities to comprehensively calculate their greenhouse gas emissions.[9] Globally, it is the most widely used tool for quantifying emissions of the 7 greenhouse gases named in the Kyoto Protocol.

The GHG Protocol's 'Corporate Standard' tool separates greenhouse gas emissions into 3 'scopes':

Scope 1 – Emissions from a source that you, or your organisation, directly own or control, for example, gas boilers, or fossil fuels for company vehicles.

Scope 2 – Indirect emissions from generation of electricity purchased from a provider (where the emissions occur at the provider's facility).

Scope 3 – Any other indirect emissions, from sources not owned or controlled by the company. For example, production of materials purchased by the company.

Benefits of a global, standardised way of producing an accurate and comprehensive inventory of emissions are that it:

- Reduces the cost of assessing emissions and makes it accessible to all
- Allows easy identification of focal points for reduction
- Allows investment in lower carbon strategy to be guided to the areas where it will be the most effective
- Facilitates comparison over time and between companies or products.

UK: The Climate Change Act (2008)

The Climate Change Act is an Act of Parliament that obligates the Secretary of State for Energy and Climate Change to ensure that the net UK carbon account for 2050 is at least 100% lower than the 1990 baseline, to avoid 'dangerous climate change'.

The Committee of Climate Change (CCC) is an independent body of expert advisors, established by the Climate Change Act. They advise the government on emissions targets and progress towards meeting them, carrying out analyses of science, politics and economics related to climate change.

The initial figure set in law was 80% lower than the 1990 baseline, with the aim to keep atmospheric carbon dioxide concentration below 550 particles per million (ppm). This was thought at the time (incorrectly) to be enough to avoid an increase in global average temperature of more than 2°C.[10]

The target was increased to 100% in 2019 by the Climate Change Act (2050 Target Amendment) Order 2019, following guidance from the Committee on Climate Change in their 'Net Zero Technical Report',[11] which was in turn informed by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.[12] The Intergovernmental Panel on Climate Change (IPCC) is a UN body which analyses scientific evidence relating to climate change. The report showed that global heating can be limited to 2 degrees only if carbon dioxide levels are kept to less than 450 ppm. Carbon dioxide levels were 300ppm or less for more than a million years prior to the industrial era.[13] Levels for 2020 are forecast to be 414ppm at the time of writing, increasing by around 2.5 to 3ppm each year.[14]

The 2019 revision of the Climate Change Act is essential if the UK is to honour the Paris Agreement. The challenge is for net-zero, rather than gross-zero. This means that there will still be emissions, but they will be offset by forests and oceans -natural carbon sinks.

How the Climate Change Act Works

For each five-year period until 2050, a maximum quantity of greenhouse gas emissions or 'carbon budget' is set. This occurs at least 12 years ahead of each five-year period to allow adequate preparations. When each carbon budget is set, the government must respond by publishing strategy and policies which enable the budget to be met. It is recognized that the process is dynamic and that proposals must be constantly measured and adapted. Strategy, progress, shortfalls and predictions are monitored continuously by the CCC who then advise the government on the best course of action, considering emerging scientific research and evidence, and cost effectiveness. The government are obliged to consider but not to follow the advice from the CCC, but meeting the budgets is enshrined in law. See table 1 below for more details.

Table 1: UK carbon budgets 1-6

Budget number	Time period	Target $MTCO_2e$	% below 1990 baseline	Further details
1	2008 – 2012	3018	25	Outperformed by 1%
2	2013 – 2017	2782	31	Outperformed by 14%
3	2018 - 2022	2544	37	Shortfall predicted
4	2023 – 2027	1950	50	Implemented via carbon budgets order 2011
5	2028 - 2032	1725	57	Implemented via carbon budgets order 2016
6	2033 - 2038	Delayed due to COVID-19	Not yet known	First budget to incorporate net zero legislation

The first 3 carbon budgets (covering the time period from 2008 to 2022) were set in 2008 when the Climate Change Act was made. The 4th carbon budget (2023-2027) was set in 2011 and the 5th in 2016 – 12 years ahead. The Climate Change Act 2008 requires government strategy to be published 'as soon as is reasonably practicable' after setting the carbon budget.

The Clean Growth Strategy 2017[15] sets out plans for how the 5th carbon budget (2028-2032) will be met. The government came under criticism for the 16-month wait for this plan following the publication of the carbon budget. At the time of writing, the 6th carbon budget, due to be set in April 2020, remains to be determined. It has been delayed on account of COVID-19.

UK progress towards a carbon-zero future

The UK has shown clearly that the economy can grow whilst emissions diminish. It was the first country to legislate greenhouse gas emissions targets and to enshrine net-zero in law. Its first three carbon budgets were outperformed. Total CO_2 emissions are currently around 40% lower than they were in 1990, and the country is decarbonizing more rapidly than any other G20 country.[16] A few UK milestones and projections are outlined in figure 2.

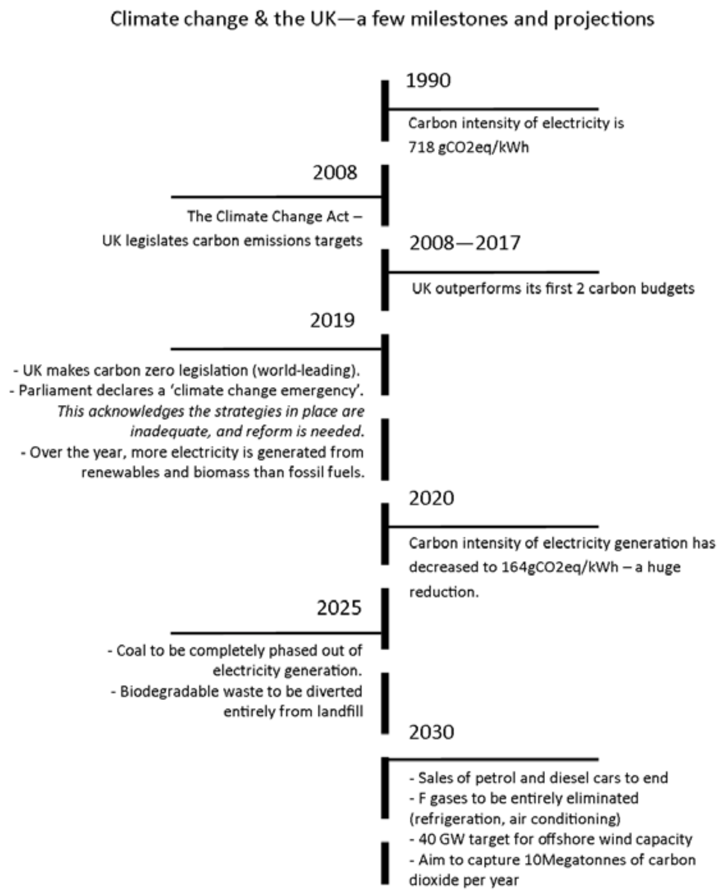

Figure 2: Climate change and the UK - a few milestones and projections

The move away from coal and towards gas and renewables (wind, biomass, solar and nuclear) for electricity is the main player in the reduction in total emissions observed. The carbon intensity of electricity generation has decreased dramatically. It compensates to an extent for growth or stagnation in other major areas. Clean electricity and the electrification of other areas, such as transport and industry, forms a major component of ongoing carbon reduction strategy. The impact of this on total emissions is large but will not be enough to achieve carbon neutrality. Changes beyond electrification require major investment, innovation, and lifestyle changes. Emissions are rapidly rising in the transport, business, domestic and agricultural sectors.

The UK's government's Committee on Climate Change (CCC) predict that the fourth and fifth carbon budget targets will not be met, and that the net zero target is not credible unless major reform takes place. Some of the major cuts in emissions have been attributable to outside factors rather than strategy; the move from coal to gas, the economic recession in 2008, and a large increase in imported goods from China, for which the carbon footprint is not accountable by current means.

UK Climate Change Strategy

The CCC in their Net Zero Technical Report[17] break the challenges down into eight major areas. Below are some of the ways that these areas will be addressed. This is not an exhaustive list.

1.Power and hydrogen production

- Increased development of renewables – nuclear, wind, solar, green hydrogen
- Carbon capture and storage (CCS) – construction of 4 major UK CCS centers by 2030
- Closure of coal stations

Power emissions from burning coal and gas for electricity form about 15% of total emissions in the UK. About half of the reduction in total emissions from the 1990 baseline have come from reduction in energy supply emissions. This is due to increased development of renewables, and closure of coal stations.

CCS forms a major part of the plan going forward – but currently there are no carbon capture facilities in the UK, and the price of carbon capture is very high.

2.Buildings

- New buildings are to be entirely carbon neutral by 2025
- Existing homes will have improvements in efficiency such as wall insulation and low carbon heating.

3.Industry

- Eight industrial sectors (cement, ceramics, chemicals, food and drink, glass, iron and steel, oil refining, and pulp and paper) currently emit around 2/3rds of industrial carbon emissions. Investment from government will allow major changes – for example, energy efficiency of commercial buildings and electrification of heating.

- **Green GB and NI** - A campaign running over a week each year, dedicated to businesses, government and civil societies to explore how to tackle climate change, and how clean growth will affect our futures.

- **London Green 500** - A carbon mentoring program to reduce London's emissions by 60% by 2025, making businesses sustainable and creating tailor made plans for lower carbon alternatives, whilst remaining lucrative.

4.Surface Transport

- Legislation will terminate sales of new petrol or diesel cars and vans by 2030
- By 2035, all vehicles sold are to have zero tailpipe emissions.
- Investment in EV charging capability.
- Systematic changes to public transport.
- Infrastructure changes to make cycling, walking and working remotely easy.

5.Aviation and Shipping

- Operational measures (air traffic management and efficiency)
- Fuel efficiency
- Sustainable biofuel
- Constrained growth
- Carbon offsetting (for example, planting compensatory trees)

International shipping and aviation are not included formally in the carbon accounts, a subject of considerable contention. Greta Thunberg has accused the government of 'very creative carbon accounting' with regard to this. Aviation and shipping emissions are addressed by UN agencies, but there is growing doubt, as the sectors continue to grow, that these have the ability or power to curb this major source of carbon emissions. Strategy relies heavily on carbon offsetting, which many believe not to be a solution moving forwards. The net zero legislation however does include emissions from shipping and aviation, so it remains to be seen how this will be achieved.

6.Agriculture, land use, forestry

- Planting trees – a new forest network including forests on farmland. Boris Johnson pledged to plant 30,000 hectares of new woodland by 2025.
- Restoring peatland
- Carbon Capture and Storage

The CCC and government are careful about suggesting changes in diet. It is well established scientific fact that a plant-based diet has a drastically lower carbon footprint than one that includes meat and dairy. 78% of global farmland is used to raise animals, which provide 18% of calories eaten.[18] Over half of all land farmed in the UK is for animal fodder. Only a fraction of this would be needed to grow crops for direct human consumption. This has massive implications regarding climate change, and has a gross detrimental effect on global biodiversity.

Despite overwhelming evidence, the CCC cautiously suggests only a 20% reduction in beef, lamb and dairy in their most ambitious projection. Government strategy for emissions reduction in agriculture fails to address this.

7.Waste

- Divert biodegradable waste from landfill
- Limit emissions from waste combustion
- Investment to reduce food waste by 20% by 2025

8.F gas emissions

- Completely move away from F gas emissions (by 2030)

The Green Recovery Plan

In November 2020, the UK government published a summary document laying out plans for a 'Green Industrial Revolution' following the COVID-19 pandemic. It breaks the areas down into 10 points.[19] The shortfalls, ambitions, feasibility, optimism and inadequacy of the ten-point plan have been dissected at length by the media and scientists worldwide.

1. Offshore wind – 40GW by 2030
2. Low carbon hydrogen production – 5GW by 2030
3. Nuclear – a large scale nuclear plant is suggested, and the potential for jobs it would create is praised, but there are no solid proposals other than investment in targeted nuclear research.
4. Shift to electric vehicles – no new petrol or diesel cars to be sold after 2030, all new vehicles to be carbon-zero by 2035.
5. Green public transport, cycling and walking – for example, thousands of miles of cycle lanes and 4000 electric buses
6. Jet zero and green ships – operational measures and investment in sustainable aviation fuel
7. Greener buildings – 600,000 heat pumps installed per year by 2028, investment in decarbonizing the public sector, carbon-zero new homes and extended grants to make improvements to existing homes.
8. Carbon capture and storage – Aim to capture 10Mt of carbon dioxide per year by 2030
9. Protecting natural environment – Creation of new National Parks, Landscape Recovery projects.
10. Enhancing green finance and innovation

Climate Change and Healthcare

Healthcare Without Harm (HCWH)

This is an international Non-Governmental Organisation (NGO) of healthcare systems and professionals, which works within the healthcare sector to reduce its negative effects on the environment.[20]

Their main targets include:

- Dangerous chemicals (e.g. Mercury and Endocrine Disrupting Chemicals)
- Greenhouse gas emissions
- Antimicrobial resistance
- Sustainable procurement of goods and services by the healthcare sector

In 2019, HCWH in collaboration with ARUP released a report – "Health Care's Climate Footprint'[21] which stated that 'If the health sector were a country, it would be the fifth-largest emitter on the planet'. The report:

- was the first report to estimate emissions from global healthcare.
- shows that healthcare, which exists only to improve health, is itself a king pin in the greatest threat to global health - the climate crisis.
- establishes comparisons between areas – estimating that Europe's healthcare footprint is disproportionately high and combined emissions from healthcare in the US, China and Europe form 56% of the global total.
- breaks down the relative contributions according to the greenhouse gas protocol: Scope 3 forms 71% of emissions.
- makes recommendations which compel the sector to address their emissions and work towards meeting the terms of the Paris Agreement.

NHS Net Zero Carbon

On 1st October 2020, The NHS published the first world document to commit to net zero carbon by 2050.[22]

This summary outlines the stages in a patient's care pathway where action must be focused to achieve that goal.

1. Developing a framework to evaluate carbon reduction associated with new models of care . See e-module within this series entitled '*Processes, pathways and journeys*' for further details and examples.
2. To work with NHS suppliers to ensure that all of them meet or exceed the commitment on net zero emissions before 2030. See e-module within this series entitled '*Procurement, supply chain and carbon costing'* for further details and examples.

3. Working towards road-testing for what would be the world's first zero-emission ambulance by 2022, with a shift to zero-emission vehicles by 2032 feasible for the rest of the fleet. For example, rewards for staff driving carbon neutral vehicles.
4. Ensuring the digital transformation agenda aligns with the ambition to be a net zero health service, that it reduces wastage and replication of visits, tests and investigations.
5. Construction of 40 new 'net zero hospitals' as part of the government's Health Infrastructure Plan
6. Completing a £50 million LED lighting replacement program
7. Building resilience and adaptation into the health and social care network – can our health service function in the setting of severe weather events be they floods or heat waves
8. For a greener NHS, and ensure that every NHS organisation has a board-level net zero lead, making it clear that this is a key responsibility for all staff.

UK Net Zero and Anaesthesia

Many of the above areas of carbon reduction can be favourably influenced by changes in perioperative and anaesthesia practice. Considering specifically reducing the effect of inhalational anaesthetics and nitrous oxide, please see section 3.4.2 within 'Delivering a net zero NHS'[22] as well as to the e-module within this series entitled *'Medical gases'*.

Global strategies for climate change

Throughout the world, countries are working to meet targets and form strategies to slow global heating. The United Nations Framework Convention on Climate Change (UNFCCC) is a driving force behind many policies. It was founded in 1992 and has 197 member countries.[23] The ideas it promotes aim to reduce GHG emissions and avoid a dangerous temperature increase by reporting national emissions, funding climate action in its member countries and unifying global action. Only through global policy will GHG emissions be substantially reduced and climate change be tackled effectively. The UNFCCC recognises this and although there is a long way to go, its strategies have had a positive impact on global awareness of climate change, and the fight to prevent it.

The enormity of the problem may seem daunting but everyone in every stage of their daily lives can make a difference. It is only by working together that we can pull back from the precipice and preserve the planet for the future generations.

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[a] Ozone depleting substances generally contain chlorine. One ODS molecule is capable of destroying tens of thousands of molecules of stratospheric ozone. Importantly ODS also have significant global warming potentials. For example, the GWP of CFC-11 (CCl3F) is 4660.

[b] Nitrogen Trifluoride added in the Doha Amendment in 2012, treaties.un.org/doc/Publication/CN/2012/CN.718.2012-Eng.pdf (Accessed September December 2020)

[c] The propellants in MDI inhalers are mainly HFC-134a (tetrafluoroethene GWP 100 1430) and to a lesser extent HFC-227ea (heptafluouropropane GWP 100 3220). There is a well-established, though perhaps not so well advertised, MDI recycling scheme operated through pharmacies. Any residual propellant is recycled minimising the immediate environmental effect and sold to other industries as general manufacture is phased out as part of the Kigali Agreement. All MDI users are encouraged to make use of the inhaler recycling scheme. The value of the scrap aluminium in an inhaler is about 1p.

Royal College of Anaesthetists

e-LA e-Learning Anaesthesia

Sustainability:
Sustainable healthcare

Version 1.00 September 2020

Dr Tim Smith
Dr Dominic Hutchinson

Contents

Module Learning Outcomes

- Definitions (sustainability and sustainable healthcare)
- Value in healthcare – triple bottom line
- Proportion of CO_2e attributable to healthcare (UK and worldwide)
- Targets for emissions reduction and UK wide organisations (Sustainable Development Unit and Centre for Sustainable
- Healthcare Principles of sustainable quality improvement

This e-learning module introduces the concepts of sustainability and sustainable healthcare, looking specifically at the various environmental impacts of healthcare, and what is currently being done globally and nationally to address these issues. At a local level, anaesthetists can help shape healthcare systems so that they not only provide social and economic value, but also protect the natural environment. One way in which we can do this is using Sustainable Quality Improvement (SusQI) methodology, which is also considered below.

