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e-Learning Anaesthesia

Sustainability: **Energy use and water consumption**

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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.

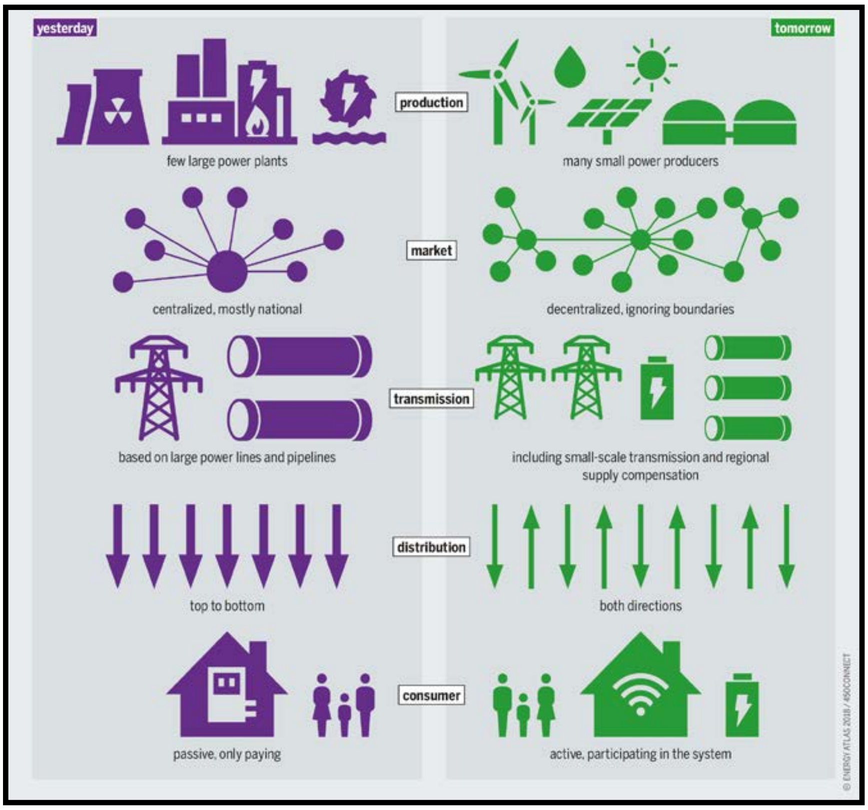

Figure 1: Electricity infrastructure. This figure illustrates how traditional grids of the past might compare with smart grids of the future.[1] Reproduced as per the licence agreement – the attribution (Bartz/Stockmar, CC BY 4.0).

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.

