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Ecological Sustainability in Anaesthesiology and Intensive Care Medicine

A DGAI and BDA Position Paper with Specific Recommendations*

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Summary

This position paper with specific recommendations was commissioned by the DGAI and BDA executive committees in March 2020 and was compiled by the joint “Commission on Sustainability in Anaesthesiology”.

With the impending climate disaster in mind, the aim of this position paper is to delineate with which specific measures anaesthesiologists can contribute to a consistent and sustained reduction in CO_2 emissions and minimise the negative ecological implications associated with the fields of anaesthesiology and intensive care medicine. The paper is divided into six sections and, on the basis of published literature, presents the currently available evidence on how anaesthesiologists can incorporate sustainability aspects in their professional sphere of influence. Special attention is directed towards the environmental effects of drugs used in anaesthesiology and intensive care and their impact on climate change. In that regard, the direct and potent greenhouse gas effects of volatile anaesthetics are emphasized. In consequence, specific recommendations are made on reducing the damaging effects of volatile anaesthetics on the climate. With regard to consumables, the increasing use of disposable single-use items is the subject of critical analysis, and the need to incorporate the carbon footprint in the selection of products is stressed. As waste has significant direct and indirect ecological effects, the 5R concept is used to show how waste can be avoided in both the operating theatre and intensive care unit without upsetting existing processes.

In addition to these measures directly related to the field of anaesthesiology, this position paper addresses further areas of concern indirectly associated with the everyday professional role of the anaesthesiologist. As such, the paper alludes to the significance of sustainable mobility with regard to everyday commutes, patient transfers, and conferences. Improved energy management may commence in the operating theatre and intensive care unit but must ultimately encompass the whole hospital as a significant source of CO_2 emissions. Numerous measures can already be implemented today, and appropriate steps should be taken at a local level. Last but not least, the importance of research and teaching is emphasized as a key factor in successfully facing the challenge of ecological sustainability in anaesthesiology and intensive care medicine.

Preface

In March 2020 the Professional Association of German Anaesthesiologists (BDA) and the German Society of Anaesthesiology and Intensive Care Medicine (DGAI) executive committees assigned the joint **“Commission on Sustainability in Anaesthesiology”** the task of compiling a position paper with specific recommendations. Both executive committees approved the publication of this position paper in its current form during their sessions on the 16th March 2020

(DGAI) and 24th April 2020 (BDA). With the publication of this position paper, both BDA and DGAI expressly commit themselves to the goal of carbon neutral, sustainable health care and will therefore, together with other actors in the health care sector, use their influence on politics and on the industry to actively further the necessary transformational process.

Introduction

The 2018 **Intergovernmental Panel on Climate Change** report was climate scientist's warning not to exceed the 1.5 °C limit of global warming. Only a rapid and substantial worldwide reduction in CO_2 emissions over the next few years can avert runaway effects such as the melting of Antarctic ice masses or thawing of permafrost soils, which threaten to make the effects of climate change uncontrollable [1].

As physicians we are under a special obligation. Over the next decades, climate change will lead to a change for the worse in health care for a great number of people across the planet and pose grave challenges to health care systems in almost every country [2]. At the same time, the health care system is itself responsible for significant emissions of greenhouse gases, owning 4.4% of global greenhouse gas emissions in 2014 [3]. In response, numerous professional medical bodies have issued their own statements alluding to the urgent need to reduce CO_2 emissions across the health care sector [4–8]. Physicians are called upon to adjust their consumer behaviour and – in the spirit of divestment campaigns – their investment decisions to prioritise climate protection [9].

As high-tech, resource hungry fields, anaesthesiology and intensive care medicine are involved in a significant portion of CO_2 emissions across the health care sector [10–12]. In the past few years, numerous professional anaesthesiologic bodies have published recommendations for anaesthetists on how they can contribute to reducing CO_2 emissions [5–8].