Definitions

Sustainability

It is generally agreed that for anything to be sustainable it must satisfy social, economic and environmental factors. This is known as the **tripartite nature of sustainability.**

One of the best-known definitions of sustainability is from the Brundtland Report[1] referring specifically to sustainable development:

> **"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"**

However, this definition has been criticized for being too broad, and weak ecologically. Ideally, it is preferable to use the term **ecological sustainability**, which may be defined as:

> **"Economic and social development that protects and restores the natural environment and social equity"[2]**

Without this specific reference to the natural world, sustainable development becomes an oxymoron and tends to become shorthand for economic sustainability. This distinction is important, as it recognizes that human activity (including healthcare and economics) is a subsystem of the global ecosystem (see figure 1). Human health and survival are understood to be completely dependent on the presence of intact ecosystems and biodiversity.[3,4]

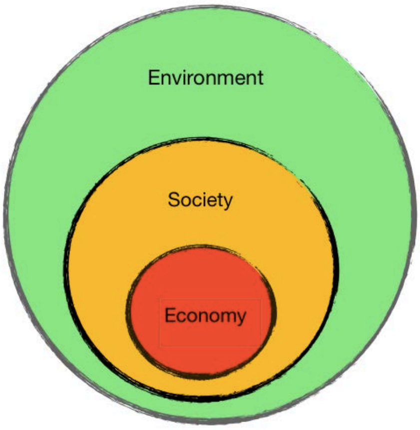


Figure 1: The tripartite nature of sustainability (adapted from Harding et al[5])

Sustainable healthcare

Current healthcare systems are anything but ecologically sustainable. They are responsible for multiple negative environmental impacts including greenhouse gas emissions, waste generation, air pollution, water consumption and pharmaceutical pollution,[6,7,8] and as a result are unwittingly contributing to human morbidity and mortality.

A genuinely sustainable healthcare system would not only meet immediate healthcare needs and promote population health with minimal financial costs, but also safeguard the health of future generations, by conserving natural resources and minimising ecological damage.[9]

Impact of healthcare

Carbon emissions

Since 2007, the NHS England Sustainable Development Unit (SDU) has monitored the carbon emissions of the health and social care sectors. SDU data from 2017 estimates NHS emissions to be 21.54 Megatonnes of CO2 equivalents (MtCO2e).[8] If these figures were representative of a country it would rank as the 87th largest contributor to global CO2e emissions out of 204 countries and territories![10] If we include the entire health and social care (HSC) sector, this figure is higher at 27.1 MtCO2e, which represents 6.3% of the carbon emissions of England.[8]

Carbon hotspots

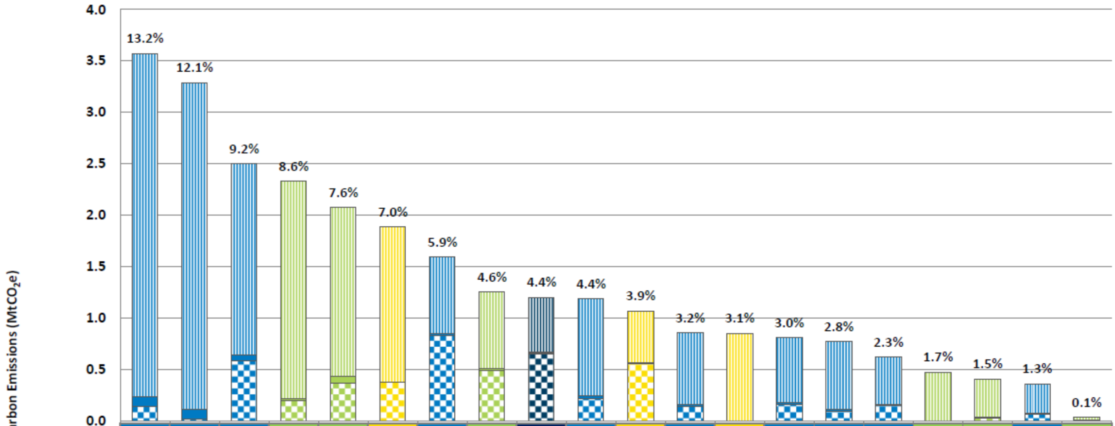
The SDU also identifies and reports on those areas within healthcare with the highest carbon emissions, known as **carbon hotspots.** [8, 11, 12] This is very useful, as it allows more effective targeting of mitigation efforts and allows us to track progress in these areas over time.

SDU data from 2012[12] suggested that the key carbon hotspots in health, public health and social care were:

- **Pharmaceuticals, medical devices and gases**
  - Accounted for 16% of the emissions
  - 9% relates to medical devices and equipment
  - **Gases used in anaesthetics account for 1.7% of the total overall carbon footprint and 5% of the entire acute care footprint (the vast majority of this is due to nitrous oxide)**
- **Energy**
  - Represented 15% of all emissions
  - Efforts at reduction include reducing energy usage, improving energy efficiency and increasing the amount of low carbon energy used
- **Travel and transport**
  - Accounted for 13% of all emissions
  - Includes staff travelling to work and to see service users, service users travelling to care sites and transport of goods

More recent data from 2017[8] suggests that the overall health and social care carbon footprint has decreased by 18.5% since 2007. The two largest hotspots were medical equipment and pharmaceuticals. Business services, energy and travel were again significant contributors. Metered dose inhalers, used in the treatment of asthma and chronic obstructive pulmonary disease also stood out as a targetable carbon hotspot, accounting for 3.1% of HSC emissions.

The graphic below in figure 2 illustrates how healthcare CO_2 emissions can be broken down (SDU data from 2017).[8]



	Medical Instruments /equipment	Pharmaceuticals	Business services	Fuels	Electricity	Patient and visitor travel	Food and catering	Business travel / fleet	Commissioned Healthcare	Manufactured fuels, chemicals and gases	Staff Commuting	Freight transport	MDI usage	Construction	Paper products	Other manufactured products	Anaesthetic gases	Water	ICT	Waste
Total	3.57	3.29	2.50	2.33	2.07	1.89	1.59	1.25	1.20	1.19	1.07	0.86	0.85	0.81	0.77	0.62	0.47	0.40	0.36	0.03
%	13.2%	12.1%	9.2%	8.6%	7.6%	7.0%	5.9%	4.6%	4.4%	4.4%	3.9%	3.2%	3.1%	3.0%	2.8%	2.3%	1.7%	1.5%	1.3%	0.1%
NHS	3.34	3.18	1.86	2.11	1.64	1.51	0.74	0.74	0.53	0.94	0.50	0.70	0.85	0.63	0.66	0.46	0.47	0.37	0.28	0.03
Public Health	0.10	0.09	0.05	0.02	0.06		0.02	0.02	0.02	0.03	0.02	0.02		0.02	0.02	0.01		0.01	0.01	0.00
Social Care	0.14	0.02	0.58	0.20	0.37	0.38	0.83	0.49	0.65	0.22	0.55	0.14		0.16	0.09	0.15		0.03	0.07	0.00

Figure 2: Health and Social Care carbon emissions detailed breakdown 2017 (source: SDU[8])

Given the urgent need to tackle climate change, there is an understandable focus on the carbon footprint of healthcare systems, however, it is important to understand that the impact of health and social care extends much more widely than this.

From a UK perspective, in 2017 the health and social care sector was responsible for the following:[8]

- 590,000 tonnes of waste, generated by NHS providers alone
- 5% of all road travel in England, leading to a £345m cost to society as a result of the mortality from the air pollution generated (3.5% attributable to the NHS)
- 10% of the country's economy and workforce
- A water footprint of 2.23 billion m^3, which would fill the equivalent of 1.1 million Olympic swimming pools!

In addition, **pharmaceutical pollution** is emerging as a major threat to human and ecosystem health.[7] Drug prescribing is the most common intervention in the NHS, resulting in medications entering wastewater systems via urine and inappropriate disposal into toilets and sinks.

However, wastewater treatment plants are inefficient at removing drugs, resulting in contamination of ecosystems and drinking water with bioactive chemicals such as hormones, antibiotics and antidepressants. This has negative consequences for aquatic life and human health and promotes antimicrobial resistance. [6,7]

The global climate impact of health and social care

In terms of carbon footprint, global healthcare emits 2000 $MtCO_2e$ per year. This represents 4.4% of all CO_2 emissions. In fact, if global healthcare represented a single country it would be the 5th largest emitter of greenhouse gases, and produces the equivalent emissions of 514 coal-fired power plants![13]

The United States and China are the two biggest emitters. When combined with the European Union they comprise 56% of the total health care carbon footprint. The United States healthcare sector produces 57 times more emissions per person than India, which is the seventh largest global contributor to healthcare emissions.[13]

Targets for emissions reduction and UK wide organisations

Global emissions reductions

In 2015, as part of the Paris Climate Agreement, nations pledged to limit global temperatures to 2°C above pre-industrial levels, and pursue efforts to further limit the rise to 1.5°C.[14]

In 2018, the Intergovernmental Panel on Climate Change (IPCC) warned that it was crucial to **limit global warming to 1.5°C** in order to keep the effects of climate change within relatively safe limits and avoid catastrophic changes.[15]

In order to stay below the 1.5°C threshold, no more than 420 GTCO_2e can be released into the atmosphere. This is our global carbon budget. At the time of writing this module (2020), with the current rate of emissions, it is estimated that this budget will be exhausted in just over 7 years.[16]

It is clear that we need to achieve net zero CO_2 emissions (global anthropogenic CO_2 emissions balanced by anthropogenic CO_2 removals) as soon as possible. The IPCC report[15] outlines pathways that involve a 45% reduction in emissions by 2030, becoming **net zero by 2050.**

For a detailed description of international agreements please see the e-module within this series entitled *'International agreements'*.

The UK targets

In the UK we have a number of national and organisational drivers in place, aimed at addressing climate change and other environmental crises:

The Climate Change Act (2008)[17] sets out the UK's commitments to climate change mitigation between 2008 and 2050. It can be summarised as follows:

- A commitment to **reducing greenhouse gas emissions by 100% by 2050, from 1990 levels**
- Establishing committees on climate change that extend to devolved administrations
- Setting legally binding carbon budgets to act as stepping stones to the 2050 target

In 2009, in response to the climate crisis and the Climate Change Act (2008), the SDU published its **Carbon Reduction Strategy**[18], setting goals for the NHS. These aimed for a reduction in carbon emissions of 10% by 2015 and 34% by 2020. Although the 2015 target was exceeded, the current trajectory suggests that the target for 2020 of 34% may not be met.[8]

In recognition of the widespread detrimental environmental effects of healthcare, the **SDU** also supports transformations in several other key areas of impact:[8]

- **Plastics**
  - Limit plastic use and waste by engaging with suppliers, innovators and care providers
  - Identify areas where use of plastic can be avoided and, if this is not possible, to establish effective and safe re-use, recycling and disposal
- **Water**
  - Implement water and energy efficiency savings throughout the sector with transparent reporting of water use
- **Air Quality**
  - Identify targeted approaches and incentives to improve local health inequalities through action on air pollution

Furthermore, in addition to national legislation and leadership from the SDU, we also have drivers of environmental change embedded within key NHS policy documents:

The 2019 NHS Long Term Plan[19] outlines commitments to meeting the carbon targets in the UK Climate Change Act (2008), and to reducing air pollution and waste.

The NHS Standard Contract (clause 18) requires providers to maintain a sustainable development plan, minimise environmental impacts (specifically air pollution, greenhouse gas emissions, single use plastics and waste) and demonstrate progress in these areas in an annual report.[20]

Value in healthcare

Value in healthcare is simply a way of expressing how well a healthcare system meets its objectives. It can be defined as the **outcomes** of a process, relative to the **costs**.[21]

An ecologically sustainable approach broadens the definition of value. Costs include **environmental and social impacts**, not simply economic costs, giving what is referred to as a **triple bottom line**.[22] Outcomes refers to both individual patients and population outcomes.

Sustainable value can therefore be expressed as in figure 3 below:

$$\text{Value} = \frac{\text{Outcomes for patients and populations}}{\text{Environmental + social + financial impacts}}$$

(the 'triple bottom line')

Figure 3: Sustainable value in healthcare [22]

Principles of SusQI

It is important to appreciate that anaesthetists (and other health professionals) can help to shape ecologically sustainable healthcare systems at a local level. One tool for doing this that is gaining traction is **Quality Improvement.**

Quality improvement (QI) is the ongoing, systematic effort to improve patient outcomes and system performance.

You can find more information about QI as applied to anaesthetic practice at The Royal College of Anaesthetists QI Recipe Book,[23] which contains sections on Sustainable Quality Improvement.

For more information about QI as it relates to healthcare generally, the Institute for Healthcare Improvement is a good resource, which also offers free online courses.[24]

Sustainable Quality Improvement (SusQI) [22, 25] is a practical framework that extends the scope of QI to include:

- Ecological sustainability
- Adding social value
- A long-term perspective

Thus, **a SusQI project in Anaesthesia** would consist of 4 stages, which can be incorporated into existing QI methodologies:

- Set goals (e.g. minimising waste in operating theatres, instituting waste segregation streams and recycling)
- Study the system
- Design the improvement effort
- Measure impacts

The key difference with SusQI is in nature of the **improvement efforts** and the **impacts measured.**[25]

Improvements focus more on patient empowerment and self-care, prevention of disease, lean service delivery and low carbon alternatives.

Impacts would include not only clinical impacts and financial costs, but also social impacts and environmental impacts.

Ideally, when considering the environmental impacts of a system, one would calculate **total ecological footprint**, rather than simply estimating greenhouse gas emissions. However, we commonly see only carbon footprint reported, as this is much more easily quantifiable and reflects the current focus on the climate crisis.

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Royal College of Anaesthetists

e-LA e-Learning Anaesthesia

Sustainability: **Procurement, supply chain and carbon costing**

Version 1.00 October 2020

Dr Murray Connolly, Dr Tim Keady,
Dr Michael O'Sullivan and Dr Vincent Wall

Contents

Module Learning Outcomes

- Overview of procurement process and NHS supply chain.
- Scope 1, 2 and 3 emissions (see the Greenhouse Gas protocol).
- Carbon analyses – life cycle, cradle-to-gate and cradle-to-grave.
- Whole-life-cycle costing.
- Current supply chain and procurement models vs ideal sustainable system.

The procurement of the goods and services necessary for the NHS to function comes at a significant environmental cost. This module outlines the procedures surrounding procurement, areas where sustainability can be improved and summarizes the common concepts used to measure and reduce the total environmental impact of NHS procurement activities.

Overview of the Procurement Process and NHS Supply Chain

Procurement is the process whereby an organization meets their needs for goods, services, works and utilities by finding these amenities and agreeing terms with vendors. Procurement processes include many key steps, as described in Figure 1. Each of these offer an opportunity to improve the sustainability of the organization.

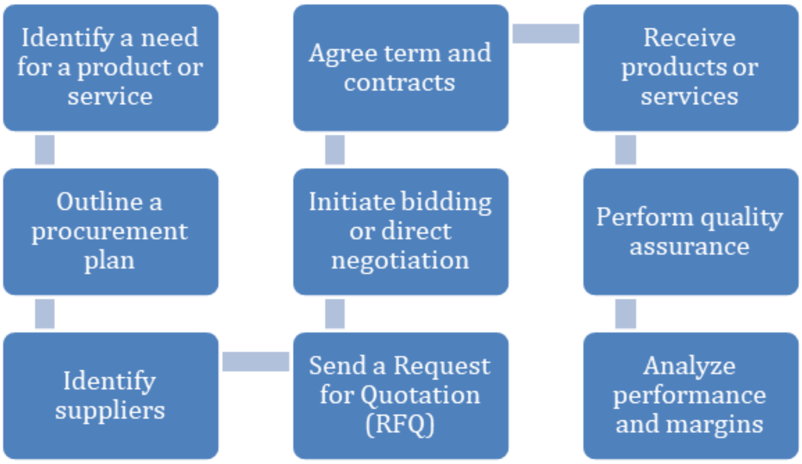

Figure 1: An example of a typical procurement process flow chart, designed by the authors

The compartmentalization of the NHS into Trusts means that there could be a risk of significant overlap in contracts and a high risk of inefficiencies. In order to minimize this the NHS Supply Chain manages the procurement of healthcare products, services and food for NHS trusts and healthcare organizations across England and Wales equating to more than 4.5 million orders per year, across 94,000 order points and 15,000 locations. Its systems aim to consolidate orders from over 800 suppliers, saving trusts time and money and removing duplication of overlapping contracts.[1]

Traditional tendering processes concentrated primarily on a single variable, the economic value. However, there is a growing realization that the "value" of a product or a service can also be measured by its social and environmental impacts.

The Sustainable Development Unit (SDU) introduced to the NHS the concept of the Triple Bottom Line (TBL) to develop services, processes and products that are truly sustainable. The TBL provides a framework which can be used to examine the performance of an organization according to three aspects: economic success, social variables, and environmental impact.

NHS Supply Chain is now giving far more consideration to this, and they have developed an ethical Procurement Strategy,[2] which aims to deliver environmental and economic savings, as well as ensure that the goods and services procured are produced in a socially responsible manner.

Current Procurement Models vs the Ideal Sustainable System

The NHS Supply Chain was created in 2006 to help the NHS deliver clinically assured, quality products at the best value, and to use the buying power of the NHS to negotiate better deals. However, a report into efficiency and productivity in the NHS, published in 2015, identified unwarranted variation in procurement across the NHS, and huge potential for financial savings.[3] Using the TBL framework, as promoted by the Sustainable Development Unit since its inception in 2008, there has been a drive towards more sustainable procurement.

What is ideal sustainable procurement?

The UN environment program defines ideal sustainable procurement as a process

"whereby public organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole life-cycle basis in terms of generating benefits not only to the organization, but also to society and the economy, whilst significantly reducing negative impacts on the environment."[4]

See Figure 2.

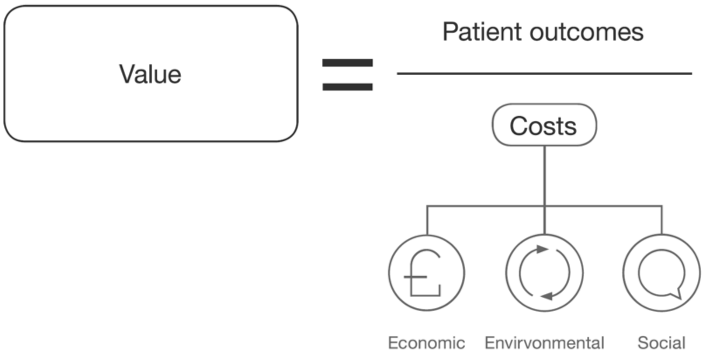

Figure 2: Value in Ideal Sustainable Procurement[5]

Fortunately, in most cases, environmental and cost savings go hand in hand. For example, the increasing problem of "Single Use Disposable" plastics in the NHS has recently been outlined.[6] Medical plastics account for 2% of global plastics production by value.[7] Potential practice changes including switching from single use to reusable items and the reprocessing and reuse of single use medical devices have unsurprisingly been found to be cost saving or cost neutral, while being safe for patients.[7] This area contains myriad opportunities for quality improvement initiatives that save money and protect the environment.