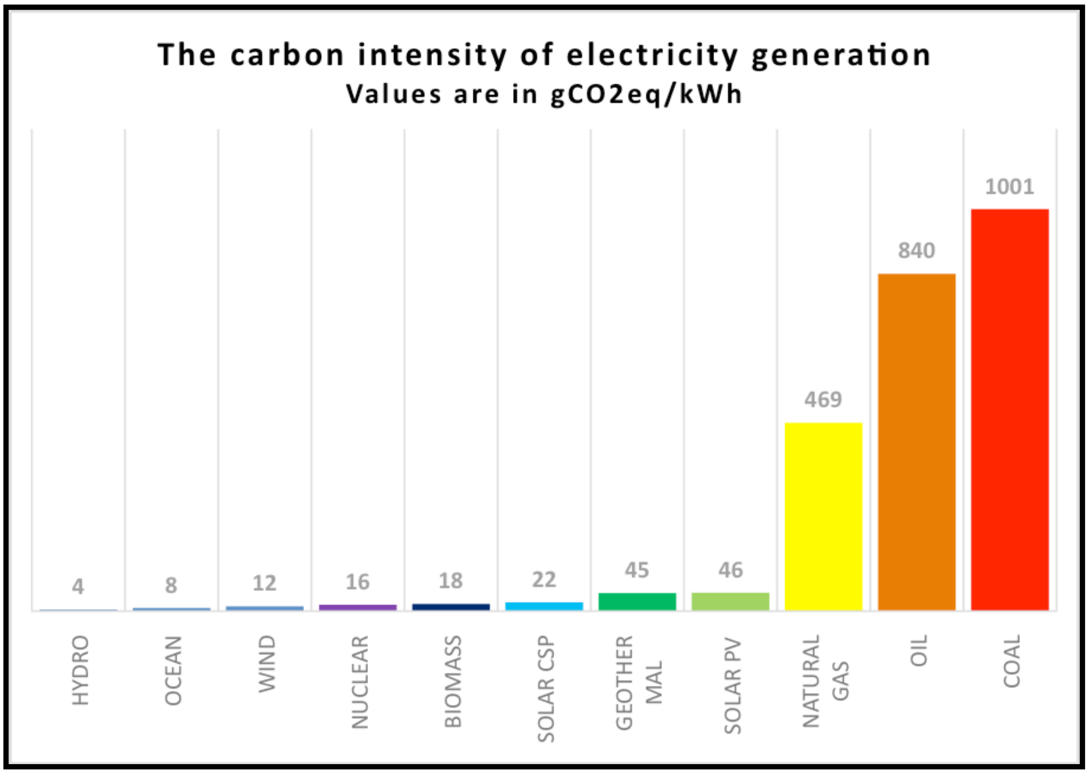

Figure 2: The carbon intensity of electricity generation. This chart illustrates how much more carbon intensive fossil fuels (namely coal, oil and natural gas) are in comparison with renewable alternatives.[2]

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.

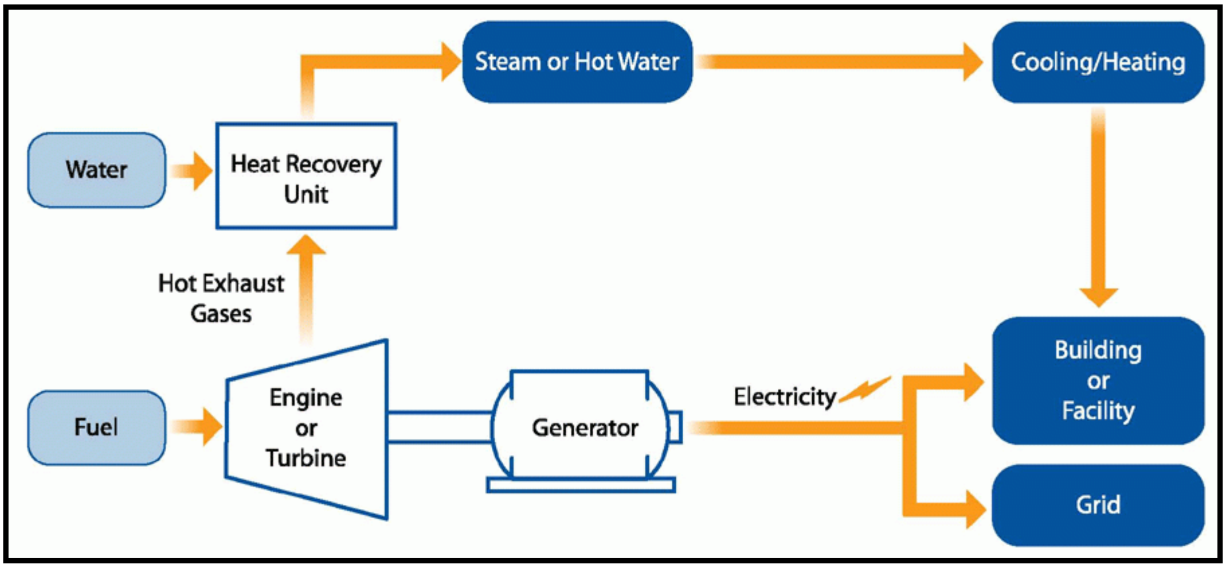

Figure 3: Typical combined heat and power configuration.[3] Environmental Protection Agency, EPA CHP Partnership Program, 2020. Permission granted for use by EPA.