The following recommendations focus on those measures which can be implemented immediately at a local level by anaesthesiologists. However, a good number of measures, including many with significant leverage, are arduous to implement at a local level alone. As such, achieving carbon neutrality in anaesthesiology and intensive care medicine over the next three decades will require wide-ranging technological innovation and significant investment in energy efficient refurbishment and in the infrastructure of individual hospitals. Major issues such as assuring generation of energy from renewable sources or realising sustainable transport are tasks for society as a whole and require political implementation. As a professional and a scientific body, we will use our influence to demand these changes.

In the past, close coordination between practising physicians and the industry – especially in the fields of anaesthesiology and intensive care medicine – have led to a variety of technical innovations which have made patient care safer and opened new horizons of clinical possibility for the good of patients. Seen in the light of the climate crisis, this close coordination should be further strengthened, aiming to promote the transformation to ecologically sustainable patient care.

Glossary

CO_2e: CO_2 equivalents

Emissions of greenhouse gases other than CO_2 can be converted to **CO_2 equivalents**. This entails calculating the quantity of CO_2 which would exhibit the same effect in the atmosphere as the emission in question by using the mass of that emission and its Global Warming Potential [13].

GWP: Global Warming Potential

The **Global Warming Potential** describes the substance-specific greenhouse effect compared to CO_2 over a specified length of time. In general, the interval chosen is 100 years (GWP100) [14].

LCA: Life-Cycle Assessment

A **life-cycle assessment** can be used to determine the actual carbon footprint of consumables, drugs and medical procedures. This involves analysing the ecological footprint from "the cradle to the grave", including the following positions: 1) extraction of raw materials, 2) processing and manufacturing, 3) transport and packaging, 4) use, reutilisation and maintenance, 5) recycling and 6) disposal. Water use and release of toxins are additional important factors besides CO_2 release [15].

A. Drugs

R1: General anaesthesia using volatile anaesthetics and/or nitrous oxide should be maintained in such a fashion that the smallest quantity of anaesthetic possible is discharged into the environment. This requires consistent use of minimal-flow anaesthesia.

R2: Use of desflurane should be reserved for cases in which it appears mandated on medical grounds. Of those volatile anaesthetics commonly used, sevoflurane is the least potent greenhouse gas.

R3: Use of nitrous oxide should be avoided unless its use appears mandated on medical grounds.

R4: The development, trialling and use of scavenging and recycling systems for volatile anaesthetics should be expedited.

R5: In contrast to inhalational anaesthesia techniques, total intravenous and regional anaesthesia do not intrinsically cause direct greenhouse gas emissions. Use of these techniques to avoid greenhouse gas emissions is judicious when they are appropriate from a medical standpoint.

R6: Pharmaceutical waste should be avoided on both economic and ecological grounds.

R7: Pharmaceutical waste must be disposed of in an appropriate fashion and must not be introduced into the sewage system. As a rule, it is appropriate to dispose of such waste resulting from anaesthesia and intensive care by incineration together with other residual waste.

Volatile anaesthetics (VA) and nitrous oxide exhibit potent greenhouse effects when released into the atmosphere. Both sevoflurane and desflurane are hydrofluorocarbons (HFCs), whilst isoflurane, enflurane and halothane are chlorofluorocarbons (CFCs) and exhibit additional ozone-depleting effects. The same is true for nitrous oxide (N_2O) [11,16–19]. VAs show a significantly larger negative impact on the climate than CO_2. That impact is recorded as the comparative greenhouse effect in relation to CO_2 (**Global Warming Potential**, GWP). To ensure the total atmospheric lifetime of CO_2 is taken into account [22], an observation period of 100 years (GWP100) is typically selected [17,19–21].

VAs exhibit their principal greenhouse effect during their atmospheric lifetime, instead of uniformly throughout the 100-year timeframe. Applying GWP100 will lead to the negative impact of VAs on the climate being underestimated for the next 10–30 years. As such, a GWP observation period of 20 years can be helpful in demonstrating the greenhouse effect which will set in within the relevant social and political time remaining to battle global warming (Tab. 1) [19].