Scope 1, 2 and 3 Emissions: The Greenhouse Gas Protocol

The terminology of Scope 1, 2 and 3 emissions refers to a means of categorizing carbon emissions produced by an institution laid out in the Greenhouse Gas Protocol.[8] The standard helps companies identify greenhouse gas (GHG) reduction opportunities, track performance, and engage suppliers at a corporate level.

- **Scope 1** emissions are onsite or **direct** emissions from owned or controlled sources. e.g. fossil-fueled boilers, vehicles and chemical production. This also includes the GHGs released as part of clinical care, including inhalational anaesthetic agents, nitrous oxide, metered-dose inhaler propellants and sulfur hexafluoride.

- **Scope 2** emissions are **indirect** emissions from the generation or purchase of energy e.g. electricity use, energy recovery from waste disposal.

- **Scope 3** emissions are all **indirect** emissions not including scope 2 that occur in the supply chain of the reporting institution e.g. procurement.

This system of analysis is useful in identifying hotspots in the supply chain and activities of an organization. It also allows comparison from year to year and between organizations. However, it must be remembered that only measuring the GHG ignores other environmental impacts of an organization such as air pollution, waste, and water consumption. Further information on the additional impacts of unsustainable processes can be found in the accompanying e-modules; "*Health and climate change*", "*Waste - what happens to it*?" and "*Energy use and water consumption*".

The Sustainable Development Unit reports the carbon footprint of health and social care provision in the UK using four categories; core, commissioned, supply chain and community. These categories reflect the level of influence of the health system on these emissions. In the 2018 report it was calculated that the supply chain accounted for 57% of its carbon footprint.[9] The report identified three major hotspots: pharmaceuticals, medical equipment, and business services. All three of these are part of the supply chain and correspond closely to Scope 3 emissions. For this reason, reducing the carbon emissions of any health sector is a difficult task. However, there are certain tools which can enable clinicians, procurement officers and everyone involved in healthcare to choose the product or process that offers most value for money.

Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool that may be used to measure the environmental impact of a product or process. It is a standardized practice that allows an organization to quantify the energy consumption, resource depletion and both direct and indirect emissions of a product at every step throughout its lifespan i.e. from cradle-to-grave (Figure 3).[9] Life Cycle Costing (LCC), which measures the financial cost of a product over its lifespan, will be discussed later.

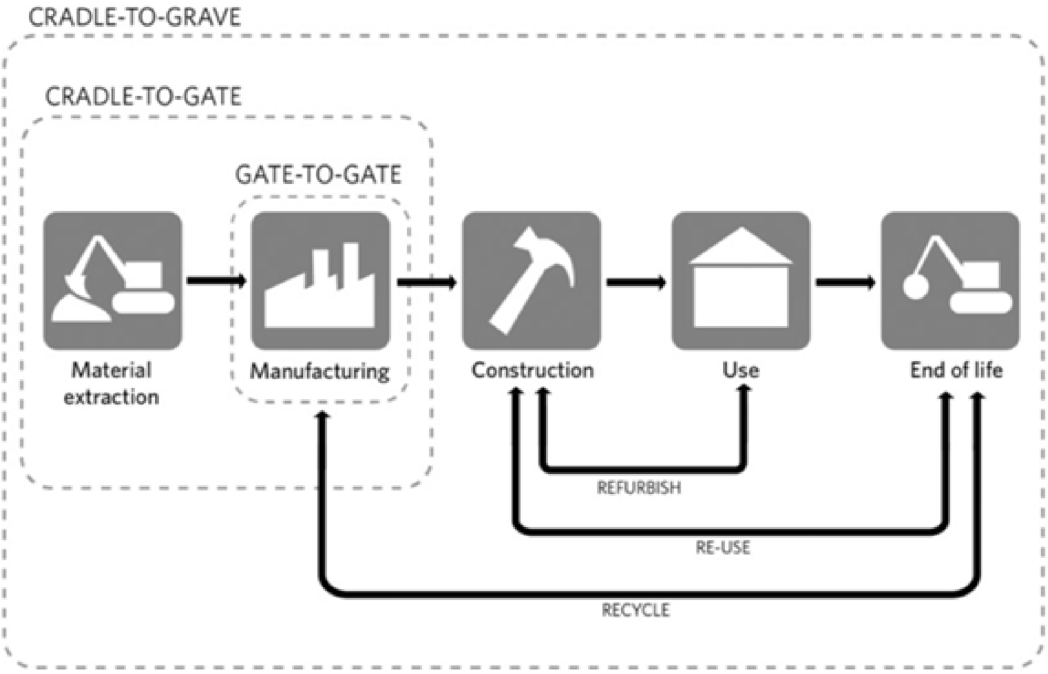

Figure 3: Life Cycle Assessment is a tool that can be used to measure the environmental impact of a product or process. The assessment may have a variety of boundaries. Manufactures sometimes assess the gate-to-gate or cradle-to-gate environmental footprint. A cradle-to-grave approach allows us to account for the re-use and recycling of products as well as their disposal. Adopted with permission from K Simonen, Life Cycle Assessment.

Carrying out an LCA requires the aggregation of large amounts of data relating to inputs and outputs (e.g. emissions) at every step in the life of a product or process. There are broadly two methods of conducting an LCA.

Process-based LCA

This method itemizes inputs and outputs of a process at every stage, using Life Cycle Inventory (LCI) databases that report emissions and direct measurements. For example, producing a laryngeal mask airway will require plastic for manufacturing, electricity for powering the machines at the manufacturing plant, transportation of the laryngeal mask airway to distributors and hospitals, and the eventual disposal of the airway. Consideration of the environmental impact of the process could potentially extend into impractical layers of data i.e. to include the emissions from producing the machines required for raw material extraction, etc. It is therefore important to set system boundaries that define the scope of the LCA. Process-based LCA is most useful in assessing and comparing the environmental footprints of small easily defined products. It is too labour intensive for most large systems.

Environmental Extended Economic Input-Output (EEIO) LCA

Economic input-output analysis is a method of measuring the monetary interactions of sectors of the economy. It is a dynamic matrix which evaluates how a unit of currency spent in one commodity sector can influence how money is generated or spent in another. This model can be modified to measure the environmental inputs/outputs throughout a supply chain. Environmental EEIO systems add resource consumption and energy outputs to the matrix and so measure how production in one sector leads to resource depletion in another. A relationship between energy flow and monetary flow throughout the whole model is established. Carbon emissions per monetary unit can thus be approximated, allowing the environmental footprint of large processes such as healthcare systems to be estimated. Environmental EEIO modelling does have some drawbacks, however. For example, if NHS supply chain were to begin purchasing a generic version of a pharmaceutical, this lower financial cost would seem to indicate lower carbon cost, but this may or may not reflect reality. Furthermore, the macroeconomic scale of the calculations can make it difficult to demonstrate modest emissions reductions.

LCAs in practice

In practice, a combination of the two modes of LCA is often used. A good example of how LCA can be applied to a medical supply chain can be seen in the work by Sherman et al[10] who compared lifelong greenhouse gas emissions generated by using volatile anaesthetic agents vs intravenous agents in the conduct of general anaesthesia. A four order of magnitude difference was found, in favour of intravenous anaesthesia.[10]

There are four main steps involved in carrying out a comprehensive LCA as defined by the ISO-14000 series of standards:

1. **Goal and Scope:** this defines the reason for the study, the intended application and audience. Systems boundaries for data collection must also be defined.

2. **Inventory:** Life Cycle Inventory (LCI) refers to the cataloguing of the environmental emissions of materials. Commercially available software such as Ecoinvent™ contains large databases which provide the input and output values for systems.

3. **Impact analysis:** this step uses LCI data to quantify the resultant environmental impact of the production system. Various tools are

available to conduct this analysis, one of the more popular being Simapro™.

4. **Interpretation:** finally, a conclusion of the assessment is provided along with limitations. Recommendations are then given based on the analysis of the results.

Incorporating LCA into the procurement process allows organizations to make conscious decisions regarding the environmental impact of a supply chain. This bolsters the Triple Bottom Line, increases compliance with local and international standards and encourages other industries to engage in sustainable procurement. But of course, LCA is time consuming and expensive.

Whole Life Cycle Costing

Whole Life Cycle Costing is at the heart of green public procurement. It refers to the combination of life cycle assessment (LCA) and life cycle costing (LCC). and addresses all the associated financial costs of a product over a period of analysis as well as the environmental and social effects.

LCA calculation has been previously addressed in this chapter. To calculate the LCC of a product, procurement managers need to consider much more than the invoice price: [11]

1. **Acquisition**: the purchase price or leasing cost of a product
2. **Transport**: if not already included in the cost of purchase
3. **Installation: for heating**, lighting or anaesthetic machines for example
4. **Operation and maintenance**
5. **Disposal**

Much of the whole life cycle costing literature focuses on construction projects and energy efficiency of buildings, some compare re-usable versus disposable medical products. For example, McGain et al performed a consequential assessment based in an Australian Hospital with six operating theatres showing that converting from reusable anaesthetic equipment would result in a 46% decrease in cost but a 9% increase in CO_2 (relating to coal generated electricity). A similar analysis produced an 84% reduction in CO_2 emissions in Europe and a 48% reduction in the USA (due to more sustainable energy generation), with significant financial gain.[12]

Summary

Procurement and Supply Chain account for the majority (57%) of the carbon emissions of health and social care provision in the UK. Although not under our direct control, we can influence these emissions by striving for ideal sustainable procurement. The evaluation of the cost and carbon footprint of products and processes is complex but Life Cycle Assessment and Life Cycle Costing can help us. These tools allow us to address the triple bottom line of environmental protection, social equity and economy, and are the key to achieving sustainable procurement.

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Sustainability: **Medical gases**

Version 1.00 October 2020

Dr Pavan Raju
Dr John Hickman

Contents

Module Learning Outcomes

- Greenhouse gas effect and CO_2e.
- Main areas of use and Control of Substances Hazardous to Health Regulations (COSHH).
- Actions to mitigate their environmental impact, including innovations such as capture (volatiles) and cracking (N_2O).
- Lower-carbon alternatives to their use.
- National strategies and initiatives to measure and audit medical gas use and their environmental impact.

Medical gases are used extensively in healthcare to provide anaesthesia and analgesia, to aid surgeries and to drive several medical devices and tools. The gases and vapours commonly used in the operating theatre are oxygen, medical air, carbon dioxide, nitrous oxide and inhalational anaesthetic agents (IAAs). Among these, IAAs and nitrous oxide are relevant both to anaesthesia and environmental sustainability. The IAAs that are currently in use in the United Kingdom are isoflurane, sevoflurane and desflurane. Along with nitrous oxide, the use of these agents in anaesthesia and their advantages are well established. However, they have some harmful effects on our environment with both direct and indirect adverse effects on our health. For more details on these deleterious effects please see the e-module in this series entitled '*Health and Climate change*'.

Greenhouse gas effect and CO_2e

Inhalational anaesthetic agents are potent greenhouse gases (GHG) and responsible for 5% of the carbon dioxide equivalence emissions of acute NHS hospitals.[1] They undergo minimal metabolism in the body and enter the environment virtually unchanged from the parent compound. The effect of a GHG is measured using carbon dioxide equivalency (CO_2e) which is based on the idea of demonstrating an individual GHG's impact over an agreed time scale (generally 100 years) in equivalent quantity of CO_2 that would produce the same global warming effect. This enables us to use a single unit to measure the global warming potential of different GHGs. So, it is the product of the mass of the GHG released multiplied by its global warming potential (GWP).[2] See '*Background science*' e-module in this series for more information.

Although nitrous oxide (N_2O) is reported in the UK GHG inventory,[3] exact data on emissions due to medical use of N_2O is not included as it is believed to be small. However, medical use has been estimated in the range of 1.3% of total UK emissions.[1] Along with its potent GHG effect (GWP_{100} 298),[4] N_2O is responsible for depletion of the ozone layer and, with an atmospheric lifetime of 114 years, this is not insignificant. The GWP is exaggerated when it is used in combination with other inhalational anaesthetic agents.

Inhalational anaesthetic agents have significant GWP due to their radiative efficiency and atmospheric lifetime. It is their difference in atmospheric persistence that explains the wide range in GWPs, as they all have a similar radiative efficiency. Desflurane has the highest GWP and sevoflurane the least (GWP_{100} of desflurane, isoflurane and sevoflurane 2540, 510, 130 respectively), as the former's atmospheric lifetime is over ten times that of the latter.[4] Given that the minimum alveolar concentration (MAC) of desflurane is three times that of sevoflurane coupled with the difference in GWP, desflurane is nearly sixty times more warming than sevoflurane per MAC hour of use. The interrogative estimate of global inhalational anaesthetic agent release was 3.1 +/- 0.6 million tonnes CO_2e in 2014, with 80% from desflurane alone.[5] See '*Background science*' e-module in this series for more information. Desflurane and sevoflurane lack the ability to deplete the ozone layer as they do not contain chlorine atoms when compared to isoflurane. The impact of isoflurane on ozone depletion is negligible as the tropospheric lifetime is short.

Main areas of use and COSHH (Control of Substances Hazardous to Health) regulations

Inhalational anaesthetic agents are mainly used in an operating theatre environment. Use is gradually increasing in remote areas involving radiology and cardiology intervention suites. N_2O is predominantly used on labour ward in the form of Entonox®. However, other areas such as the dental hospital, emergency department, acute pain services and some pre-hospital settings utilise N_2O for its analgesic property.

Apart from environmental hazards, IAAs have an impact on individuals subjected to occupational exposure. Hence, it is a legal requirement to ensure their safe removal and minimise exposure in the work area. In 1977, National Institute of Occupational Safety and Health (NIOSH) in United States set a limit of 2 parts per million (ppm) for exposure to IAAs and this was based on the lowest levels that could be detected using sampling and analysis techniques, rather than any established safe level of exposure.[5] The UK Health and Safety Commission Advisory Committee on Toxic Substances recognised 50ppm as the threshold for occupational exposure to isoflurane and 100ppm for N_2O over an 8-h time-weighted average below which there is no significant risk to health.[6] This remains the standard as recommended by the most recent COSHH guidance.[7] Unfortunately, the newer agents (desflurane and sevoflurane) are not included, possibly due to lack of evidence of direct human harm. Our veterinary colleagues have set a limit of 60ppm for sevoflurane.[8] Hence, it is prudent to employ the same standards for the newer agents. However, this recommendation is limited to the United Kingdom with other countries having their own standards.[9]

Medical oxygen and medical air

Manufacturing medical oxygen, a highly energy dependent process, is by initial compression of atmospheric air to a liquid followed by fractional distillation. The CO_2e depends on the energy source of electricity and the accepted value is 0.001 kWh energy/litre. The UK daytime CO_2 intensity is 300gCO_2e/kWh meaning that the CO_2e of Oxygen is 0.0003 kg/litre (approx. 0.3g/litre oxygen).[10]

Medical air is produced in house by compressors, filters and dryers. The CO_2e (SimaPro) is smaller than that for oxygen at 0.0003 kWh/litre equating to 0.00009kg/litre (approx. 0.1g/litre medical air).[10]

The process for both is inexpensive, oxygen from the VIE costs about £3 per hundred cubic meters (HCM at 15C) or 0.003 pence per litre. However, it is relatively more expensive (nearly 200 times) from CD cylinders at 0.5 per litre. An environmental advantage would be to use medical air as the driving gas for the ventilator instead of the standard setting where oxygen is typically used.[11]

Actions to mitigate their environmental impact

In the past two decades we have seen the evolution of a number of techniques and innovative technologies aimed at mitigating the negative environmental impact of these anaesthetic agents.

Techniques when using IAAs include:

- Avoidance of agents with high CO_2e (desflurane and nitrous oxide), selection of sevoflurane when IAA required
- Use of low flow anaesthesia (<0.5L/min)[12]
- Turn flows off, not IAA, when manipulating the airway or disconnecting from the circuit
- Over-pressuring the breathing system to allow reduced fresh gas flows, subsequently minimising the volume of IAA used
- Use of anaesthetic machines with end tidal control function have been shown to reduce IAA usage[13]
- Utilising adjuncts to reduce the mean alveolar concentration (MAC) required to maintain anaesthesia e.g. opiates, ketamine and regional techniques.

Innovative techniques:

There are a number of technologies commercially available that aim to address the issue of the venting of waste anaesthetic gases (WAGs) into the atmosphere. Broadly there are two ways in which these function, either to capture, purify and reuse the WAGs or to capture and destroy the WAGs.

Chambers containing absorptive compounds are placed within the anaesthetic gas scavenging system (AGSS) limb of the anaesthetic circuit. The absorbed WAGs are then condensed and either re-purified or destroyed. Metal organic frameworks are solid crystalline structures containing pores of varying and specific size which are able to accommodate and capture IAAs. Other absorption condensation systems also include the use of supercritical carbon dioxide and aluminosilicates[14] and are described in detail in reference by *McGain et al 2020.*[14]

Of all the anaesthetic gases 75% of the associated carbon footprint is due to nitrous oxide.[3] It is possible through the use of a heated catalyst unit to crack nitrous oxide into its constituent molecules, nitrogen and oxygen. This technology is however costly and has not gained popularity in the United Kingdom to date. In Sweden such technology has been in use since 2004, the largest of these units can be found at the Karolinska University Hospital in Stockholm.[15]

Lower carbon alternatives

Alternative techniques to inhalational anaesthesia:

- Use of Total Intravenous Anaesthesia (TIVA), which has been shown by *Sherman et al 2012* to have a significantly lower environmental impact when compared to all inhalational anaesthetic agents.[16]
- Use of regional anaesthetic techniques.

Alternative techniques to Entonox® analgesia:

- Use of alternative analgesic techniques in the obstetric setting, e.g. epidurals, remifentanil patient-controlled analgesia, transcutaneous electric nerve stimulation, oral opiates and holistic methods such as aromatherapy and hypnotherapy.
- Methoxyflurane is a short acting IAA and is gaining popularity as a substitute to Entonox® for the management of acute pain in the emergency and pre-hospital setting. With a GWP_{100} of 4 and an atmospheric lifetime of 54 days it is significantly less harmful for the environment when compared to nitrous oxide.[17] However, it does not have a license for use in children, must be avoided in patients with renal impairment and used with caution during pregnancy and in patients with liver impairment.[18]

National strategies and initiatives to measure and audit medical gas use and environmental impact

It is clear that the decisions we make as healthcare professionals have an impact on the health of the planet and subsequently our patients. The Royal College of Anaesthetists (RCoA) has published its sustainability strategy[19] and the Guidelines for the Provision of Anaesthetic Services (GPAS) now acknowledge the importance of sustainability, suggesting that departments should aspire to engage in sustainable quality improvement and academic activities within this domain.[20] The Association has also included environment and sustainability in its long-term strategic planning, with an environment and sustainability committee tasked to guide the specialty on matters of sustainability and green anaesthesia.[21]

The NHS has taken a number of steps towards sustainability in its long-term plan including the launch of ‘For a Greener NHS’ and publication of ‘Delivering a net zero National Health Service’, which have both mandated a reduction in the use of desflurane and nitrous oxide.

