



Towards environmentally sustainable health systems in Europe

A review of the evidence



ABSTRACT

This review provides evidence to illustrate the environmental impact of health systems in Europe, the potential benefits of fostering environmental sustainability in health systems and the barriers to and incentives for such action. The evidence is clear that health systems have a considerable impact on the environment, contributing to greenhouse gas emissions and climate change, releasing ecologically toxic substances into the environment, producing large volumes of waste material and contributing to the depletion of natural resources such as drinking-water. Nevertheless, health systems also have positive environmental effects, particularly as a result of environmental health protection and some health promotion activities. Overall, the evidence reviewed in this report illustrates the compelling rationale for fostering environmental sustainability in health systems.

KEYWORDS

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EXECUTIVE SUMMARY

OBJECTIVES

This review aims to provide evidence to illustrate the following:

- the environmental impact of health systems in Europe;
- the potential benefits of fostering environmental sustainability in health systems;
- the barriers to and incentives for such action.

METHODS

A literature review was framed around these three objectives. A total of 172 research articles that met the inclusion criteria were identified. The evidence reported is based on a review of these 172 articles, plus relevant reports and grey literature.

FINDINGS

Environmental impact of health systems

The evidence is clear that health systems have a considerable impact on the environment.

- Health systems contribute to greenhouse gas emissions and climate change as a result of direct energy use in health care facilities, through patient and staff travel and via procured goods and services. Embedded emissions in procured goods account for a large part of the carbon footprint of health systems, highlighting the importance of supply chain management, particularly in relation to pharmaceuticals, medical devices and food.

- Health systems release ecological and human health hazards into the environment – for example, through wastewater. These include pharmaceutical compounds, heavy metals such as mercury and endocrine-disrupting chemicals.
- Health systems produce large volumes of different types of waste, including hazardous waste. Improper management, including disposal of these materials, can have direct consequences for environmental and human health, particularly in low- and middle-income countries.
- Health systems also contribute to the depletion of natural resources.

Nevertheless, health systems also have positive effects on the environment, particularly as a result of environmental health protection and some health promotion activities. Health protection measures such as the introduction and enforcement of regulatory requirements concerning air pollution, water pollution and soil contamination have achieved significant environmental benefits while also protecting human health. Promotion of healthy lifestyles (such as active transport and low-meat diets) could help to reduce the burden of cardiovascular and other noncommunicable diseases as well as helping to mitigate climate change. The potential exists to develop more environmentally sustainable elements in all areas mentioned above.

Benefits of fostering environmental sustainability in health systems

The notion of fostering environmental sustainability in health systems incorporates three related objectives:

- reducing the negative environmental impacts of health system activities;
- strengthening those areas where health systems have a positive effect on the environment;
- improving the resilience of health systems to environmental change.

In most cases the evidence available is not sufficient to quantify the scale of benefits that could be achieved by pursuing actions in these three areas. Nonetheless, there are sufficient examples to indicate that opportunities might exist. The potential benefits include:

- environmental benefits from reducing negative and strengthening positive impacts;
- financial benefits, such as through more efficient use of energy and other resources;
- health benefits, such as through improved management of waste materials;
- access/quality benefits, such as through use of telehealth technologies to reduce the need for patient travel;
- workforce benefits, such as increased levels of employee engagement and improvements in recruitment and retention;
- improved climate resilience, such as better preparedness for extreme weather events.

Barriers and enablers

The literature review identified barriers and enablers for fostering environmental sustainability in health systems at a number of levels.

Individual-level barriers and enablers included:

- lack of knowledge or awareness of sustainable practices;
- diffuse/unclear responsibilities for environmental impacts;
- psychological barriers, such as the “moral offset”.

Organizational barriers and enablers included:

- inadequate procedures and resources – for example, in relation to waste management;
- organizational culture and leadership styles;
- ability to devolve responsibility, permit experimentation and create conditions for learning.

System-level barriers and enablers included:

- weak governance at the national level;
- absence of appropriate regulatory frameworks and/or weak enforcement;
- financial incentives such as low-interest financing, tax incentives and seed funding.

CONCLUSIONS

Overall, the evidence reviewed in this report illustrates that the rationale for fostering environmental sustainability in health systems is compelling: there is no doubt that health systems have a substantial impact on the environment, and in their current form are highly dependent on access to energy and other natural resources. As concerns mount worldwide regarding environmental change, and as efforts to counter this gather momentum, all sectors are increasingly expected to operate in a sustainable way. What is not yet clear is how this ambition could best be put into practice in health systems. While minimizing adverse impacts is important, clear opportunities are also available to strengthen areas where health systems have a positive impact on the environment, such as health promotion and environmental health protection activities. Policy-makers and others need comprehensive, reliable information regarding the environmental costs and benefits of alternative courses of action, as well as insight into how to foster environmental sustainability effectively. Investment in relevant research and coordination of research efforts across countries and sectors is therefore vital.



1. BACKGROUND

As part of overall economic activity, accounting for around 8–10% of the gross domestic product of most European countries, the activities of health systems have significant and multiple consequences for the natural environment. Mounting concerns regarding global environmental change make it inevitable that questions are asked about health systems' responsibilities and abilities to contribute to efforts to mitigate and adapt to these changes.