In addition to the greenhouse effect per quantity of substance used, the actual quantity of the VA required to reach an adequate minimal alveolar concentration (MAC) needs to be factored into the equation. During **steady state** and assuming identical flow rates, use of desflurane for general anaesthesia emits approx. 50 times as much CO_2 equivalent as when sevoflurane is used. This difference becomes all the more apparent when the emissions caused by inhalational agents for maintenance of anaesthesia during steady state are converted and expressed as kilometres travelled by car [17,21,24]. Emissions from 6 hours of inhalational anaesthesia – the equivalent of one working day – are set out in this fashion in Table 2, based on GWP100s. The results assume general anaesthesia during steady state, and so do not include the induction and emergence phases. Using nitrous oxide as a carrier gas for sevoflurane or isoflurane significantly worsens the carbon footprint of the volatile agent [21,25].

During the maintenance of general anaesthesia, doubling the flow rate will double the emissions from VA [19,21, 24–26]. As such, utilising minimal flow for maintenance of anaesthesia is to be recommended in any case. A higher fresh gas flow should be reserved for situations in which the depth of anaesthesia needs to be changed rapidly. Also when initiating emergence, high flows should only be used once the vapor has been shut off [25].

Volatile agents used for general anaesthesia are currently discharged into the environment in their entirety, causing a significant greenhouse effect. Worldwide emissions from VA totalled 3 m tons CO_2 equivalent in 2014, not including the effect ascribable to nitrous oxide. 80% of these emissions were attributable to desflurane alone [11]. In an average anaesthesia department, use of VAs will be responsible for between 3.5 and 118.3 kg CO_2 equivalent per anaesthesia case [27,28]. Assuming 10,000 anaesthesia cases per annum, the annual carbon footprint is equivalent to that of up to 200 average citizens in Germany. Avoiding desflurane could obviate 67% of emissions attributable to an anaesthesia department [28].

Various technical solutions for capturing rather than emitting VAs and nitrous oxide are currently in development or almost ready for market. Using such technologies, VAs can be destroyed by thermal, catalytic or photochemical means, or processed for reuse [24,25, 29–31]. Today, systems which capture nitrous oxide used in obstetrics, destroying it by means of a thermal catalytic process, are already in practical use [24, 30]. The technical means for reacquiring sevoflurane from specially designed activated carbon filters, making it available for reuse on patients after distillation and sterilisation, already exist. As such, at some point in the future, VAs could represent a test case for licensing recycled drugs. The process of capturing VAs in carbon filters – as is commonly practised on intensive care units in Germany – is

Table 1
Global Warming Potentials and atmospheric lifetimes of inhaled anaesthetics (Sulbaek Anderson et al. 2012 [17]).

	GWP100	GWP20	Atmospheric lifetime (in years)
CO_2	1	1	30–95 (23)
N_2O	298	289	114
Sevoflurane	130	440	1.1
Desflurane	2,540	6,810	14
Isoflurane	510	1,800	3.2
Halothane	50	190	1.0
Enflurane	680	2,370	4.3

Table 2
Emissions from 6 hours of inhalational anaesthesia during steady state, converted to kilometres travelled by car (based on Sherman and Feldman 2017 [24]).

	Minimal-Flow Anaesthesia 0.5 l/min	Low-Flow Anaesthesia 1 l/min	High-Flow-Anaesthesia 2 l/min	High-Flow-Anaesthesia 5 l/min
Sevoflurane 2,2%	19.3 km	38.6 km	77.2 km	183.5 km
Desflurane 6,7%	898.0 km	1,825.0 km	3,650.0 km	9,067.0 km
Isoflurane 1,2%	38.6 km	67.6 km	144.8 km	366.9 km
Nitrous oxide (N_2O) 60%	280.0 km	550.4 km	1,081.5 km	2,723.0 km

insufficient on its own, however, as those VAs are released from the filter into the atmosphere after the filter has been disposed of [24,25].