On an individual level, the profile of sustainability has been raised in recent years, with an emphasis being placed on the clinician to adapt their practices. Resources such as the *Anaesthetic Impact Calculator*[22], two sustainability chapters (11.1 and 11.2) in the RCoA quality improvement compendium[23] and this series of sustainability e-learning modules enable us to quantify and understand the impact our clinical choices have on the environment.

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Royal College of Anaesthetists

e-LA e-Learning Anaesthesia

Sustainability: Intravenous and local anaesthetic agents

Version 1.00 October 2020

Dr Kathryn Greaves
Dr Juliette Fletcher

Contents

Module Learning Outcomes

- Carbon emissions - inhalational Vs intravenous Vs regional (CO_2e)
- Pharmaceutical water course contamination - implications and strategies to minimise
- Limitations of current evidence base and areas that future research should focus on
- Role and responsibility that industry has to play in sustainable healthcare

This module addresses our individual clinical practice and choices with respect to anaesthesia provision in the context of a move towards delivering a net zero NHS.[1] To truly provide sustainable practice we need to consider not just the environmental, but also the financial and social aspects of a course of action, the so-called triple bottom line.

In 2017 the Health and Social Care (HSC) sector in England was responsible for 4% of the total carbon footprint of the country.[2] The Sustainable Development Unit (SDU) of the NHS, now renamed ‘Greener NHS’, has reported a fall of 18.5% in the carbon footprint between 2007 and 2017 against a backdrop of a 27% increase in clinical activity.[2] Whilst this is encouraging and has helped to meet the interim Climate Change Act targets, this rate of reduction will be nowhere near enough to ensure that we are net zero (against a 1990 baseline) by 2050 and an excess of 10Mt of CO_2e per year over the target is forecast by 2030.[3]

There are many ways in which we, as anaesthetists, can make small changes to our daily practices that will help to shift the balance and accelerate these changes toward net zero. By way of shorthand, we use the term emissions to encompass all greenhouse gases.

Carbon emissions – inhalational vs intravenous vs regional (CO_2e)

Inhalational anaesthesia

The NHS Long Term Plan (2019)[4] identified the anaesthetic gases (sevoflurane, isoflurane, desflurane and nitrous oxide)[2,4,5,6] as a carbon hotspot within the HSC[2] and although they account for 1.7% of all carbon emissions this amounts to 5% of emissions from acute hospitals[2,4,5] equating to around 500,000 metric tonnes CO_2e annually (see Figure 1).

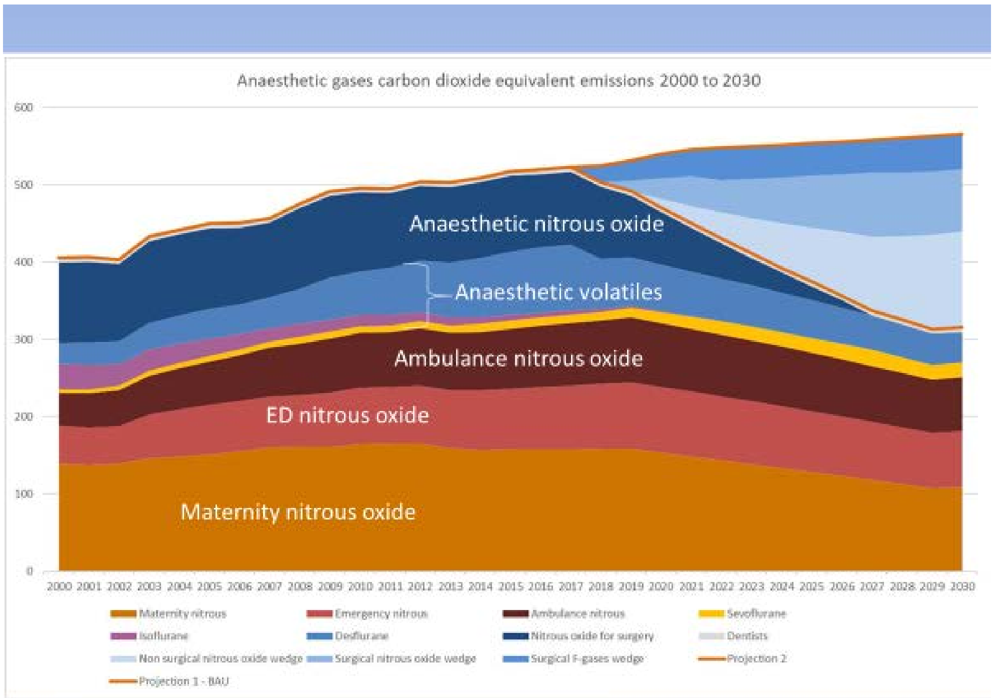
The fluorinated anaesthetic gases absorb infrared radiation at around 10µm. As absorption by naturally occurring greenhouse gases (GHG) does not occur at this wavelength, the agents exert an effect far out of proportion to their low atmospheric concentration. As they are vented to atmosphere unchanged, the more agent that is used and the longer the atmospheric life, the greater the effect. Thus, desflurane has a value twenty times that of sevoflurane (per mass equivalent) but as the MAC is 3 times higher, the global warming effect of a desflurane anaesthetic can be thought of as being approximately 60 times that of sevoflurane (per MAC hour).[7,8] For more details relating to this please see the e-modules within this series entitled '*Background science*' and '*Medical gases*'.

The Anaesthetic Impact Calculator smart phone app[9] calculates the CO_2e of inhaled anaesthesia and allows for comparison between the different agents. Using the validated mathematics behind the calculations, Table 1 was derived and compares the environmental impact of these inhalational anaesthetic agents 'per MAC hour'.[10] To quantify the CO_2e produced from your own practice using inhalational anaesthetic agents, as well as the impact that any changes in practice make to this, download the Anaesthetic Impact Calculator [9] and start inputting your data and tracking reductions. For more details on quality improvement projects pertaining to reductions in emissions relating to anaesthetic gases see the Royal College of Anaesthetists Quality Improvement Compendium, chapter 11 project 11.1 *"Focus on sustainability: reducing our carbon footprint through inhalational agents"*.[11]

	Sevoflurane	Isoflurane	Desflurane	N_2O
MAC	1.85	1.15	6.0	101
Tropospheric lifetime (y)	1.1	3.2	14	114
GWP_{100}	130	510	2540	298
Mass of agent used per hour with low flow anaesthesia (500ml FGF) and 1 MAC (g)	4.7	2.6	13.4	55 At 500ml/min
CO_2e of an hour's low flow anaesthesia at 1 MAC (kg CO_2e)	0.59	1.37	34	16.4 At 500ml/min
Comparative carbon emissions per MAC hour of agent (compared to sevoflurane)	1	2.3	57.6	n/a

Table 1: comparative characteristics of inhalational anaesthetic agents. Kindly provided by Dr JMT Pierce with figures from the Anaesthetic Impact Calculator.[9]

Nitrous oxide emissions in the NHS in England amount to 0.47MtCO_2e, over 5 times the emissions of the total inhalational anaesthetic agent use (0.08MtCO_2e) combined.[6] Anecdotally, the use of nitrous oxide in the operating room has fallen (per hour of anaesthesia) and is predicted to fall further still (Figure 1). Data from Greener NHS indicates that most nitrous oxide emissions come from Entonox® and it is therefore important to consider other locations where nitrous oxide is used for analgesia, including the emergency department, maternity and prehospital care. These are areas where there is a compelling argument to reduce nitrous oxide emissions further, but only where suitable alternative analgesics are available. See the e-module in this series entitled '*Medical gases*' for more details on this.



SDU Presentation to Association of Anaesthetists Glasgow 2019 with permission

Figure 1: With permission from the Sustainable Development Unit. This illustration plots the rise in CO_2e and then models the reductions in anaesthetic gas use in accordance with the NHS long term plan[4] (that 2% of the NHS carbon emissions reduction must come through transformation of anaesthetic practices). Over 80% of the CO_2e of inhaled anaesthetic and analgesic agents is due to nitrous oxide use throughout the healthcare system. Anaesthetic use of N_2O accounts for 25% of the total N_2O CO_2e and 75% is derived from the use of N_2O/O_2 mixes in maternity, emergency department and ambulance services.

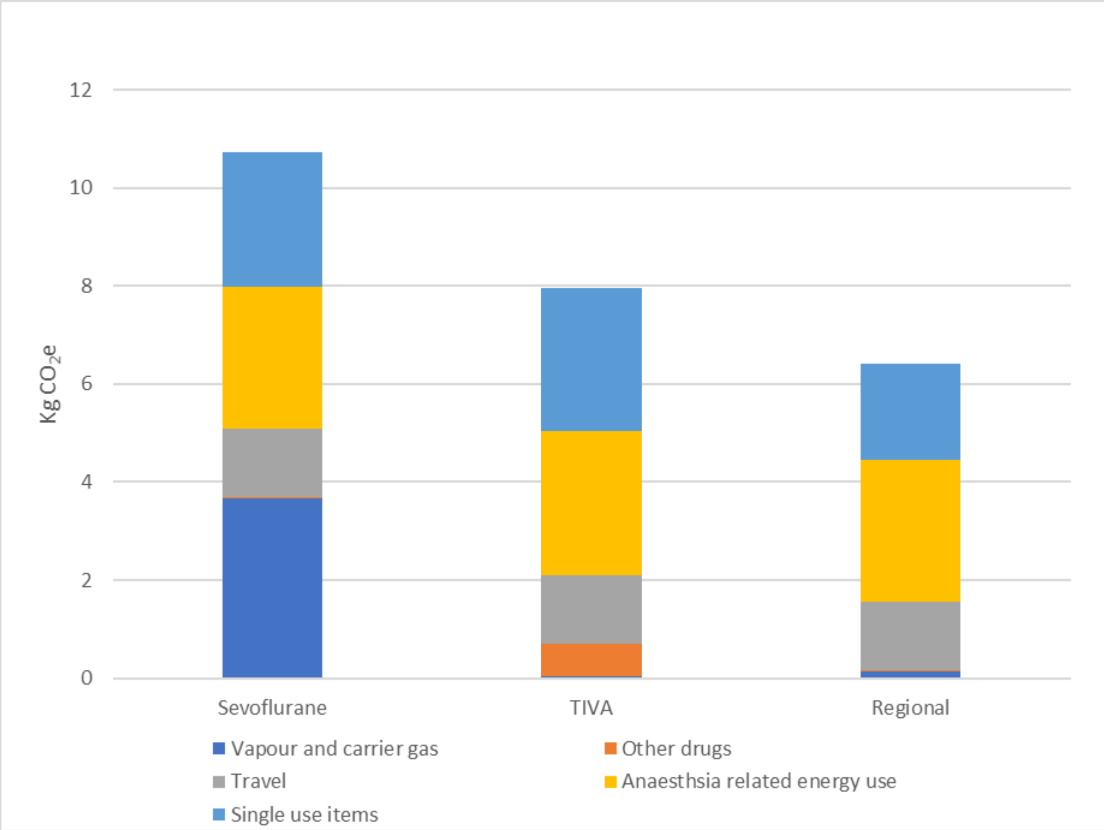
Intravenous and regional anaesthesia

Greenhouse gas emissions from propofol total intravenous anaesthesia (TIVA) are 4 orders of magnitude less than those from nitrous oxide and desflurane.[12] The use of TIVA and regional techniques removes or reduces the use of inhalational agents and thus their carbon emission contribution. Regional techniques, when used in combination with inhalational agents, also enable this due to a 'MAC' sparing effect, reducing the amount of inhalational agent required. TIVA completely abolishes the use of anaesthetic vapour.[12]

A common concern pertaining to the negative environmental impact of TIVA and regional anaesthesia over inhalational methods seems to be surrounding the increased use of single use plastics in the form of syringes in these anaesthetic techniques compared with inhalational. Disposable plastic components (e.g. syringes) used in these procedures are commonly made of polyvinyl chloride (PVC). 1kg of PVC produces 6 kgCO_2e throughout its life cycle, 3 kgCO_2e on manufacture and another 3 kgCO_2e on disposal through incineration. Packaging and residual drugs are also combusted. 1kg of paper produces 2.1 to 2.6kgCO_2e.[13]

Using a worked example and comparing an inhalational anaesthetic with the same procedure performed under TIVA or a regional block we can illustrate the savings, in terms of carbon, that can be made through changes in anaesthetic technique (see

Figure 2). These are not the only benefits to performing procedures in this manner.[14] Patient outcomes and experience may be enhanced if TIVA or regional techniques are successfully employed and there may also be financial savings for the hospital in reduced length of stay, increased day case surgery, reduced postoperative nausea and vomiting and pain, demonstrating that these techniques are sustainable across all three elements of the triple bottom line.



$KgCO_2e$	Sevoflurane	TIVA	Regional
Vapour and carrier gas	3.66	0.03	0.15
Other drugs	0.03	0.66	0.005
Travel	1.4	1.4	1.4
Anaesthesia related energy use	2.89	2.94	2.89
Single use items	2.74	2.94	1.97
Total	10.72	7.97	6.415

Figure 2: Comparison of different anaesthetics for a total knee replacement in an 80kg male for a duration of 2 hours. Kindly provided by Dr JMT Pierce.[15]

Regional anaesthesia

Considering simply the mass alone of single use items and active pharmaceutical ingredients (API), required to achieve safe regional anaesthesia, it would seem that of the three forms of anaesthesia, regional is the most sustainable. However, until there is a good science basis for this statement, we urge a word of caution. We need engagement from industry to determine accurate life cycle assessments for the entirety of contents within a pharmaceutical product and not just limited to the API to gain a clearer understanding of the true difference in impact between these modalities of anaesthesia. One must also remember that the carbon emissions alone do not tell the full negative environmental impact of one anaesthetic technique over another.

Pharmaceutical contamination of watercourses

The process of converting raw materials to active pharmaceutical ingredients, and ultimately to waste products and metabolites risks not only the atmospheric burden but watercourse contamination too.

The term pharmaceuticals relate to compounds manufactured for use as medicines, intended for either human or animal consumption. These compounds are specifically developed to produce a biological effect, their very reason for existence becoming the cause of ecological problems if they are leached into the environment.[16] As pharmaceutical usage has increased over recent decades, so too have the potential polluting effects medicines can have on the environment. These effects will damage wildlife and their natural habitats, and as biologically active compounds enter our drinking water and the food chain, humans may also suffer side effects of their presence. The long-term consequences of watercourse contamination have only been considered in recent studies, and much work needs to be done so that we can prevent environmental damage in the future.

A watercourse is defined as a channel through which water flows, including streams, rivers and estuaries.[17] Pharmaceuticals and their metabolites can reach watercourses through direct and indirect routes (see Table 2 below). Direct routes include sewerage systems, effluents (liquid sewage discharged into the river or sea) from sewage treatment plants, industrial discharges and through livestock and fish farming.[18]

Direct	Indirect
Sewerage systems	Incorrect medicine disposal
Sewage effluents	Reuse of wastewater
Industrial discharges	Fertiliser contamination
Livestock farming	
Fish farming	
Pharmaceutical production	

Table 2: Sources of pharmaceutical watercourse contamination

The majority of direct pharmaceutical watercourse contamination in the UK occurs through domestic and hospital sewage disposal, as human medicines are mostly excreted as metabolites or unchanged in urine and faeces.[19] Indirect contamination is more difficult to monitor, and combines the incorrect disposal of medicines, (being flushed down the toilet or sink,) the recycling of wastewater, and the application of sludge produced in sewage treatment plants onto crops by farmers.[18] This last method of contamination allows pharmaceuticals to enter the soil and crops, thus appearing in the human food chain.

Although research in this area is limited, drug groups most commonly causing concern for their potentially harmful effects on wildlife include the following, with those commonly used during anaesthetic and critical care practices highlighted (in bold):

- **Antibiotics**
- Antidepressants
- **Anti-epileptics**
- Anti-parasitics
- **NSAIDs**
- **Analgesics**
- **Beta-blockers**
- Statins
- **Steroids**
- Oral contraceptives
- Hormone replacement therapies
- Drugs used in the treatment of cancer.[20]

Many of these drugs have also been found in lakes and reservoirs, as well as in seawater.[17]

Implications of watercourse contamination

Drugs that are lipophilic and designed to cross cell membranes have the potential to accumulate in species that they were never intended to reach, such as aquatic animals.[16] The most notable example of this has been the feminisation of male fish in English rivers, a mutation shown to be directly proportional to the amount of oestrogen containing sewage effluent found in the water.[21] This has serious implications for the future sustainability of various fish species, as the affected fish have lower rates of reproductive success.

Phase 1 drug metabolism reactions such as oxidation and hydrolysis result in metabolites that are more water-soluble and sometimes more active than the parent drug. Propofol undergoes glucuronidation and sulphonation to produce water-soluble compounds that are then renally excreted.[22] A very small fraction of propofol is renally excreted unchanged.[23] Perhaps more concerning is the amount of propofol entering the sewerage system through incorrect disposal down the sink. No pharmaceutical waste should be disposed of into the sewers in this way, but propofol has been identified in hospital effluents, and is known to be toxic to aquatic life.[24] Further research will be necessary to determine the implications of the presence of propofol on the aquatic environment. Until these effects are fully understood, action that can be taken easily and immediately is the encouragement of safe waste drug disposal and avoidance of expelling it down the sink.

Veterinary medicine has also been responsible for pollution of watercourses, with anti-parasitic drugs used in sheep dip washing off animals when they enter streams and rivers.[20] These pharmaceuticals kill the larvae of certain fly populations, removing the food source for birds further up the food chain.

Perhaps the most concerning reported public health phenomenon in recent years has been the development of antibiotic resistance, a developing crisis as bacteria change to become less responsive to antibiotics.[25] Global mortality from drug-resistant bacterial infections has recently been estimated at up to half a million people per year.[26] Unnecessary prescribing of antibiotics when they are not clinically indicated, and inappropriate consumption of them in countries where they are available to purchase without a prescription have both contributed to antibiotic resistance, and the World Health Organisation have called for a change in global behaviour in an attempt to prevent this crisis from worsening.[25] Antibiotics have also been implicated in their use in animal feeding operations and fish farming, where they are routinely given to treat disease and promote growth of animals. This has led to dissemination of antibiotic resistant genes into the wider environment.