This review aims to provide evidence to illustrate the following:

- the environmental impact of health systems in Europe;
- potential benefits of fostering environmental sustainability in health systems;
- barriers to and incentives for such action.

“Health systems” are defined with reference to the four health system functions (resource generation, service delivery, stewardship and financing) outlined in WHO’s *World health report 2000* (WHO, 2000), and hence the scope of this review includes both the delivery of health services and the supply chains on which services depend.

The report was commissioned by the WHO Regional Office for Europe to support the preparation of a document proposing a strategic approach to fostering sustainability in health systems. The need for health systems to play a leadership role in environmental sustainability was endorsed by European Member States in 2010 through the Parma Declaration on Environment and Health and its Commitment to Act (WHO Regional Office for Europe, 2010). Health 2020, the current European health policy framework, gives further weight to this by calling for health systems to act in a more environmentally responsible manner (WHO Regional Office for Europe, 2013). A new global framework, applied through the Sustainable Development Goals, is an overarching opportunity for sustained action to be taken by health systems in protecting human health and the environment.

The idea that health systems should be resourced, governed, financed and delivered in ways that allow them to meet the needs of future generations as well as today’s population is not new. Professionals working in health systems are accustomed to the notion that services must be financially sustainable. What is perhaps less familiar is the notion that sustainability extends beyond having a sound financial basis for the future. The most widely used framework from the field of sustainable development recognizes three interdependent elements – economic development, social development and environmental protection – that are sometimes referred to as the “triple bottom line” (Elkington, 1994). Applying this framework to health shows that health systems should not only be financially sustainable but should also minimize adverse impacts on society and on the natural environment that could otherwise jeopardize the ability to meet the health needs of future generations.

The concept of “shared value” is also important. Porter and Kramer (2006) argue that in the long term the financial performance of an organization is dependent on the health of the communities and natural environments in which it operates. According to this view, acting in a sustainable way is not merely a question of being charitable or responsible; it offers opportunities to serve the core objectives of the organization, promoting innovation and creating competitive advantage. In the context of health systems, this principle suggests that health systems would further their own goals by pursuing points of intersection where improvements in human and environmental health can be pursued simultaneously.

It is well established that human activities create a variety of pressures on the environment and that these pressures inhibit the functioning of ecosystems in a number of ways. The main trends in global environmental change, according to the Sustainable Development Goals agenda, include:

- climate change caused by emissions of greenhouse gases;
- ocean acidification;
- depletion of fresh water reserves and other essential natural resources;
- changes in land use and soil erosion;
- disruption of biogeochemical flows by nitrogen and phosphorus pollution;
- increasing exposure to toxic chemical pollution;
- generation of waste materials that must be disposed of through landfill, incineration or other means – all of which have associated environmental impacts;
- loss of biodiversity.

Health systems can be seen as a microcosm of society, and as such it is reasonable to assume that the activities of the health sector will contribute to all the pressures and impacts listed above. This review concentrates on the areas where the evidence is specific to the health sector. As such, it should not be seen as a comprehensive assessment of all the ways in which health systems affect the environment, but rather, as an evidence-based illustration of the magnitude of some of the pressures and impacts exerted by health systems on the environment, focusing solely on those areas where health-specific evidence is available. Section 4 discusses the knowledge gaps and research needs that may need to be addressed in order to inform policy-making on the environmental sustainability of health systems.



2. METHODS

A literature review was conducted to identify evidence relevant to the three objectives outlined in section 1. The search strategy is described in full in Annex 1. Given the breadth of the subject matter, it was not considered appropriate or feasible to adopt a full systematic review methodology. Instead, the review intends to provide illustrative evidence gathered through a methodical and rigorous process.

The primary search was conducted using the PubMed database. This was supported by a number of secondary search strategies, including using the ScienceDirect database, citation indices and manual searching of reference lists. Academic articles were supplemented with grey literature identified using the websites of key relevant organizations and the Open Grey online database.

Articles were assessed for relevance before being reviewed in full. The key inclusion criterion was that articles must be based either on original empirical data or on a review of empirical research. Hence, opinion pieces, commentary and journalistic articles were excluded. A complete list of inclusion and exclusion criteria is included in Annex 1.

Research on the impact of global environmental change on human health was considered outside the scope of the review. For a review of the evidence on the health impacts of climate change in the WHO European Region, readers are referred to Menne et al. (2008).

The primary search identified 4230 articles of possible relevance. Following review of the titles and/or abstracts of these articles, 117 remained for inclusion in the study. Secondary searches identified a further 55 articles, giving a total of 172 research articles. This report is based on a review of these, plus relevant reports and grey literature. Table 1 provides an overview of the main topic areas covered in the 172 articles.

Table 1. Main topics covered by articles identified in the literature review

Topic area covered	Number of articles ^a
Global warming	74
Hazardous substances	34
Waste production	58
Resource consumption	11

^aThe values in this column do not sum to the overall number of articles reviewed, as some covered multiple topics.