With regard to CO_2 emissions attributable to production, distribution and disposal of almost all other drugs commonly used in anaesthetics, precise data are lacking such that it is impossible to make detailed statements with regard to specific drugs.

As methods such as TIVA or regional anaesthesia do not generate direct emissions of greenhouse gases, the emissions associated with those methods are significantly lower than from inhalational anaesthesia [24,25,32–34].

When considerable drug quantities are discarded, it is expedient to consider using smaller vials [25]; up to 20% of propofol waste, for example, is considered to be avoidable [35]. In some situations, switching from 50 or 100 ml vials of propofol to 20 ml vials can reduce the quantity of drug wasted by more than 90% [36]. This can, in addition, be economically viable; wasted drugs make up for approximately one quarter of the total cost of drugs [35]. This calls for a comprehensive review taking other waste (see below) into account. Drugs kept drawn up ready for use not only cause significant costs when they ultimately remain unused but also bear a relevant negative ecological impact [36]. 50% of emergency drugs drawn up end up being discarded unused [37]. This applies to drugs which have to be available for use immediately and without delay (such as those for anaesthesia for emergency caesarean section) and to those which require dilution, which may lead to delay and dosing errors (such as bolus injections of catecholamines). It is appropriate to consider having these drugs prefilled into syringes under clean and sanitary conditions by the pharmacy or to purchase prefilled syringes, which typically have a longer shelf life and can therefore reduce waste [15].

The Swedish **Stockholm County Council Drug Therapeutic Committee** has developed an environmental classification for pharmaceuticals. The **Hazard Score** (based on the earlier **Persistence, Bioaccumulation and Toxicity (PBT) Index**) was designed to grade the risk pharmaceuticals pose to the environment. The score should be consulted whenever possible when selecting drugs, so as to ensure the smallest possible impact on the environment. Unfortunately, a significant portion of anaesthesiologic drugs have yet to be graded [38].

Waste drugs can be introduced into the environment when they are discarded improperly via the sewage system – propofol remnants have been found in hospital wastewater [39]. Propofol has a **Hazard Score** of 4 (on a scale of 0 to the maximum of 9) and is neither biodegradable in water nor under anaerobic conditions [25,33,36,40].

All departments must establish procedures for correct disposal of pharmaceutical waste and train staff in the implementation.

Disposal of left-over pharmaceuticals “down the drain”, that is via the sewage system, is unacceptable from an ecological point of view. As a rule, drugs must be disposed of by incineration. The requisite temperatures vary [25]. Propofol remnants aren’t destroyed until heated to over 1000 °C for at least 2 seconds [36], whilst most other drugs used in anaesthesia can be incinerated at lower temperatures [25]. The disposal of pharmaceuticals should be organised in a pragmatic, error-resistant way: it is recommended that left-over drugs should be emptied into paper towels and placed together with resiudal waste for incineration. Balanced electrolyte solutions without the addition of any drugs can be emptied down the drain.

B. Consumables

R1: The increasing use of single-use disposable consumables in place of reusable items should be the subject of critical analysis. An assessment should be undertaken to determine in which cases reusable items could present an alternative.

R2: Use of reusable fabrics such as surgical gowns, caps and drapes should be considered.

R3: Single-use items made of metal have a particularly poor carbon footprint and replacing them with reusable products should be assessed.

R4: Manufacturers should be called upon to provide full life-cycle assessments of the carbon footprints of medical devices.

Single-use items are ubiquitous in anaesthesia and intensive care and are increasingly displacing reusable products. The main influencing factors in the decision process between single-use and reusable products are quoted as concern for hygiene, convenience, and cost. Environmental factors have traditionally played a lesser role [15].

Life-cycle assessments are available for an ever-increasing number of medical products. A review of 6 LCAs comparing washable, reusable surgical textiles (surgical gowns and drapes) with single-use items showed that the reusable textiles featured a 30–50% smaller carbon footprint. Single-use items require 200–300% more energy, 250–330% more water and produce 750% more waste than reusable items, even when both the water and energy requirements for washing and sterilising reusable items are taken into account [41].