Hospital effluents have been identified as concentrated sources of antibiotic resistant pathogens such as E. coli containing extended-spectrum beta lactamases (ESBL), and vancomycin resistant enterococcus (VRE).[27] Antibiotic resistant genes can accumulate in nitrogen-rich waste, and while sewage treatment plants utilise numerous methods to reduce the transmission of harmful compounds into the environment, they cannot remove antibiotic resistant genes altogether. The solid portion of sewage is particularly difficult to rid of these contaminants, and if these bio-solids are then used as fertiliser for crops, a new avenue of contamination will exist for antibiotic resistance to develop.

Strategies to minimise watercourse contamination

Recommendations for future practice to minimise pharmaceuticals contaminating watercourses have been summarised by the CHEM-Trust Report,[20] and include the following points:

- Rationalising the use of medicines, and discontinuing any that are no longer indicated
- Ensuring the correct disposal of unwanted medications, for example utilising pharmacy take back schemes
- Improving the functioning of sewage treatment plants to remove pharmaceutical contaminants
- Encouraging the development of more environmentally friendly medicines
- Reducing the use of veterinary medicines in livestock and fish farming

In addition to these points, anaesthetists should all be educated in the correct disposal of unused drugs, to minimise the flushing of potentially harmful medicines into the sink, causing contamination of the aquatic environment. The Association of Anaesthetists has produced a guideline to help clinicians ensure the appropriate disposal destination for waste products within anaesthesia.[28]

The Environment Agency is the Government body responsible for the protection of the environment in England, and the quality of water and water discharges into rivers, lakes and the sea, providing information to their European counterparts.[29]

In order to address the evolving crisis regarding antimicrobial resistance, the EU issued the One Health Action Plan against Antimicrobial Resistance in 2017.[30] Their report acknowledges the importance of environmental contamination by antibiotics and emphasises the need for further research to ascertain the level of threat certain pollutants pose to both wildlife and humans through watercourse contamination.

There are opportunities for almost every healthcare professional as well as members of the public to take responsibility for some of these strategies to minimise watercourse contamination. Recognising the part that we all play in both the environmental contamination by pharmaceuticals, and the drive for sustainability in healthcare is essential if we are to minimise the damage caused by our daily practice.

Limitations of current evidence base and areas for future research

Evidence is key in determining the negative impact that anaesthesia is having on the environment, and consequently how we can improve our working practices to limit such an impact. Whilst much has been done to date, there are still gaps in our knowledge pertaining to this area with further work being necessary.[8] The NHS Net Zero Expert Panel[31] has been created by NHS England in 2020, with the aim to create instructions on how we can achieve net zero carbon emissions and deliver the sustainable elements of the NHS long term plan.[4]

The accepted methodology to evaluate the environmental impact of a drug or device is a Life Cycle Analysis (LCA). An LCA incorporates the impact of the development, evaluation, manufacture, packaging, transport, storage, administration and waste management of drugs and devices and often touch upon more than just carbon emissions, including water and air pollution to allow for fairer comparisons between techniques to be made.[13] The limitations of LCAs are discussed in more detail in the e-module within this series entitled '*Procurement and Carbon costing*', however it is worth outlining some details here.

Considering the LCA of anaesthetic drugs, including gases, the main focus has been on comparing carbon emissions, which reveals part, but not all the environmental impact of our agents. By focusing on carbon emissions alone we may be disregarding other equally, if not more important environmental impacts of our agents, such as water and soil contamination and pollution, air pollution (aside from carbon) and the negative impacts to economies.[7,8] It is only when taking all of these impacts into account that we can have a more balanced approach in choosing the right drug and anaesthetic technique for each patient that we are caring for.

Perhaps one of the biggest limitations in the LCA work into anaesthetic drugs that we have is lack of engagement from pharmaceutical companies. This has meant that the LCA work pertaining to drug production and manufacture from raw materials to parent compound is based on derivations from first principles, as drug manufacturing 'recipes' remain a closely guarded secret, with carbon emissions being very well-educated calculations and estimates rather than actual emissions data. Greater transparency is necessary as often only the API is focused on within these life cycle analyses and the manufacturers do not account for the other excipients in the drug's ‘recipe’. Collaboration with the pharmaceutical industry using this life cycle method will create more accurate LCAs of anaesthetic drugs and may allow anaesthetists to make more informed decisions.[7,13]

In the context of waste drugs further research is needed to understand the environmental impacts they might have other than greenhouse gas emissions. With some measure of unprocessed drugs, and their metabolites likely to make their way into the aquatic and agricultural environment, it is important for future research to investigate what course these agents take within ecosystems, whether they are harmful, and actions that we can take to mitigate these detrimental effects.[7]

The role of industry in sustainable healthcare

Looking into the future, it is clear that techniques to reduce carbon emissions alone will not be sufficient to avert a climate catastrophe in coming years. Projections by Greener NHS have outlined that significant innovation, as well as 100% uptake of current sustainability initiatives (both governmental and clinical) will still leave a huge shortfall to our net zero carbon emissions 2050 climate change target.[2] Innovation will be necessary to bridge this gap, with schemes such as the introduction of an environmental ratings system for anaesthetic drugs already being postulated.[32] Examples of environmental protective strategies already utilised in anaesthesia include techniques to capture, extract and reuse anaesthetic gases [8,33,34,35] 'cracking' of nitrous oxide, use of reusable equipment over single use where appropriate, reduction of waste and wasteful processes and procedures, along with appropriate waste segregation. All these techniques are summarised in the recent BJA article "Environmental sustainability in anaesthesia and critical care".[8] The search for an ideal, sustainable anaesthetic agent with minimal environmental impact is still ongoing. Further information can also be found in the following e-modules within this series – '*Sustainable healthcare*', '*Procurement and carbon costing*', '*Medical gases*', '*Processes, pathways, and journeys*', '*Energy use and water consumption*', '*Waste- what happens to it*' and '*The anaesthetist as an educator*'.

A sustainable healthcare system has been defined as one that is able to deliver "high quality care and improve public health without exhausting natural resources or causing severe ecological damage".[1] The NHS is one of the largest public sector contributors to climate change, with carbon dioxide emissions in excess of 20million tonnes each year.[36] In an effort to improve environmental sustainability the NHS Carbon Reduction Strategy was set out in 2009. This outlines the measures that will need to be taken for the NHS to meet the targets from the Climate Change Act (2008). As previously stated, the overall target is for the UK to demonstrate a reduction in its carbon emissions to net zero, in relation to the 1990 values, by the year 2050.[37]

To assist the NHS in meeting this target, in 2008 two organisations came into existence, the Centre for Sustainable Healthcare, and the Sustainable Development Unit (now known as Greener NHS). The Centre for Sustainable Healthcare is a charitable organisation working with healthcare professionals, patients, and members of the public to promote the connections between maintaining good health and caring for the environment.[38] They have outlined 4 principles of sustainable clinical practice, which are:

- Prevention
- Patient empowerment and self-care
- Lean systems
- Low carbon alternatives

These principles have been reiterated by Public Health England, who collaborated with the NHS and social care providers in 2014 to address the issues of sustainable healthcare. Their three aims focus upon creating and maintaining a healthy environment, building resilience within the population to achieve health, and preventing or managing health problems where possible.[39] Greener NHS is an organisation working with the NHS and Public Health England to promote the three elements of sustainability – environmental, social and financial.[1] They work with the Government assessing the sustainable development requirements of public healthcare in England and supporting processes to reach the zero carbon emission goal by 2050.

On a global scale, the World Health Organisation (WHO) recognised the changing demands of healthcare in 2012, introducing the Health 2020 policy to address these needs.[40] Ensuring the sustainability of all European health care systems was one of its central policies. Within this report they stress that "collaboration between environmental and health sectors is crucial to protect human health from the risks of a hazardous or contaminated environment".[40] The achievement of these targets will rely upon investment from every possible sector, ranging from the government to healthcare professionals and patients themselves.

As anaesthetists we are uniquely situated in the healthcare service battle against climate change. We are the largest specialty amongst hospital doctors, and our collective actions can therefore be used to exert leverage within our organisations and beyond. We are frequently individual practitioners with the freedom to choose how we deliver the best care to our patients from a wide range of techniques. However, collectively our influence can stretch far beyond the encouragement of TIVA and regional options, and the avoidance of desflurane and nitrous oxide. Through working with our industry partners, we are able to change the supply chain and procurement, opting for more sustainable options wherever possible. This has already been demonstrated through surveying anaesthetists on whether they utilise plastic hook rings on anaesthetic facemasks, and subsequently discontinuing their use.[41] We all have a responsibility to take action, lowering carbon emissions and reducing drug wastage. Ensuring we remain updated with new developments and making more environmentally considerate choices will be the first step in our journey towards providing greener anaesthesia for our patients.

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e-LA
e-Learning Anaesthesia

Sustainability: **Processes, pathways and journeys**

Version 1.00 October 2020

Dr Ania Dean
Dr Fiona Brennan

Contents

Module Learning Outcomes

- Increasing efficiencies and minimising waste (Muda principles, and SUSQI – the Centre for Sustainable Healthcare's 'Sustainability in Quality Improvement' framework).
- Cutting waste in clinical care (lean patient pathways) and choosing wisely.
- Healthcare related transport – contribution to climate change and chronic disease.
- Active transport, low-carbon transport and positive health benefits for patients, relatives and staff.

This module describes methods to minimise the environmental impact of the NHS. This includes the creation of lean patient pathways, principles for minimising waste as well as the impact of healthcare related transport and the benefits of active and low carbon transport.

Lean Patient Pathways

The “Lean Approach” is a concept taken from the Japanese car industry that can be used to increase efficiencies in healthcare by the elimination of waste, referred to as Muda which means waste in Japanese.[1] Most waste within healthcare is due to inefficiencies in models of care or systems, rather than wasted physical products.[2]

Value is the opposite of waste. Hence, promoting low waste in healthcare will allow for high value. A “value-promoting doctor”[2] follows a patient centred approach to develop a sound differential diagnosis, allowing only essential testing to be carried out. Clinicians need to have a good understanding of healthcare systems to enable the “leaning” of patient pathways.

The five **“lean principles”**[3] aim to increase efficiency.

Lean principles:

1. **Value** – caring for the patient effectively to meet their expectations
2. **Value Stream** – mapping out the steps and processes in the healthcare pathway to identify and eliminate wasteful steps where possible
3. **Flow** – streamlining the process to remove obstructions and minimise interruption wherever possible
4. **Pull** – ability of the patient to manipulate the service according to their needs
5. **Perfection** – continual improvement

‘A Blueprint for Streamlining Patient Pathways Using a Hybrid Lean Management Approach’[4] is an excellent resource providing a blueprint for clinicians looking to streamline pathways.

Minimising waste

Healthcare Professionals (HCPs) have a responsibility to promote environmental sustainability in the healthcare service and reduce waste at all levels. This is in line with the Public Services (Social Value) Act 2012.[5]

HCPs are trusted advocates in society; they have the ability to lead by example in both their personal and professional lives and can push for sustainability as a core value in their workplaces and homes.

Figure 1 is a list of wastes from the 2014 Academy of Medical Royal Colleges (AoMRC) report: Protecting resources, promoting value; a doctor's guide to cutting waste in clinical care.[2] The report commented: 'Maintaining NHS services may depend on doctors engaging with this issue to an extent that has not previously been the case'. The report spelt out that 'avoiding waste and promoting value are about the quality of care provided to patients – which is a doctor's central concern. One doctors' waste is another patient's delay. Potentially it could be that other patient's lack of treatment'.[2]

1. **Overproduction**
   For example, automatically requesting blood tests for pre-op assessments or duplicating patient information across different services or teams.
2. **Inventory**
   For example, inappropriately using inpatient beds for patients who are waiting for tests but could be discharged safely, or ordering excess medical equipment because the supply is unreliable.
3. **Waiting**
   For example, surgeons waiting for a theatre to become available.
4. **Transportation**
   For example, moving a patient to an inpatient bed for review at post-op ward round and then to another ward for discharge.
5. **Defects or errors**
   For example, an inaccurate patient history or the incorrect recording of a blood test.
6. **Staff movement**
   For example, separate sites for outpatient clinics or large distances between clinically related areas.
7. **Unnecessary processing**
   Using complex equipment or processes to undertake simple tasks. For example, a referral to a specialist service that involves having to be reviewed by several different people before acceptance.

Figure 1: There are seven "wastes" (7 types of Muda) as described in the AoMRC Report Protecting resources, promoting value: a doctor's guide to cutting waste in clinical care[2]

Sustainable Quality Improvement in Healthcare

The Centre for Sustainable Healthcare (CSH) is the world's foremost institution for sustainable healthcare research and practice. The CSH describes 4 principles of sustainable clinical practice: prevention, patient empowerment and self-care, lean clinical pathways and low carbon alternatives.[6]

Sustainability in Quality Improvement (SusQI)[7] embeds these 4 principles into traditional quality improvement (QI). Including sustainability and resource stewardship in QI allows health professionals to respond to ethical challenges such as climate change and social inequalities. It also benefits the QI process itself: inspiring new energy for change, highlighting wastes and opportunities otherwise overlooked, and directing projects systematically towards the highest value improvements.

A high value intervention will allow the best patient outcome but with the least impact on the patient and staff striving for that outcome, the planet and finances, also referred to as the 'Triple Bottom Line'.

This has been described in the equation below (figure 2), with the most 'sustainable value outcome for patients and populations' being the one with the lowest 'triple bottom line' analysis.

$$\text{Sustainable value} = \frac{\text{Outcomes for patients and populations}}{\text{Environmental + social + financial impacts}}$$

(the "triple bottom line")

Figure 2: The triple bottom line equation explains this principle with costs described in terms of environmental, social and financial.[7]

The four principles of sustainable clinical practice, outlined below, are embedded into the CSHs principles of lean service delivery, an example of which is outlined in Figure 3.

Four principles of sustainable clinical practice[6]

1. **Prevention**
   Good peri-operative care; for example, keeping patient's pain free, warm and well hydrated to minimise complications, multi-disciplinary team (MDT) working, World Health Organisation (WHO) checklists, enhanced recovery after surgery (ERAS) pathways.

2. **Patient empowerment**
   As health professionals we can help empower patients to look after their health, participate actively in their disease management and in decisions about their care. Understanding that health inequalities are driven by structural societal inequalities far more than by individual choices, gives us a starting point to rethink ways we can help people overcome these.

   Promotion of health education in society to allow patients to manage their own health. The "Fitter, Better, Sooner" campaign[8] first published in 2018 and endorsed by the Royal College of Anaesthetists, General Practitioners and Surgeons is a good example of this. It challenges the patient to take an active role in preparation for their surgery giving direction on how to target weight, diet, exercise, smoking and alcohol and gives information about how to prepare for specific operations. It also signposts where to get help.

3. **Lean service delivery**
   Streamline patient pathways, minimise unnecessary face-face appointments, the rise of virtual clinics/pre-assessment, sophisticated online patient centred care models, optimise resource utilisation (equipment, time, space, financial and workforce capacity), question the use of single use devices.

   TheGetting it Right First Time[9] initiative is a good example of lean service delivery; sharing best practice between trusts to reduce system variations.

4. **Low carbon alternatives**
   Estates can lead on economical low energy alternatives for heating and lighting in clinical spaces.

   Clinical leadership is needed to accelerate adoption of low carbon alternatives in clinical care, such as inhalers, anaesthetic techniques (avoiding/minimising inhalational agents especially desflurane and nitrous oxide) and reusable vs single use equipment.

   For example, the hospital for special surgery in New York carried out a study in 2019 whereby they tried to perform as many knee and hip replacements as possible under regional anaesthesia (only 4% had General anaesthetics of 10,000 cases). They calculated that potential saving of greenhouse gases was the equivalent to 60,500 car miles.[10]

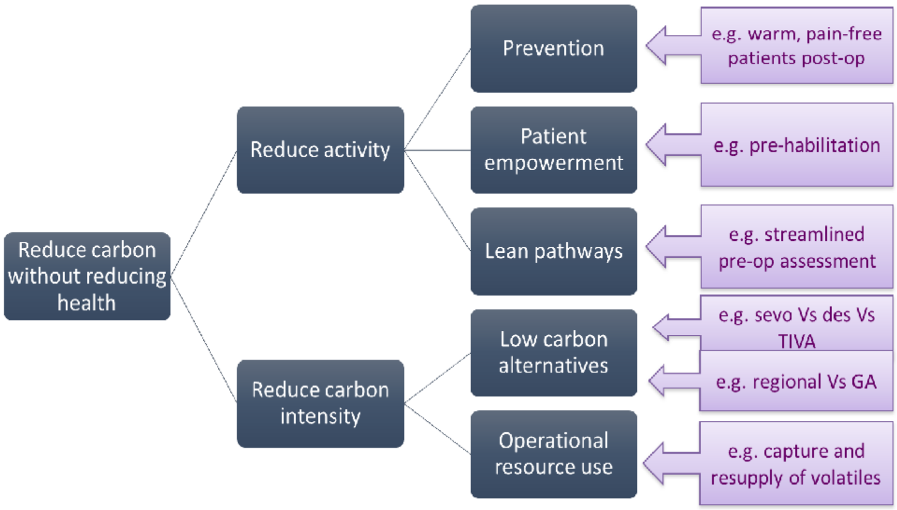

Figure 3: Principles of Lean service delivery from the Centre of Sustainable Healthcare[8]

Healthcare related transport

Healthcare related transport refers to all transportation to and from healthcare institutions. As well as staff and patients travel, the NHS has an enormous global supply chain.[11]

A report by Sustainable Development Unit[12] in 2018 suggested that the health and social care contributed to 5% of road travel every year and the NHS contributed 3.5% which equated to 9.5bn miles. Data from 2017[13] demonstrated that patient and visitor travel accounted for 57% particulate matter (PM) and 55% nitrogen dioxide (NO_2); the staff commute contributed 22% of PM and 24% NO_2 of the overall NHS emissions.

In order to reduce healthcare related transport emissions, we need medical manufacturers, regulators and end users to work collaboratively to build more local resilient supply chains and ensure lean ordering and delivery.

Active transport, low carbon transport and positive health benefits for patients, relatives and staff

Our sedentary lifestyles contribute to the twin pandemics of type 2 diabetes and obesity. According to the World Health Organisation,[13] nine out of ten people are breathing in polluted air resulting in the deaths of 7 million people every year and contributing to a third of the deaths from stroke, heart disease and lung cancer, whilst also contributing to respiratory disease in children.