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]

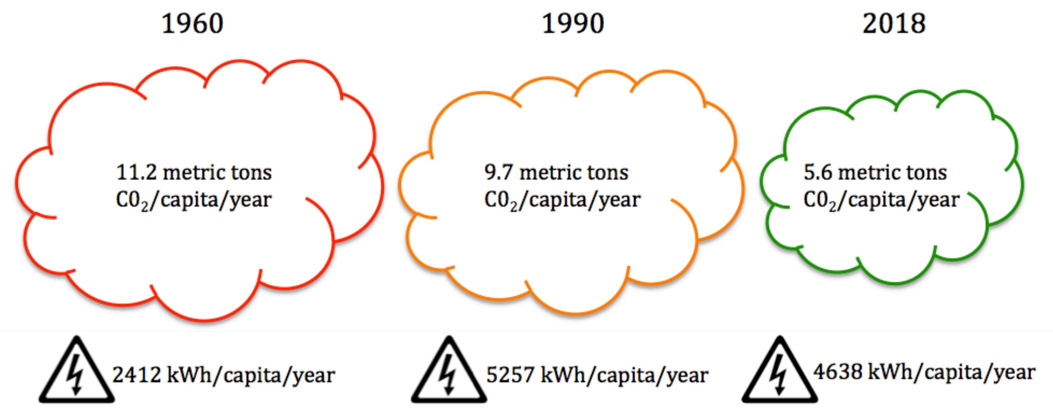

Figure 4: The reduction in CO2 emissions per capita in the United Kingdom over time.[6,7] This is due to a gradual shift from fossil fuels to renewable energy sources. Overall electricity consumption per capita is also stated for the years illustrated. The 1960 and 1990 figures are from the World Bank.[8] 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.

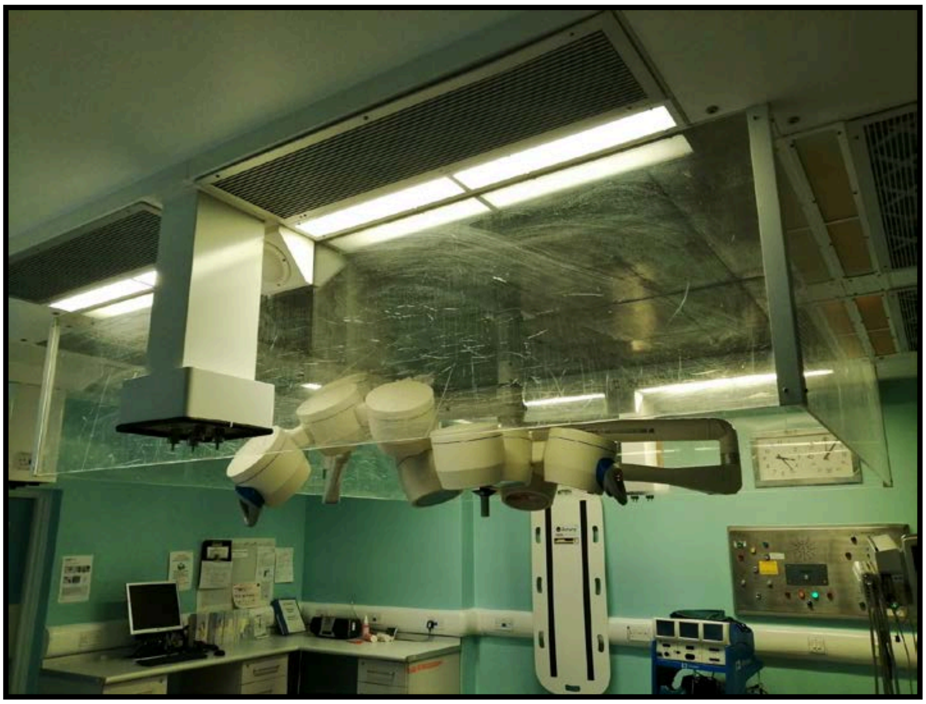

Figure 6: A typical orthopaedic theatre laminar flow HVAC system. Photo Dr J Major

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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