A comparison between single-use and reusable plastic anaesthetic drug trays showed the reusable item to be not only more ecological but also more economical [42]. For reusable laryngeal masks, a significantly smaller negative ecological impact was shown across all examined categories of ecological sustainability [43]. Utilising single-use laryngoscopes increases the CO_2 emissions by 16 to 25 times when compared with reusable stainless-steel devices, especially when both the laryngoscope blade and the handle are single-use items [44,45].

Extracting metals from ore is extremely energy intensive and leads to a very large carbon footprint [27,46]. The German Society of Hospital Hygiene (DGKH) notes that use of single-use metal instruments (laryngoscopes, scissors, needle holders, forceps etc.) is of particular concern as, in addition to the associated significant use of resources, erroneous introduction of such products into the sterilisation process poses a significant risk of causing corrosion of other instruments. They go on to point out that a good number of single-use products are manufactured under ethically problematic conditions in underdeveloped countries [47]. As such, single-use metal items should be replaced by reusable products whenever possible. When this appears impossible, at the very least effective recycling should be implemented. 1 m ton of recycled steel reduces CO_2 emissions by approx. 80% when compared to manufacturing with metal extracted from raw materials [48,49].

Using LCAs, the purchasing process can incorporate sound ecological factors. They can also show ways to implement improvements. As energy sources and transport show significant heterogenicity, LCAs are specific to their respective geographic region. Extrapolations should be regarded with circumspection and manufacturers called upon to provide national LCAs [15,50].

C. Waste Management

R1: The 5R concept of waste management (reduce, reuse, recycle, rethink and research) should be implemented.

R2: An efficient recycling concept should be shown to be operating in all areas of operating theatre suites and intensive care units.

R3: It is to be required that plastic packaging should, when possible, be manufactured from single-type plastic, which can undergo high-grade recycling.

R4: Dangerous waste and the requisite special modes of disposal cause very large emissions of CO_2. Economical and ecological considerations dictate that other waste – which could be disposed of as standard waste or even recycled – must not through thoughtlessness or laziness be disposed of as dangerous waste.

Approximately 20–30% of waste accrued in hospitals is generated in the operating theatre; 25% of this waste is generated by anaesthesia, much of it is packaging [51,52]. Each theatre case generates between 7.62 and 16.39 kg of waste [27]. The 5R concept **(reduce, reuse, recycle, rethink and research)** was coined to reduce the ever-increasing quantity of waste produced [50].

Reduce:

"Doing more with less" is the most effective method of sparing resources and producing less waste and is both an ecologically and an economically sustainable concept [53]. There are a good number of ways to conserve materials without risking patient safety or quality along the way.

The following measures can be named as examples:

- When used in conjunction with individual patient filters, ventilator circuits can be used for 7 days (except when soiled or used for contagious patients); several studies have shown that the number of pathogens in the circuit was not increased after 7 days vs 24 hours [54–57], leading the DGAI and DGKH to recommend this approach [58]. Furthermore, the use of washable, reusable ventilator circuits should be considered [55].
- Pre-packed sets, e.g. for insertion of central venous lines or for regional anaesthesia, and surgical trays often contain unnecessary plastic, gauze or other materials which are disposed of unused. Upon request, manufacturers can often slim down sets in a cost-effective manner [59].
- The decision to order diagnostic tests should not be taken lightly – consider, for example, routine blood tests in healthy patients prior to minor elective surgery [60]. Effective patient blood management is at the same time a sound ecological approach.

Recycle:

Approximately 60% of waste generated in operating theatres can potentially be recycled. A lack of containers and infrastructure, lack of knowledge, laziness and lack of support have been listed as barriers to effective recycling in the theatre environment [61].

As the largest proportion of packaging waste is accrued when opening **equipment** before the patient is brought to theatre, contamination of that waste is practically inconceivable. One option to ensure recycling waste remains uncontaminated is to seal the recycling bags as soon as the patient is brought into the operating theatre [15]. Clearly structured programmes facilitate the introduction of recycling programmes and increase their efficiency. Recycling bins should be easily accessible and marked with clear instructions as to what belongs in them. Involving local recycling companies and providing recurring training to staff are essential [15].