Active transport refers to a mode of transport that is human powered such as walking, running or cycling. This allows obvious health benefits by increasing physical activity, reducing the incidence of non-communicable diseases and also improving mental health. For example, the SDU[12] showed that the actual health benefit from regular staff active transport equated to savings of £18million pounds per year. This was just in the reduction of treatment costs.

There are also wider benefits due to a reduction in road traffic congestion, which leads to reduced incidence of road traffic accidents and improved air quality. Most areas require investment in infrastructure for people to feel safe walking and cycling, as well as improvements in facilities at the health facility itself.

Low carbon transport refers to electric (E) and hybrid vehicles, which produce less air pollution. Cycle to work schemes could increase their 'cap' so that E-bikes, inclusive bikes and cargo cycles could be purchased. The Green Commute Initiative[14] has introduced this already allowing people greater choice as to which bike to purchase.

Individual health boards can look to move to E-fleets to transport patients, staff and goods locally. The NHS car lease schemes can be preferential towards E-vehicles.

Cutting waste in clinical care and choosing wisely

This section looks at practical ways to "cut waste". The application of Lean Principles, Muda Wastes and Sustainable Clinical Practice can be seen in Cardiff's modern pre-assessment pathway which is outlined below.

In 2010 a typical pre-operative assessment pathway for the more complex patient would have involved:

- The initial surgical out-patient department (OPD) appointment and discussion about the operation, in this case a Hartmann's procedure
- Four months later the patient attended the nurse led pre-operative assessment clinic (POAC). Any concerns highlighted would warrant 'notes review' by an Anaesthetist who would decide if the patient required further investigations e.g. an echocardiogram
- The patient attended out-patient investigations and once they were reported the Anaesthetist reviewed the results and, if abnormal, booked the patient into a Consultant Anaesthetic led clinic 4 weeks later
- Further cardiac and respiratory assessments following on from this face to face appointment, if needed, to allow so for further assessment and optimisation
- Medication adjustments and advise for the patient to quit smoking result from these specialist appointments

This would equate to 6 hospital visits at a minimum, a lot of wasted time and we expect a very anxious patient.

The same patient in 2020:

- Attends the surgical OPD and decides to proceed with the procedure
- Following this discussion, the patient proceeds to POAC next door in the main ODP. The nurse will perform pre-operative assessments (POA) and because the patient is undergoing major intra- abdominal surgery, the patient has Cardiopulmonary Exercise Testing (CPET) on the same day with a Consultant

Anaesthetist. CPET performance suggests some element of deconditioning and no evidence of LV dysfunction therefore an echocardiogram is not needed. No significant respiratory limitation proven; therefore, inhaler medications appear optimised. No need for referrals to cardiology or respiratory colleagues.

- Long discussion with patient regarding the benefits of quitting smoking and improving exercise activities such as walking and cycling.

- Blood pressure noted to be high at POAC, so referral to the patients' General Practitioner for blood pressure optimisation.

- A follow-up telephone review 3 months later by the POAC nurse confirms that the patient has quit smoking and their exercise tolerance has significantly improved.

So now the same pre-operative assessment pathway can be achieved in 1 hospital visit, 1 local GP visit and lots of walking/cycling! This new patient pathway is also outlined in figure 4 below.

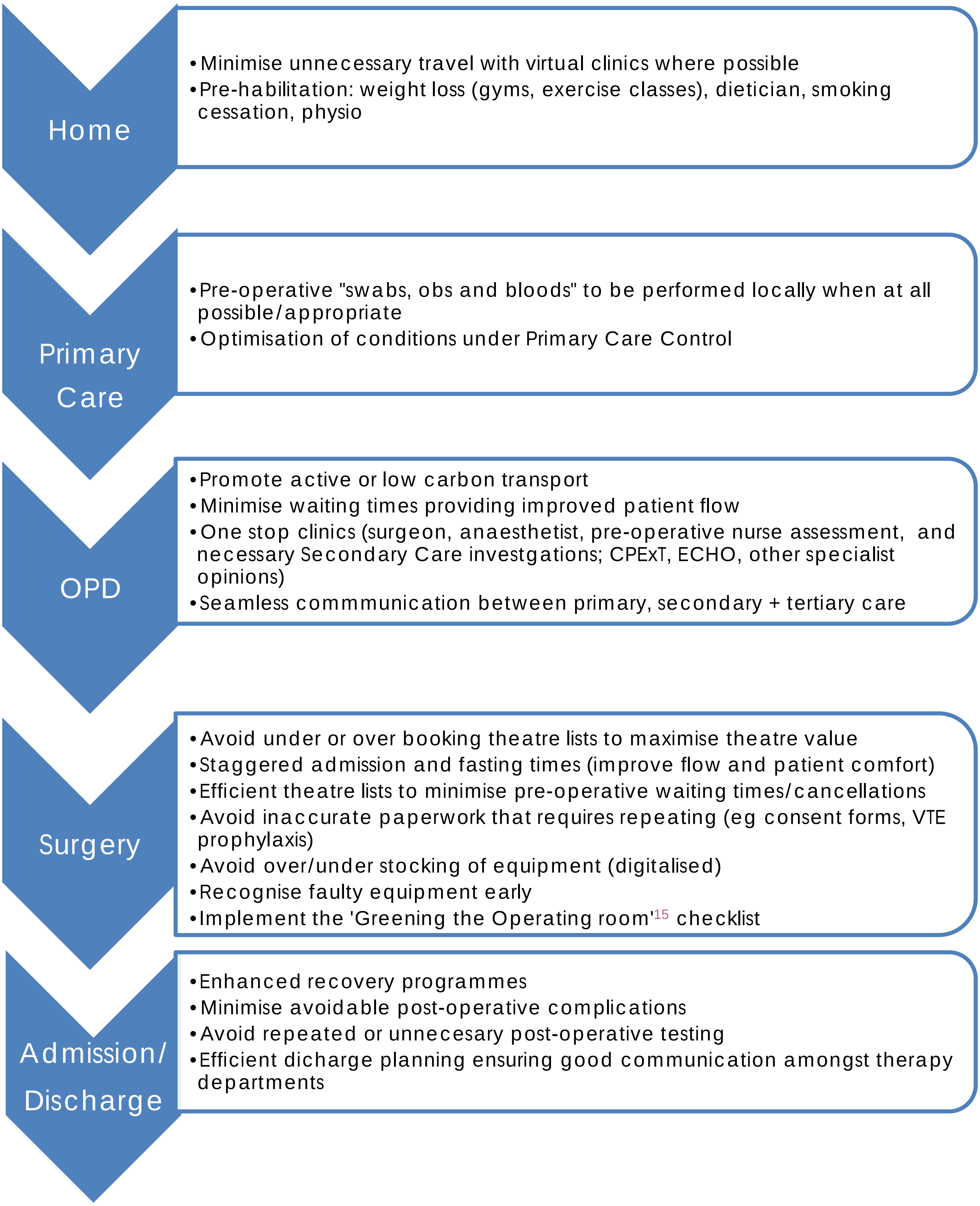

Figure 4: Ideas for a lean peri-operative pathway minimising waste

We hope this module has provided some strategies to aid us all in minimising the environmental impact of the NHS and encourage us to strive for the most sustainable value; our processes, pathways and journeys can all become leaner, greener and less wasteful.

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Royal College of Anaesthetists

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Sustainability: **Energy use and water consumption**

Version 1.00 October 2020

Dr Jonathan Major
Dr Elizabeth Puddy

Contents

Module Learning Outcomes

- Carbon intensities of electricity – grid vs combined heat and power (CHP).
- Reduction of carbon intensity – renewable sources, grid decarbonisation.
- Operating theatre and ICU as high-intensity energy areas – initiatives to reduce waste and increase efficiency.
- Water consumption – areas of high use and potential waste.
- Water-reuse management and how pharmaceutical pollution may impact on this.

This module describes the evolving role of renewable fuels as the basis of electricity generation and the ways in which new technologies may shape the electricity grids of the future. We look at the 'carbon footprint' of high-intensity energy areas within the healthcare sector with a particular focus on the operating theatre, and examine what we may be able to do as anaesthetists to reduce energy waste and increase efficiency. We describe the 'water footprint', identify ways that we may be able to shrink this and finally consider ways to minimise pharmaceutical watercourse contamination.

Electricity infrastructure

Our traditional **electricity grid** consists of generating stations that produce electric power from a fuel source, as well as step-up and step-down transformers, high-voltage transmission lines and distribution lines connecting individual consumers. While it has been in successful operation for over a century, its top down structure is less suited to the ever growing and increasingly dynamic demands of the 21st century.

A **'smart grid'** is enabled by the use of technology allowing two-way communication across the electricity network. Domestic smart meters are an example of such communication devices, they relay information both to the consumer and to the utility providers. Smart grids represent an evolution of the traditional grid rather than its replacement and have the potential to increase efficiency (for example, plug-in electric vehicles may be charged during times of otherwise low demand), increase reliability (electricity disruption is less likely to cause a 'domino effect' of downstream failure) and better integrate new power generation systems into the grid (e.g. wind turbines). This concept is illustrated in figure 1 below.

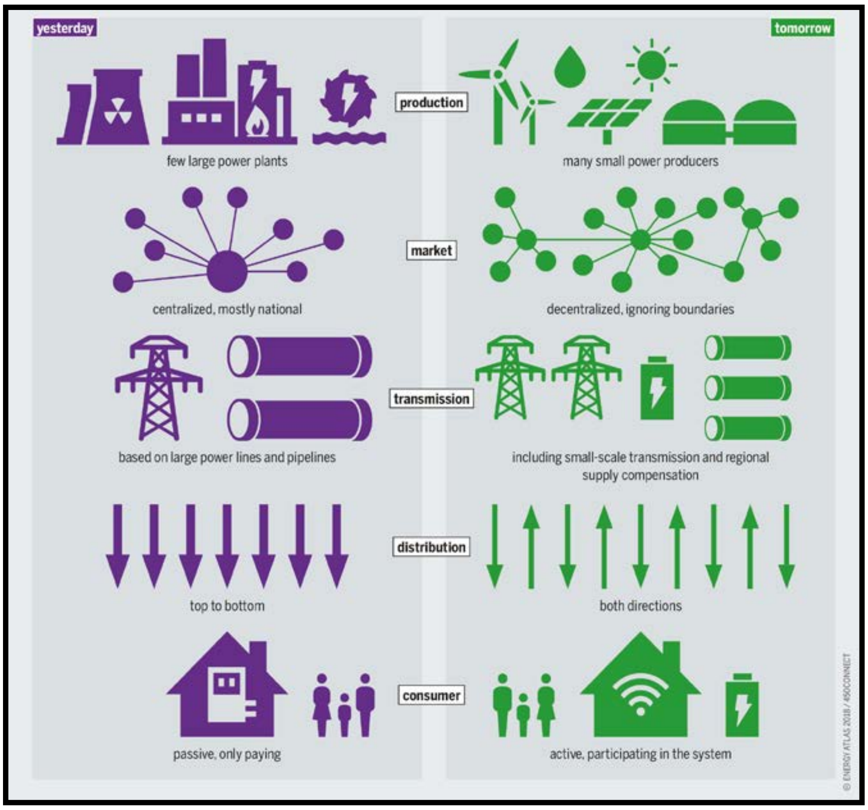

Figure 1: Electricity infrastructure. This figure illustrates how traditional grids of the past might compare with smart grids of the future.[1] Reproduced as per the licence agreement – the attribution (Bartz/Stockmar, CC BY 4.0).

Carbon intensity

With respect to energy production, the **carbon intensity** describes the emission rate of CO_2 per unit of energy produced (for example grams CO_2 per megajoule). The huge variation in carbon intensity of different fuel sources is illustrated in figure 2 (note 1kWh = 3.6 megajoules; the kWh is an energy unit commonly used for billing purposes). This metric may also be calculated for the energy sector as a whole, and is one way of making comparisons between countries, or over time.

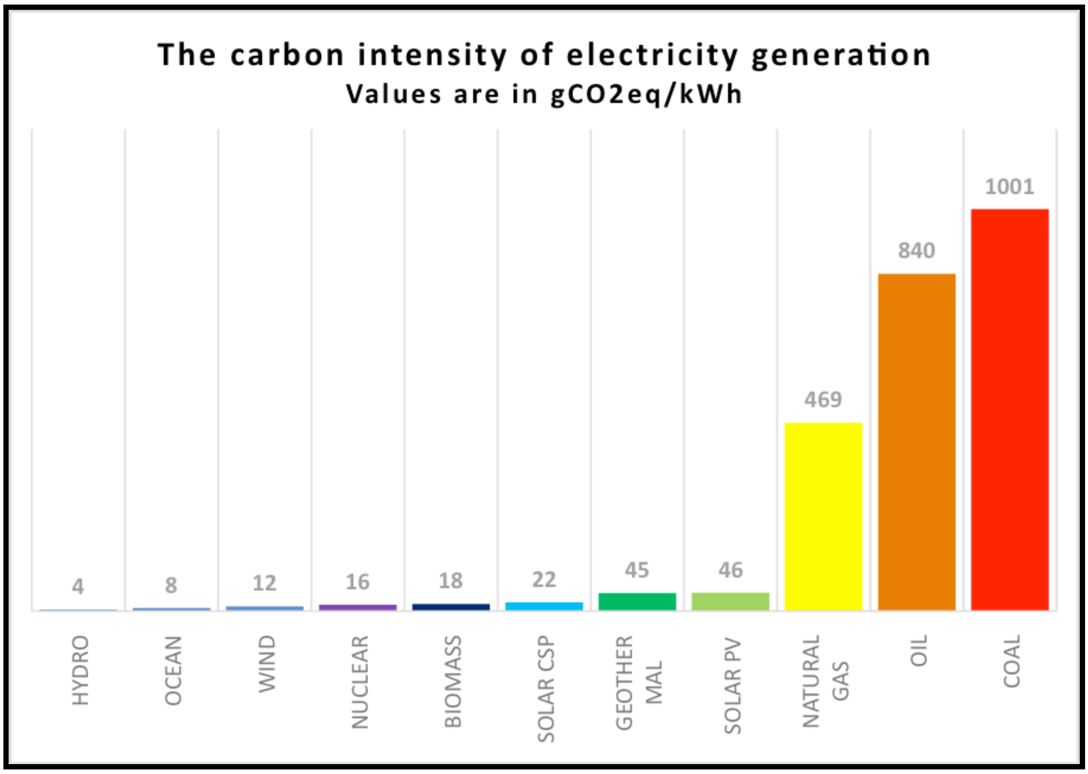

Figure 2: The carbon intensity of electricity generation. This chart illustrates how much more carbon intensive fossil fuels (namely coal, oil and natural gas) are in comparison with renewable alternatives.[2]

Without necessarily changing the fuel source, some strategies can nevertheless increase energy efficiency. During conventional electricity generation, nearly two thirds of energy is lost as heat discharged to the atmosphere.[3] **Combined heat and power** (CHP) technology captures the heat that would otherwise be wasted to provide useful thermal energy – such as steam or hot water – that can be used for space heating, cooling, domestic hot water and industrial processes. A schematic example of what a CHP system configuration might look like is illustrated in figure 3 below. Due to their high demand for round-the-clock energy, hospitals are ideally suited to make use of CHP. This potential was highlighted in the NHS Carbon Reduction Strategy,[4] and the 2010 update again championed its potential (more so than almost all other carbon-saving measures) to reduce both financial costs and CO_2 emissions.

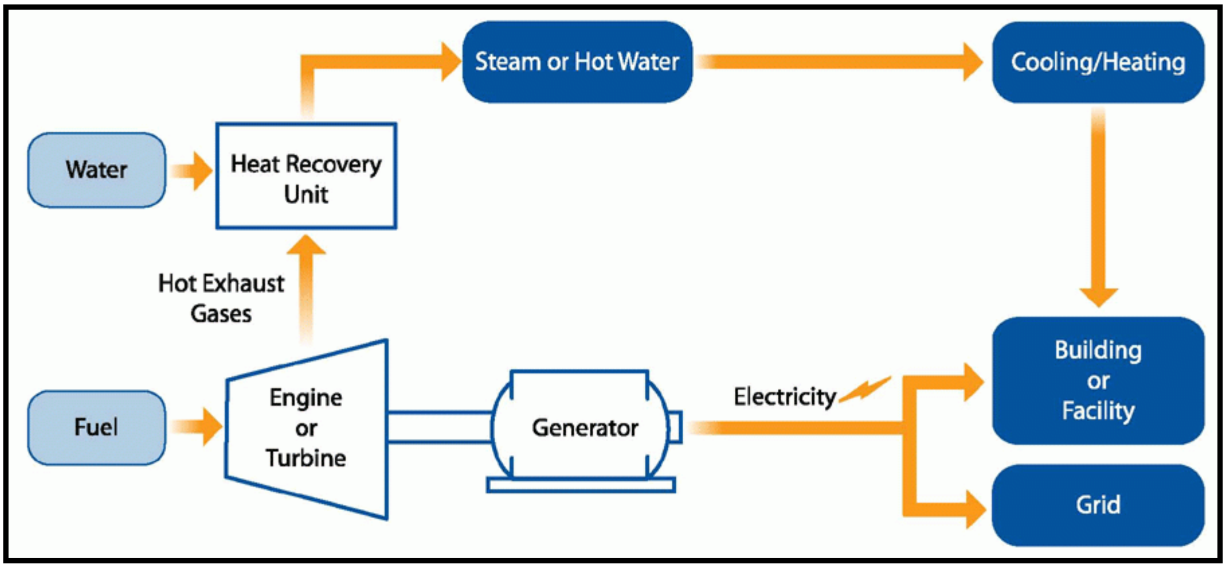

Figure 3: Typical combined heat and power configuration.[3] Environmental Protection Agency, EPA CHP Partnership Program, 2020. Permission granted for use by EPA.

Reduction of carbon intensity – renewable sources and grid decarbonisation

The Intergovernmental Panel on Climate Change (IPCC) has stated that 'virtually full' decarbonisation by 2050 is necessary to meet the Paris Agreement's target of capping global temperature rise at 1.5°C, and even to meet the less ambitious 2°C target. Decarbonising the power sector means reducing its carbon intensity: that is, reducing the emissions per unit of electricity generated.