Paper/cardboard, plastic, glass, batteries, printer cartridges, electronic waste and metal can all be collected in the operating suite for recycling. Recycling can also be cost effective [7]. Approximately 30% of theatre waste is made up of plastics, including items manufactured from polypropylene and PET (single-use textiles, blue sterilisation packaging for medical and surgical instruments), polyethylene (plastic tubing, beakers and trays), polyurethane, PVC (suction and oxygen tubing), copolymers and other compositions. Specific details are often not declared appropriately or at all. Some types of plastic such as PVC require special processing [51]. Recycled plastic requires only 25% of the energy used to produce plastic from new materials [62]. When different types of plastic are mixed and recycled together, however, the resulting products are low-grade. This has led to calls for packaging to be produced from single-type plastic and to be appropriately declared.

MacNeill et al. (2017) examined the carbon footprint of three large hospitals in Canada, the USA and England. They performed a detailed waste audit and calculated the CO_2 emissions associated with the various types of waste. Extraction of raw materials, material-specific manufacturing, transport and disposal alone (so without regard for additional CO_2 emissions from product-specific manufacturing and product packaging) caused emissions of 3,254 kg CO_2e/t for plastic, 2,708 kg CO_2e/t for steel and 895 kg CO_2e/t for glass [13, 27].

Clear definitions of the various types of waste are required [63,64]. Waste accrued in hospitals is approx. 30% medical waste originating from medical treatment and nursing, and approx. 60% household-like waste. About 10% of waste is dangerous, with 3% infectious and 7% toxic waste such as chemicals or cytostatic drugs [65]. Infectious waste has to be destroyed in specialised incinerators which, amongst other things, requires additional transport [66,67]. At 1,833 kg CO_2e/t, incineration of clinical and dangerous waste causes the most emissions from waste disposal [27]. If it were appropriately sorted, stored and transported, the largest proportion of this waste could, however, be disposed of together with municipal waste in thermal waste treatment plants; furthermore, a large proportion could potentially be recycled [66,67]. As such, the various different types of waste need to be sorted, keeping the proportion of clinical – dangerous waste as small as possible [10].

D. Mobility

R1: As mobility related to commuting is responsible for a significant proportion of the carbon footprint of anaesthesiology departments, hospitals should develop and promote alternative mobility concepts.

R2: With regard to prehospital emergency care and critical care transport, electromobility and telemedicine should be put to good use. Airborn transport of patients should be critically evaluated.

R3: With regard to participation in conferences and work related to professional associations, public transport should be preferred. Inland flights should be avoided whenever possible and only reimbursed as travel expenses in well-reasoned exceptional cases; a carbon offset for the flight should then be considered.

R4: Streaming of conferences, video conferencing and webinars should be offered as a way to reduce travel and its associated carbon footprint.

Reducing the carbon footprint of the health care sector will require a focus on mobility; specifically, the following three areas of transport require attention: health care employees' commute to their respective places of work (commuter traffic), emergency medical services and outpatient transport services (patient transport), and trips to conferences and meetings (educational travel). Reducing the carbon footprint of those individual areas requires that different approaches be considered.

Commuter traffic in particular exhibits an average motor vehicle occupancy rate of 1.2. A study showed employees' drive to the place of work to be responsible for 12–39% of the carbon footprint of a department of anaesthesiology [28]. Alternative mobility concepts, suited to respective areas of residence, are required if these work-related CO_2 emissions are to be curbed.

Possible targets for interventions in the hospital include [68]:

- Furtherance of cycling infrastructure together with a sufficient number of bicycle parking spaces on hospital grounds; calls for hospitals to be connected to bikeways.
- Charging infrastructure for e-mobility.
- Commuter ticket schemes can help promote the switch to public transport. Calls should be made for all hospitals to be readily accessible by public transport.
- For rural areas, ride-sharing platforms or centres can be developed by the hospital for its employees.
- Increased provision of work-from-home options and video conferencing can reduce commutes.

Following the introduction of a mobility concept for commuter traffic, it is likely that the improved cycling and pedestrian infrastructure and public transport offerings will also be used by patients.

With regard to emergency services, a reorientation towards alternative, non-fossil fuels (electromobility, hydrogen fuel cells) will be unavoidable. An additional option is to critically reconsider the use of systems associated with significant fossil fuel requirements – such as air ambulances – when their use is not mandated on medical grounds.

The significant proportion of emergencies involving emergency physicians but not actually requiring intervention by the physician may suggest that telemedicine might reduce the need to despatch a physician-staffed, second vehicle to emergencies. In general, implementation of telemedical consultations can significantly reduce the carbon footprint: when the drive to the surgery by car is just 3.5 km or more, teleconsultations are the more climate friendly option [69].

The number of large, international conferences with ever more participants travelling long distances is increasing. Conference participation causes significant CO_2 emissions associated with journeying, especially over long distances as is required in some cases. Participants' journeys to a single international conference were associated with a 22,000 t carbon footprint, the equivalent of the average annual carbon footprint of 2000 citizens in Germany [70]. Air travel is especially problematic because of the associated emission of 230 g CO_2e per passenger kilometre, by far the largest carbon footprint associated with travel. CO_2 emissions per passenger kilometre for travel by car and train – 147 g/km and 32 g/km respectively – are notably lower [71]. Online streaming of conferences should be expanded. Streaming of conference lectures and interactive sessions should be offered as attractive options, enabling conference participation without travel [70].

E. Energy management

R1: Concepts aimed at reducing the considerable power consumption associated with heating, ventilation and air conditioning in operating theatre suites and intensive care units should be implemented. These might, for example, include setback operation in systems in operating theatres unused outside of usual working hours and optimising the temperature and ventilation settings.

R2: All departments should work towards ensuring that their hospital evaluates its options with regard to energy saving measures, energy efficient refurbishment and use of renewable energy sources, implementing those options in a timely manner.

R3: A switch to renewable energy is essential so as to reduce the carbon footprint of hospitals in Germany.

Both operating theatre suites and intensive care are resource-hungry and use very large amounts of energy [10,72]. The energy consumption in operating theatre suites is 3 – 6 times higher than that of the rest of the hospital. Of the power consumed in operating suites, 90–99% is used for heating, air conditioning and ventilation [27].

These CO_2 emissions can be reduced by making savings in energy consumption [27,72,73]. Energy-saving measures in operating theatre suites can reduce energy consumption and with that the carbon footprint of the operating suite by 50%, a measure which also significantly cuts costs [27]. The following practical steps should be taken:

(1) In operating suites, heating, ventilation and air conditioning are commonly operational throughout in every operating theatre, despite the fact that those theatres are often unoccupied at least 40% of the time. Setback operation in systems in unused operating theatres ("night setback" or "unoccupied setback") – with the exception of required emergency theatres – can facilitate energy savings of up to 50 % [27,74].

(2) First steps with regard to heating and air conditioning concern the temperature curve settings in central control systems. In operating theatres at high ambient temperature, every reduction of temperature by 1° C can reduce the energy required for heating by 5–8% [73].

(3) When considering ventilation, it can – as a first step – be viable to review the system and adjust the air change rate to suit the room temperature [73]. In some other European countries, it is already customary to completely deactivate ventilation during unoccupied periods [75].

(4) In less frequented areas (storage or auxiliary rooms, toilets, etc.) it is expedient to control the lighting using motion detectors [76].

(5) The halogen lamps traditionally used in operating suites should be exchanged for LEDs. This measure can reduce the energy consumed for lighting by 80% [73,77]. In addition, LEDs radiate less heat, which reduces the energy required for cooling [10].