Historically, from a predominately coal-based energy sector, the UK ventured into nuclear power in the mid-1950s before turning towards North Sea oil and natural gas in the 1960s. Since then, an increasing recognition of the negative effects of burning fossil fuels has driven steady decarbonisation. Electricity generation from renewable sources in the UK (47% in 2020 Q1) now outstrips the combined output from fossil fuels (38%, the vast majority of which is from natural gas).[5] Nuclear makes up the remainder (15%). This trend accounts for the concomitant reduction in CO_2 emissions per capita[6,7] as illustrated in figure 4, despite similar levels of electricity consumption (the UK's per capita electricity consumption actually peaked in the mid-2000s but has fallen since then due to increasing efficiency, and is currently at about 1980 levels).[8,9,10]

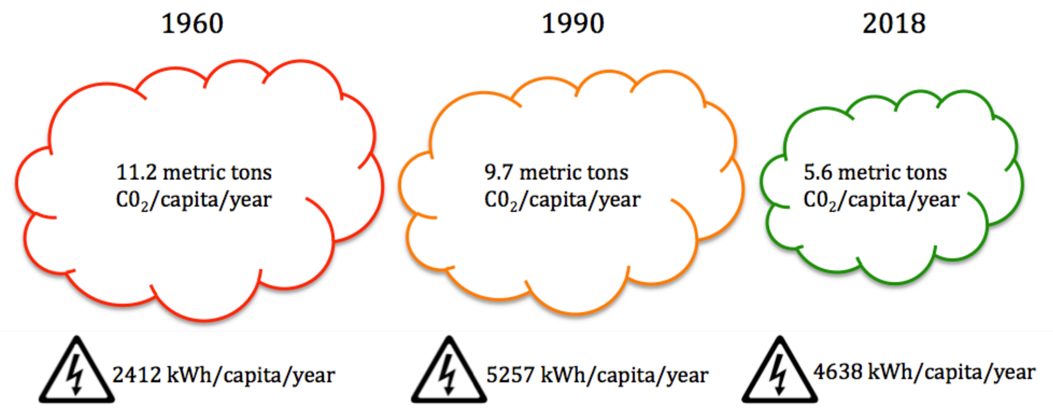

Figure 4: The reduction in CO2 emissions per capita in the United Kingdom over time.[6,7] This is due to a gradual shift from fossil fuels to renewable energy sources. Overall electricity consumption per capita is also stated for the years illustrated. The 1960 and 1990 figures are from the World Bank.[8] The 2018 figure is calculated from the European Commission Joint Research Centre (JRC) Science for Policy Report 2019.[9,10]

Renewable energy is derived from (theoretically) unlimited natural sources or processes that are constantly replenished. Figure 5 provides a simple summary of different fuel sources and technologies.

ENERGY SOURCE	EXAMPLES/EXPLANATION	ADVANTAGES	DISADVANTAGES
Biofuel	Bioethanol, biodiesel	Cleaner than fossil fuels Considered 'carbon neutral'	Crops require intensive cultivation
Biomass	Wood, plants	Cleaner than fossil fuels Considered 'carbon neutral'	Some atmospheric pollution
Fossil fuels	Coal, natural gas	Reliable Very well established use	Limited resource Atmospheric pollution
Geothermal	Exploits the earth's internal heat	Reliable	Only certain locations suitable
Hydroelectric	Exploits gravitational potential energy of water	Clean and cheap to run	Dams can cause flooding Output susceptible to drought
Nuclear	Uranium, plutonium	Reliable	Disposal of nuclear waste can be difficult
Ocean	Waves, tides	Clean and cheap to run Reliable	High initial costs
Solar	Concentrating solar power, photovoltic	Clean and cheap to run	Variable output High initial costs
Wind		Clean and cheap to run	Variable output High initial costs

Figure 5: Sources of energy and some key advantages and disadvantages. Illustrated by Dr J Major

Energy use within the healthcare sector

The ecological footprint of healthcare is enormous. Annual CO_2 emissions attributable to NHS England account for 25% of public sector emissions and exceed those from all aircraft departing Heathrow airport each year.[11] Of these emissions, 24% are linked to direct energy use in buildings (heating and electricity).[12] Unsurprisingly, this is not homogenous across the healthcare estate: operating theatres are three to six times more energy intense than the hospital as a whole.[13] This carries a financial as well as environmental cost that is often poorly appreciated. People are increasingly aware of the need to reduce energy consumption at home and it is important that the NHS educates, encourages and enables staff to do the same at work.

To provide some context, the cost of typical domestic energy consumption in an average UK home is approximately £2.50/day, of which about half is attributable to gas (for heating and hot water) and half to grid electricity. NHS England spends about £1,600,000/day on energy, which equates to over £7,000/day for an average Trust.

The operating theatre

Considering our day-to-day work environment, a brief examination of some of the most energy-intensive systems reveals potential targets for reducing waste.

The **heating, ventilation and air conditioning** (HVAC) requirements of theatres are high, necessitating specialised air handling units (AHUs). Such systems provide an environment of filtered air that minimises the risk of wound contamination and consequent infection. They also allow for the control of ambient temperature and humidity. HVAC systems commonly account for over 90% of operating theatre energy consumption.[13] Laminar flow and ultraclean ventilation (UCV) are variations that aim to achieve higher levels of air purity. Unfortunately, these are frequently left in ‘operating’ or ‘occupied’ mode, irrespective of theatre activity. HVAC ‘setback’ is an energy-saving strategy that reduces the amount of air supplied to a theatre when not in use. Setback may also allow the temperature and/or humidity to drift during unoccupied times. Retrofitting of older systems may be necessary to achieve this. With modern systems, even emergency theatres can be left in setback, as the time taken to reach occupied mode parameters is considerably less than the time taken to assemble the surgical team and prepare for surgery. Figures 6 and 7 below were taken in a UK hospital and show a fairly typical laminar flow HVAC system (the one pictured is in a theatre predominately used for trauma surgery) and the operational controls as they were found in the unoccupied theatre in the middle of the night.

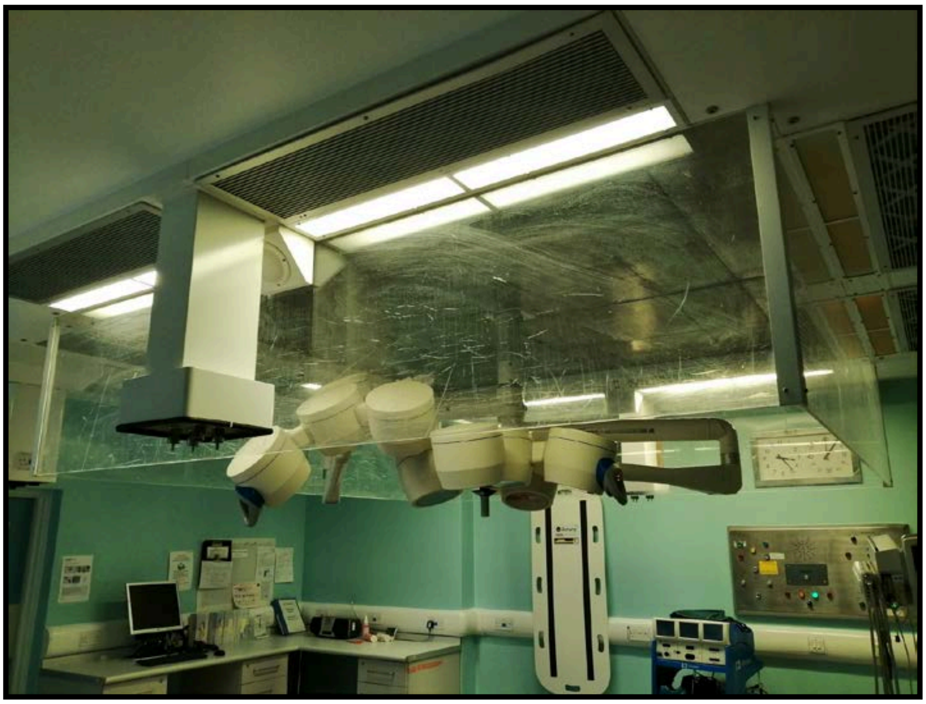

Figure 6: A typical orthopaedic theatre laminar flow HVAC system. Photo Dr J Major

Figure 7: The operational controls in the unoccupied theatre in the middle of the night. Photo Dr J Major

The removal of waste gasses in theatre is **achieved by anaesthetic gas scavenging systems** (AGSS), to levels legally specified by the Control of Substances Hazardous to Health (COSHH). These systems collect waste gasses from the exhaust port of the anaesthetic machine and transfer them to a receiving system from where they are then vented to the outside environment. A typical AGSS suction pump consumes 500-800W of power,[14] a running energy cost roughly five times higher than a 65" LED TV. Most of us would turn the TV off overnight, so why not the AGSS? It is of course, part of the daily anaesthetic machine safety check to ensure that the AGSS is on and operational and importantly this is not tested as part of the automatic electronic machine checks.

Implementing behaviour change: a case study

Operational TLC was a behaviour change programme developed by Barts Health NHS Trust and Global Action Plan and since adopted by several other Trusts across the country.

T Turn off equipment
L Lights out
C Control temperatures

Empowering staff to make changes to their working environment with a focus on the three simple measures above resulted in £500,000 of energy savings and a reduction in carbon emissions of 2200 tonnes/year.[15] It illustrates clearly that the collective effects of small behaviour change can still be very significant.

Water consumption

Contrary to common misconception, water is not a limitless resource of negligible financial cost. Global population growth is contributing to ever increasing pressure on the water supply and climate change is exacerbating this problem. The World Economic Forum's 2019 report cites 'water crisis' as a top-ten risk both in terms of likelihood and impact.[16]

In 2017 the total 'water footprint' of the Health and Social Care (HSC) sector in England was approximately 2.3 trillion litres,[12] a volume sufficient to fill 1 million Olympic-sized swimming pools. In fact, direct water use (e.g. taps, flushing toilets) only makes up a small fraction of total water use (about 7%) but this is still an enormous volume. The majority of the footprint is accounted for by indirect use that is water embedded in the supply chain of goods (e.g. food, pharmaceuticals) and services procured by the HSC sector.

Of additional concern is that current processes only partially remove pharmaceuticals, meaning that even after wastewater treatment, drug concentrations may still be high enough to harm ecosystems.

Shrinking the water footprint – water reuse management

At an organisational level, reuse of 'grey' water can reduce dependence on the mains supply, and obviates the need to subject all waste water to the same treatment processes. Greywater (in contrast to blackwater that is contaminated with human waste) remains relatively clean and refers to waste from sources such as hand basins, kitchen sinks and showers. With the correct collection and filtration techniques onsite, it can be used to meet the local demands of urinals, WCs and garden irrigation. One Trust recycled greywater from its renal dialysis unit, and used it for urinal and WC flushing in its theatre and emergency departments, reducing mains consumption by 37% and recovering the project's costs within 3 years.[17] There are myriad other suggestions for best practice, detailed in the Department for Health's 'Water management and water efficiency' memorandum, covering topics ranging from boiler houses to birthing pools.[18] In general terms, the NHS Sustainable Development Unit lists the following key actions.[4]

- Efficient use of water should be integrated into building developments at the design stage.
- Water costs and consumption should be measured, monitored and reported annually by all NHS organisations as part of their Annual Report to staff, patients and the public.
- Leaks in NHS infrastructure should be identified and fixed immediately.
- Water efficiency technology should be adopted as standard across the NHS estate.
- Routine purchasing of bottled water should be avoided.

Leaks account for a staggering 15-30% of direct water use.[18] A single tap dripping once per second wastes over 4L every day [calculated as 1 drip ≈ 0.05ml (a function of surface tension vs. fluid inertia) x60x60x24]. At an individual level, encouraging behaviour change (i.e. turning the taps off) through education can reduce this waste by 80%.[19] The installation or retrofitting of pedal or sensor-operated taps, for example, has the potential to reduce this further.

Propofol watercourse contamination and reducing drug waste

Propofol is one of the most widely used anaesthetic agents. It is extensively metabolised with 88% of injected drug excreted in the urine as inactive metabolites and <1% excreted unchanged. However, one study found that it accounted for 45% of anaesthetic drug wastage by volume.[20] It is not biodegradable so persists in the natural environment and is toxic to aquatic organisms. Destruction of the drug requires high-temperature incineration.

With this in mind the following principles should apply *in general* to our use of drugs:

- Consider carefully the dosing requirements specific to your situation/patient/theatre list. As well as carrying disposal implications, there is a significant upstream environmental burden involved in the development, manufacture and distribution of these drugs. Using appropriately-sized vials will help minimise the burden of discarded drug in the first place. Pre-filled syringes (of emergency drugs, for example) may also help in this regard.

- Where drug waste is unavoidable, ensure the correct disposal methods are employed. In the UK all drugs are accompanied by Safety Data Sheets. While they usually contain a section on disposal, the recommendations are frequently vague and generally suggest only that local regulations are followed. UK law requires pharmaceutical waste to be incinerated and more detailed information about this can be found in the waste segregation guideline produced by the Association of Anaesthetists. Anaesthetic drugs in the UK should be disposed of appropriately and definitely not down the sink.

The e-module in this series entitled '*Intravenous and local anaesthetic agents*' also considers pharmaceutical watercourse contamination. Further information on the environmental hazards and risks posed by specific pharmaceutical agents is published by the non-commercial organisation Janusinfo and available here: janusinfo.se/inenglish

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Sustainability:
Waste – what happens to it?

Version 1.00 September 2020

Dr Samina Shah
Dr Kyria Roberson

Contents

Module Learning Outcomes

- Waste regulations summarised, including specifics for pharmaceuticals disposal.
- Department for Environment, Food and Rural Affairs' waste hierarchy.
- Waste streams, including specialist recycling.
- Waste segregation (benefits and pitfalls).
- How we can reduce our waste.

Management of healthcare waste is essential in ensuring healthcare activities do not pose a risk to others or the environment. In 2016/17, the NHS produced 590,000 tonnes of waste (2% of all commercial waste in England)[1]. With such a vast amount and wide variety of waste being produced in the healthcare sector there are a number of important regulations and legislations in waste management, including how we manage and segregate waste to ensure that we fulfil our legal obligations as to its disposal.

Environmental legislation and waste regulations

European Union Waste Framework Directive (EWFD) [2]

First described in 1975, it sets out the basic ideas and definitions of waste, the risks of each waste category and the targets for reduction and recycling - limiting incineration and landfilling. The directive aimed to transform the European Union and its member states into a recycling and re-using society.

The Environmental Protection Act 1990[3]

Fulfils the EWFD by defining the structure and authority for waste management and emissions for the United Kingdom. Every producer of waste has a duty of care to prevent any unauthorised storage, treatment, disposal or transfer of waste and sets out the criminal sanctions that apply. It also states that the organisations below control the limits set on emissions and any process or substance.

- The Department of Environment, Food and Rural Affairs (DEFRA)
- Environment Agency (in England & Wales)
- Scottish Environment Protection Agency (SEPA)
- Department of the Environment for Northern Ireland (now the Department of Agriculture, Environment and Rural Affairs - DAERA)

The Hazardous Waste (England & Wales) Regulations 2005[4]

States that waste should be recovered or disposed of without:-

- Endangering human health
- Using processing methods that could harm the environment, in particular water, air, soil, plants and animals
- Causing nuisance through noise or odours
- Adversely affecting the countryside or places of special interest.

The Lists of Wastes 2005[5]

Based on the European Waste Catalogue, it classifies waste by the properties which render it hazardous. See table 1 below;

Hazardous Property Code	Property	Example
HP1 Explosive	Unstable, may cause fire, blast or projection	Hydrogen peroxide
HP2 Oxidising	Exhibits highly exothermic reactions. May cause or intensify fire.	Nitric acid
HP3 Flammable	Extremely flammable substance. May catch fire spontaneously with or without air or with heat.	Metal hydrides/phosphides
HP4 Irritant	Can cause skin/eye damage	Extreme acid/alkaline substances, azathioprine
HP5 Harmful	May cause damage to internal organds, potentially fatal if swallowed	Oxytocin
HP6 Toxic	Harmful/toxic/fatal if inhaled/swallowed/contact with skin	Ergometrine, mitomycin, finasteride
HP7 Carcinogenic	May cause cancer	Chloramphenicol, azathioprine, mitomycin
HP8 Corrosive	Causes skin corrosion on application	Azathioprine
HP9 Infectious	Contains viable micro-organisms, or their toxins, believed to cause disease in man or other living organisms	Wastes from natal care, research, diagnosis, treatment or prevention of disease
HP10 Toxic for reproduction	May cause damage to fertility or unborn child	Chloramphenicol, ganciclovir
HP11 Mutagenic	May cause genetic defects	Azathioprine, bleomycin
HP12 Produces toxic gases	Contact with water may liberate toxic gases	Metal sulphides/phosphides, hypochlorite compounds, cyanide
HP13 Sensitising	May cause an allergic skin reaction or asthma symptoms	
HP14 Ecotoxic	May be toxic to aquatic life (with long term effects), may destroy the ozone.	Finasteride
HP15 Hazardous property not listed above	May cause mass explosions when dry/under confinement,	

Table 1: Properties (with codes) that render waste hazardous[6]

The England & Wales Waste Regulation 2011[7]

Industries are required to apply the waste hierarchy, segregate waste where technically, environmentally and economically practicable and declare as such with written consignment notes when transferring waste.

The Northern Ireland Waste Regulations 2011[8]

Comparable to the England & Wales Waste Regulation 2011, it however sets specific waste management strategies for Northern Ireland overseen by the Department of Agriculture, Environment and Rural Affairs (DAERA) and the Northern Ireland Environment Agency.

The Controlled Waste (England & Wales) Regulations 2012[9]

Classifies waste as household, industrial and commercial (healthcare) waste, as well as defining:

- Clinical waste – waste from a healthcare activity that contains viable micro-organisms, or their toxins. It may contain or is contaminated with a biologically active pharmaceutical agent, body fluid or other dangerous substance and includes sharps and bodily fluids which are contaminated in such a manner as described.

- Offensive waste – which is not clinical waste but contains body fluids, secretions or excretions.

Health Technical Memorandum 07-01: Safe management of healthcare waste[10]

A comprehensive guide created to help fulfil the healthcare industry's legal obligations to waste management. It provides practical advice on the design, installation and operation of waste management for healthcare organisations. It complies with the above waste legislature and implements the European Union Waste Framework Directive.

DEFRA's waste hierarchy

The waste hierarchy was produced by DEFRA and the Environment Agency in response to The England & Wales Waste Regulations 2011.[6] It ranks waste management options in order of what is best for the environment. These options are based on current scientific research e.g. climate change, air and water quality. New technologies may emerge which improve the efficiency of waste management and therefore the hierarchy. See figure 1. Every industry has a legal duty of care to take all reasonable steps to apply the hierarchy to all waste produced from top to bottom.