Care for patients on intensive care units caused the emission of 88–178 kg CO_2e per patient day, with energy consumption (dominated by requirements for heating, ventilation and air conditioning), again making up 76–87% of the carbon footprint [72]. A switch to renewable energy is recommended together with optimisation of the energy efficiency of the building to reduce the carbon footprint [78]. Holistic energy management concepts can enable hospitals to reduce their energy requirements by up to 30%, reducing the associated CO_2 emissions by up to 50%. In addition to technical solutions, these concepts also integrate approaches aimed at optimising user behaviour. Energy saving measures such as these can lead to long-term cost reductions [73,79]. Each and every hospital in Germany should identify their options for introducing such measures and implement them.

The cogeneration (CHP) systems commonly used in hospitals in Germany exhibit a high primary energy yield by using the heat produced during electricity generation for heating or cooling the building. High energy yields can, however, only be achieved during optimum operation of the CHP system. Because they currently typically consume fossil fuels, these systems should be viewed as interim technologies [79,80]. The switch to a climate-friendly future necessitates the use of renewable energy for electricity and heating in hospitals. Using wind power, waterpower, photovoltaics, solar thermal energy, geothermal energy or biogas allows for generation of energy with a reduced carbon footprint, and can be devised to be cost efficient [73, 79].

F. Research and Teaching

R1: The effects of climate change on intensive and emergency care, and on hospital capacity have not yet been adequately researched. Appropriate research projects should be developed and supported.

R2: Research pertaining to ecological sustainability in anaesthesiology and intensive care medicine should include issues such as choice of drugs and the optimised use of volatile anaesthetics and medical devices.

R3: Conferences, seminars and vocational education events relating to anaesthesiology and intensive care medicine should be planned, organised and implemented in an ecologically responsible and carbon neutral fashion.

R4: Sustainability in health care should be an integral part of student, postgraduate and speciality training. Each and every department is called upon to integrate appropriate content into their curricula and continuing medical education.

R5: Climate-friendly behaviour should be encouraged in all departmental staff by provision of information and training.

The WHO has estimated that a further unbridled increase in the average temperature as a result of climate change will lead to an additional 250,000 deaths per annum from 2030 to 2050 alone, caused in part by heat waves and natural disasters [81]. Pulmonary, respiratory, nephrological and infectious disease will also increase by a relevant margin as a result of climate change. This will have a significant impact on required capacities for emergency and intensive care. Further research is required to determine how best to face the repercussions of climate change on the health of the population [82,83].

Providing a gross value added of 11.2% of gross domestic product, the healthcare sector is an important economic factor in Germany [84]. At the same time, the healthcare sector emits 6.7% of total greenhouse emissions, equating to 55.1 m tons CO_2 per annum or 0.68 t CO_2 per citizen [78]. To dates the carbon footprint of the healthcare sector has been the subject of very little research and calls to reduce CO_2 emissions have not focussed on healthcare. Significant research efforts will need to be undertaken during the next number of years to compile options for reducing CO_2 emissions from the healthcare sector.

Events such as conferences, seminars and vocational training should ensure the most sustainable and carbon neutral planning and implementation possible. For this purpose, unnecessary emissions from travel to the venue, the venue itself, accommodation and catering for participants, consumables and any waste produced should be avoided [85].

As academic teachers we have a special responsibility to pass our knowledge of aspects of sustainability in medical care on to the next generation of doctors. As such it is essential that sustainability be integrated into undergraduate teaching as a fundamental concept. Similar efforts are required to promote knowledge of ecologically, socially and economically sustainable patient care through continuing medical education and professional development.

Implementation of the “reduce, reuse, recycle, rethink and research” approach can further staff awareness in hospitals and show positive effects with regard to team spirit and progression to sustainable hospitals, bringing closer the requisite large transformations. Whilst its importance is often underestimated, the human factor is an essential consideration in the lead up to change [73]. Training is essential if staff is to be sensitised to the issue.

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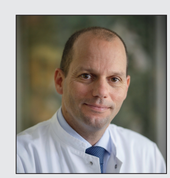

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