Figure 1: Waste hierarchy [*Gasification – reaction of waste with oxygen and/or steam, resulting in the production of carbon monoxide, carbon dioxide, and hydrogen. Pyrolysis – process of heating organic substances to above decomposition temperatures resulting in production of char and eventually ash. Backfilling – reclaiming excavated areas for landscaping purposes using non-hazardous waste as a substitute for non-waste materials.[11]

Waste streams

Globally 85% of total healthcare waste is classified as general waste, the remaining 15% is considered hazardous, infectious, toxic or radioactive[13]. Each operating theatre in the UK produces on average 2300kg of anaesthetic waste per annum, 40% of this waste could potentially be reclassified as domestic or recyclable waste with huge potential for financial and environmental benefits.[1]

A waste stream refers to the flow of a precise type of waste from source to recovery, recycling or disposal. Each specific waste stream has been developed from the legislation discussed previously, taking into account its hazardous properties, treatment methods, recovery and recycling possibilities.

Waste is segregated in healthcare using UN approved receptacles – either rigid containers with coloured lids, coloured bags, or sharps bins with coloured lids. Colours are based on nationalised colour codes. Although there is no specific legislation with regards to colour, national guidelines are based on historical precedence but may still differ between individual nations. Examples of different waste streams used in healthcare are summarised in table 2. The Association of Anaesthetists is currently developing a waste segregation flowchart, outlining streams to be used for anaesthetic and theatre waste.

Colour Code	Description	Disposal Method
	Yellow stream – infectious waste/sharps, includes chemical or medicinal samples contaminated with Category A pathogens. (Category A pathogens can cause fatality or permanent disability to humans or animals and include anthrax, Ebola, smallpox and other pox viruses).	Incineration
	Red stream - anatomical waste	Incineration
	Orange stream – infectious waste, known or suspected to be contaminated with Category B pathogens (pathogens which do not meet criteria of Category A, including but not limited to E Coli, Salmonella, Shigella, Listeria, Cryptosporidium, Toxoplasma, Tuberculosis, Influenza and HIV).	Treated to be rendered safe prior to disposal OR Incineration
	Blue stream - Non-cytotoxic/cytostatic waste consisting of medicines or sharps contaminated with such medicines. Separate containers for solids and liquids. Outer packaging should be placed in recycling if possible. Blister packs/syringes should not be opened/expelled. Syringes containing controlled drugs should be expelled, other forms of controlled drugs should be rendered irretrievable using denature kits	Incineration
	Purple stream – Cytotoxic/cytostatic Waste/sharps contaminated with such drugs	Incineration
	Yellow & black (Tiger) stream – Offensive/hygiene waste, contaminated with bodily fluids that are not considered infectious e.g. incontinence pads, catheter bags	Landfill; Energy recovery; Incineration
	Black/clear stream - domestic/municipal waste e.g. flowers, food, tissues. If possible, food should be segregated for composting (usually but not always in green bags). Aluminium, glass, paper and plastic should be segregated, and are recycled to produce base materials for re-use in new products	Landfill; Composting; Recycling
	Radioactive waste stream – healthcare waste contaminated with radioactive material	Incineration in specialised hazardous waste facility

Table 2: Summary of waste streams by type and colour coding of containers (bags, rigid containers with coloured lids, and sharps bins) and their eventual disposal methods. [Cytotoxic/cytostatic waste is defined as any drug with hazardous property codes HP 6 toxic, HP 7 carcinogenic or HP 10 toxic for reproduction. These are not limited to drugs labelled as cytotoxic in the British National Formulary]. [12]

Hospital wastewater and sewage systems do not undergo any special treatment before joining the municipal sewage system. Drugs and their metabolites can enter the aquatic environment if disposed of into the sink or sluice. All unused drugs must be disposed of into the appropriate containers for incineration.[14]

Recycling

General recyclable waste is separated at waste facilities, any non-recyclable waste is removed by hand.[15]

- Paper is separated by quality and compressed into bales before being transported to paper mills where it is mixed with water and turned into pulp. Ink is removed by washing. On drying, the pulp begins to resemble paper before it is further compressed with rollers to form new sheets of paper. Confidential waste is transported in locked containers and shredded but otherwise undergoes the same processes as non-confidential paper. Confidential waste is only recycled into tissues/hand towels.

- Glass waste (from general households and industries other than healthcare) is separated by colour and crushed to form new glass or stone aggregates to build new roads. Glass from the healthcare industry (especially that which is contaminated with medicinal waste) is incinerated.

- Metals are separated using magnets or current separators and compressed into bales. Cans are shredded, cleaned, melted, cooled and eventually rolled into new aluminium sheets.

- Plastics are separated depending on their different polymer make up[16]. Bales of plastic are then shredded, cleaned, melted, and filtered. Small filtered strands can be spun into fibres making fleeces, jackets and sleeping bags. Larger items are compressed into pellets to be moulded into new plastic items.

Specialist recycling of healthcare-specific waste can be provided by contractors that specialise in medical waste management, although the decision to employ these services lie with individual healthcare trusts.

Examples of recycling of healthcare-specific waste include:

- PVC Recycling -High quality PVC in oxygen masks, tubing, nasal cannulae and anaesthetic masks can be down-cycled and repurposed to use in the horticultural industry e.g. tree ties. Non-PVC items such as straps are removed from facemasks at the site of use, the PVC is collected and then relocated to centres for further hand sorting before they are shredded, melted and repurposed.[17]

- Sterile surgical wraps can be melted into briquettes of base element – polypropylene, using the process of "Sterimelt". This can be used to manufacture various household products including buckets, rope and stationery.[18]

- Medical Equipment[19] – CT, MRI, ultrasound and mobile surgical equipment can be refurbished. Minimal complication rates have been demonstrated from the re-use of implantable ICD devices after sterilisation.[20]

- High-cost single-use surgical devices (arthroscopic wands, laparoscopic instruments and trocars) can be “re-processed”. They are collected, disassembled, and individually inspected and tested for function, then sterilised and repackaged for clinical re-use.[21] These services are more popular in mainland Europe and North America and would require equipment to be shipped from the UK to other parts of the world including the US (increasing the carbon footprint and potentially offsetting any gain from reprocessing).

- Metals in healthcare such as single-use equipment (laryngoscope blades, Magill’s forceps and surgical scissors) can be recovered, mechanically treated (cut, sheared, shredded or granulated; sorted, separated, cleaned, de-polluted and emptied)[22] and recycled but do not re-enter the healthcare system.[23, 24]

Waste segregation

Benefits and Pitfalls

There are a number of benefits (and pitfalls) to waste segregation listed below in Table 3.

Benefits	Pitfalls
Segregating waste can reduce the cost of disposal by incineration if these products can be treated appropriately via another stream.	Staff require training to avoid using clinical waste bins as default.
Some waste can be recycled to base materials which can supply other industries and generate income – e.g. platinum and silver for used endocardial leads.	Appropriately coloured and UN approved waste containers must be available and require dedicated storage areas.
Batteries contain toxins which can affect the health of humans and animals. Segregating batteries ensures appropriate treatment and disposal therefore preventing toxins entering the environment	Incorrectly segregated waste results in contamination of entire waste containers usually resulting in their incineration.
Diverting waste to appropriate waste streams avoids the use of landfill reducing the consumption of land resources.	
Appropriate segregation of waste prevents exposure of hazardous waste to staff.	

Table 3: Benefits and pitfalls of waste segregation

How we can reduce our waste

A proportion of waste in healthcare is unavoidable but applying the principles of the waste hierarchy[11] can reduce its impact on the environment around us. There is a distinction between waste and *wasteful* practice which includes those actions and behaviours that create unnecessary waste, these can be managed using the 5R approach listed below.

The 5R Approach – REDUCE, REUSE, RECYCLE, RETHINK & RESEARCH.[25]
Working with our colleagues in theatre we can:

Reduce

- Use paperless anaesthetics records.
- Use refillable ink cartridges and rechargeable batteries.
- Use oral rather than IV drug preparations to reduce plastic/PVC waste associated with IV administration.
- Ensure sharps bins are used *only* for the disposal of sharps and are full (to the line) prior to their disposal.
- Change breathing circuits weekly instead of daily (unless recommended otherwise by manufacturer).
- Only open packaging and drugs when necessary.
- Only use equipment when clinically indicated e.g. calf compression boots.
- Turn off electrical equipment when not in use e.g. scavenging systems, anaesthetic machines, (except in those areas used for emergencies).

Reuse

- Reuse materials that are allocated for use in the same patient and in the same encounter where clinically appropriate e.g. tourniquets, TCI syringes, facemasks.
- Prioritise the procurement of reusable equipment preferentially to single-use equipment where possible e.g. laryngoscopy handles, plastic drawing up trays.
- Avoid the use of disposable plates, cutlery and cups and replace with reusable forms.

Recycle

- Ensure the correct segregation of waste to the appropriate streams in order to avoid unnecessary incineration and landfill use.
- Consult with waste management contractors to discuss the possibilities of specialist recycling schemes and which items can be accepted into general recycling streams.

Rethink

- Increase access to recycling bins and place in strategic locations (in anaesthetic rooms, theatres and communal break areas) making it easier to recycle rather than to dispose.

- Regularly train staff in waste management.

Research

- Promote audit and quality improvement in sustainability and greener anaesthetic practices.[26] More information can be found in the '*Sustainable Healthcare*' emodule in this series.

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Royal College of Anaesthetists

e-Learning Anaesthesia

Sustainability:
The anaesthetist as an educator

Version 1.00 September 2020

Dr Penelope Tinga
Dr Cliff Shelton

Contents

Module Learning Outcomes

- Education and promotion on a departmental level, including embedding SUSQI.
- Wider opportunities extending beyond the operating theatre.
- Patient engagement and health promotion, making environmentally preferable choices.
- National promotion of sustainability – College, Association, General Medical Council, and other professional bodies.

Anaesthesia has been at the forefront of sustainable healthcare in recent years. This places anaesthetists in an ideal position to act as educators in their own departments, the wider healthcare community, and on the national or international stage.[1] The need for education in sustainable healthcare is increasingly recognised, with both the General Medical Council (GMC) and the Nursing and Midwifery Council having included sustainability in their graduate learning outcomes.[2,3] The Royal College of Anaesthetists has stated that sustainability and environmental impact will be included in the 2021 curriculum.[4] In this chapter, we describe the approaches that anaesthetists can adopt as educators, in order to bring about sustainable healthcare changes.

Education and Promotion at the Departmental Level

For many anaesthetists who have an interest in sustainable healthcare, their first experience of acting as an educator will be at a departmental level. A number of different approaches can be adopted:

- Information provision: anaesthetists are well trained in many of the scientific principles relevant to sustainable healthcare but may be unfamiliar with the details.[5] Simply by being taught accurate, peer-reviewed information, anaesthetists may elect to change their behaviours.

- Advocacy: information alone may not have the desired impact. Making an argument for sustainable healthcare may be required. Opportunities include talks and debates at departmental meetings, the use of posters or other visual reminders (Figure 1), and one-to-one discussions with colleagues. Personal stories that explain why you are interested in sustainable healthcare are a useful approach,[6] but note that colleagues' autonomy should be respected, and a judgmental approach should be avoided.

- Quality improvement: changes in practice should be measured and communicated. Quality improvement (QI) principles can be used in sustainable healthcare as in other aspects of practice. Sustainable QI (SusQI) aims to maximise health outcomes whilst minimising negative impacts in terms of the 'triple bottom line' (i.e. environmental, social and financial).[7] By integrating sustainability into QI, the environmental impact of healthcare is brought into the mainstream of departmental business, alongside other aspects of safety and quality. Resources on SusQI are available from the Centre For Sustainable Healthcare: networks.sustainablehealthcare.org.uk/sus-qi-resources

Figure 1: simple visual reminders can be a powerful form of departmental advocacy (photograph used with permission. Credit: Dr Oli Pratt)

Wider Opportunities: Beyond the Operating Theatre

Anaesthetists are the largest medical staff group in secondary care and have links to many other professions and specialties. This places anaesthetists in an ideal position to support others in taking a more environmentally sustainable approach to practice. This may include holding teaching sessions or collaborating on QI projects involving settings where anaesthetists and colleagues from other specialties or professions work together. Examples may include work in the operating theatre focussing on volatiles and waste, or in the maternity setting on nitrous oxide and other forms of labour analgesia. On a strategic level, many healthcare organisations have sustainability committees; representation from clinicians is beneficial to these groups because committee members may not appreciate the considerations of practice. As doctors who work in numerous different settings, anaesthetists are ideally placed to fulfil this role.

Many anaesthetists have roles in undergraduate education; this presents an ideal opportunity to teach medical students about sustainable healthcare. Because the GMC has included sustainable healthcare in Outcomes for Graduates,[2] many medical schools are seeking ways to include sustainability in their curricula. This could take the form of dedicated lectures or student projects, but it may be more effective to integrate sustainability into other learning.[6] For example, the environmental impact of anaesthetic drugs could form part of a discussion in the operating theatre about the choice of agents for a particular case.

Patient Engagement and Health Promotion: Shared (Sustainable) Decision-Making

Patient education in the pre-operative assessment clinic is an important part of anaesthetic practice, and some hospitals adopt a 'surgery school' approach to preparation for major surgery.[8] These contacts with patients provide an opportunity for shared decision-making, and though these decisions should be patient-centred, it can be appropriate to bring environmental considerations into the discussion. In some cases, the environmental impact of healthcare will be important to patients, but if this is not the case, a more environmentally sustainable approach often aligns with better outcomes or superior care. This can be visualised in the driver diagram (Figure 2), which illustrates, for example, that pre-habilitation through increasing physical activity or smoking cessation can minimise perioperative risk and consequently reduce carbon-intensive clinical activity such as post-operative critical care admission.[1,8] This offers advantages in all three domains of the 'triple bottom line': care is simultaneously less expensive, more environmentally sound, and less invasive for the patient.

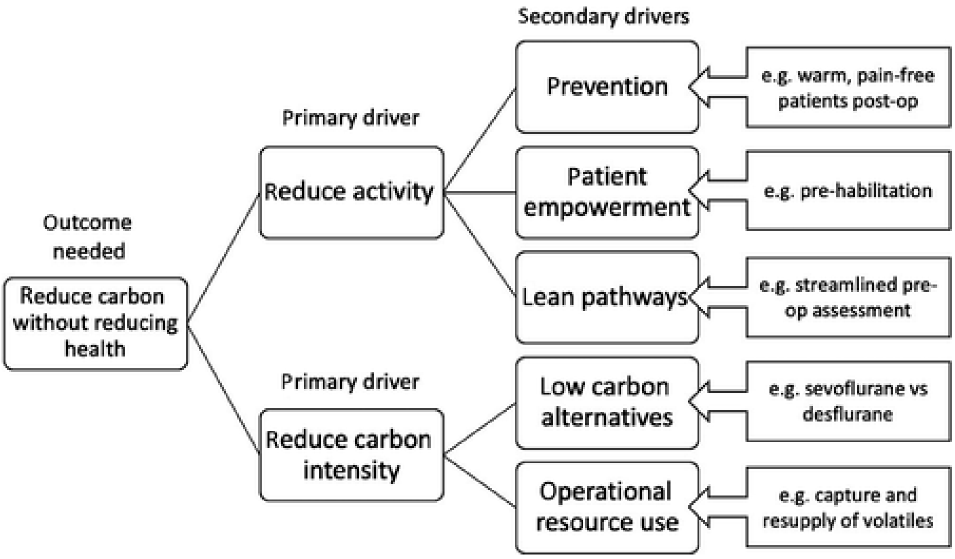

Figure 2: Driver diagram of how the Centre for Sustainable Healthcare principles of sustainable clinical practice can be applied to perioperative care.[1] Reproduced with permission.

The (Inter)National Promotion of Sustainability

The National Health Service has committed to becoming 'zero carbon' by 2050.[9] This challenging target will require a coordinated effort if it is to be achieved. In a joint policy statement in 2017, the Association of Anaesthesiologists, Royal College of Anaesthetists (RCoA) and College of Anaesthetists of Ireland acknowledged the environmental impact of our professional practice, and committed to four priority areas for action (Figure 3).[10]

1. Position our organisations as leaders in promoting sustainable healthcare, promoting the specific contribution of anaesthesia while working with others.
2. Commitment to providing the latest scientific evidence, education and the sharing of good practice to enable our members to minimise the environmental impact of their anaesthesia practice.
3. Strive to continually monitor and improve the environmental sustainability of our organisations.
4. Promote the reduction of individual and institutional wastage of financial and environmental resources in healthcare delivery.

Figure 3: The four priority areas identified in the Joint Environmental Policy Statement.[10]

There are numerous initiatives initiated by these organisations that demonstrate commitment to the environmental priorities, including the appointment of individuals or committees with responsibility for environmental sustainability, numerous educational articles, blogs, courses, and workshops, and the integration of sustainable healthcare into anaesthesia conferences. However, there remains ample opportunity for educational contributions on a national or international footing. This may be as simple as using social media to communicate the impacts of teaching or SusQI to a larger audience, or submitting case studies explaining 'what works' to the Association of Anaesthetists for dissemination via their website (See anaesthetists.org/Home/Resources-publications/Environment/Green-case-studies).

More ambitious projects could include writing for publication in a peer-reviewed journal, membership of a committee or organisation, or presenting work at a conference. However, national and international initiatives may incur a substantial environmental cost associated with travel, so it is useful to weigh this against the benefit of the activity and consider if there may be a more environmentally-friendly way to achieve the same impact. Methods such as online learning and virtual attendance should be considered from an environmental standpoint.

Conclusion

As regulatory organisations bring sustainability into training, anaesthetists will be expected to teach on this important topic. Having access to high-quality information, working with others, and maintaining a patient-centred approach are vital to the successful delivery of education. Driver diagrams and the triple bottom line are useful theoretical models for use in teaching and learning. Using these tools, anaesthetists are well-placed to provide effective education on environmentally sustainable healthcare, not only within their departments but in the wider healthcare and educational setting, and on the national and international stage.

Declaration of Interest

C.S. is a co-opted member of the Association of Anaesthetists Environment and Sustainability Committee.

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Royal College of Anaesthetists
Churchill House, 35 Red Lion Square, London WC1R 4SG
020 7092 1500 | e-LA@rcoa.ac.uk | rcoa.ac.uk/e-learning-anaesthesia
@RCoANews
RoyalCollegeofAnaesthetists
Information correct as at September 2020