3. FINDINGS

The main findings from the literature review are reported in sections 3.3 to 3.5. These describe the evidence identified regarding:

- the environmental impact of health systems in Europe (section 3.3);
- potential benefits of fostering environmental sustainability in health systems (section 3.4);
- barriers to and incentives for such action (section 3.5).

This description of the evidence base is preceded by two short sections that describe the wider context in which the review findings should be understood. The first discusses the overall scale of the health sector as an industry (section 3.1) and the second explores how the core characteristics of a health system, such as the effectiveness and efficiency of services provided, influence the environmental impact of the system (section 3.2).

3.1. HEALTH SYSTEMS: A SIGNIFICANT SECTOR OF THE ECONOMY

The health sector is an industry accounting for around 8–10% of the gross domestic product of most European countries. In 2012 government spending on health among the countries in the WHO European Region was around 10.2% of gross domestic product in European Union (EU) countries and 6.4% in the rest of the Region. Countries in the Region typically devote between 11% and 15% of general government expenditure to health (WHO Regional Office for Europe, 2015a).

The health care sector consumes large quantities of resources of all kinds, including around 5000 tonnes of antibiotics each year across Europe (Pauwels & Verstraete, 2006). Health care is also a highly labour-intensive activity with a large workforce. In 2010 there were around 17.1 million jobs in the health care sector in EU Member States, accounting for 8% of all jobs in these countries (European Commission, 2012).

On other measures too, the scale of the health sector is clear. In relation to buildings and land use, for example, health systems require extensive networks of facilities which, taken together, occupy significant areas of land. It is estimated that there are around 15 000 hospitals in the EU alone (Chevalier, Levitan & Gareil, 2009); to this must be added a much larger number of primary care and community health facilities. Any industry on this scale inevitably has an impact on the environment.

3.2. DRIVING FORCES DETERMINING THE SCALE OF ENVIRONMENTAL IMPACT

Before considering the specific environmental pressures and impacts related to health system activity (see section 3.3), it is important to recognize that the scale of the environmental impact of any health system will be determined in part by the overall design of the system and the amount and type of activities taking place within it. This section provides a short discussion of some of the high-level factors that shape the environmental footprint of health systems, illustrating how its impact is related to core system characteristics. An implication of this is that if the goal is to minimize environmental impacts, strengthening these overarching aspects of health system performance may achieve as much as or more than specific actions focused explicitly on environmental sustainability.

3.2.1. Population health status

The health status of a population is a fundamental determinant of demand for health care, and therefore also influences the scale of associated environmental impacts. When successful, public health activities and preventive interventions can lead to improvements in population health. If these improvements confer reduced lifetime use of health system resources, it is reasonable to assume that they will also reduce the environmental damage attributable to health systems. In this sense, reduced demand can be taken as a proxy for avoided environmental damage – provided, of course, that reduced resource use in one part of the system is not accompanied by increased demand for other forms of care, or for care at a later stage in life.

Whether it is indeed possible to reduce lifetime resource use in this way is a subject of considerable debate and controversy, and resolving this is beyond the scope of this report. It is worth noting, however, that there is evidence that a range of preventive approaches can successfully reduce subsequent demand and deliver a financial return on investment (Knapp, McDaid & Parsonage, 2011; Merkur, Sassi & McDaid, 2013; WHO Regional Office for Europe, 2014). This suggests that investment in public health activities could have a positive effect on the environment in two distinct ways – first by reducing environmental impacts directly (see section 3.3.5) and second by reducing demand for health care.

The demographic context makes managing demand for health care particularly challenging. All other factors being equal, levels of health need in the population are expected to rise markedly as Europe's population ages, with demand for health care also increasing. The number of Europeans aged 65 years and over is projected to increase by 76% over a 50-year period (European Commission, 2012). In the absence of other changes, this is also expected to increase the environmental impacts associated with delivering an increasing volume of health care.

3.2.2. Effectiveness and efficiency of health services

By a similar logic, the environmental impact of a health system is influenced by the effectiveness and efficiency both of the system as a whole and of the specific interventions provided within it. In an inefficient health system, resources (financial and natural) are wasted through:

- provision of treatments that are of limited clinical value;
- unnecessary admissions to hospital for conditions that could be dealt with effectively in primary or ambulatory care;
- poor communication and coordination between different parts of the system, leading to duplication of effort and poor quality of care;
- pharmaceutical products not being taken as intended, being prescribed inappropriately or being wasted as a result of inadequate stock management.

These sources of inefficiency exist to some extent in all health systems. For example, an ongoing multicountry study on ambulatory care sensitive conditions conducted for the WHO European Region shows that opportunities exist to avoid hospital admissions by strengthening primary health care in a wide range of countries (WHO Regional Office for Europe, 2015b; 2015c; 2015d; 2015e; 2015f).

The significance of these issues in relation to environmental sustainability is that each of these sources of inefficiency leads to environmental impacts for the sake of little or no added benefit to the patient. Conversely, health systems that minimize inefficiencies and generate maximum value for patients for a given level of investment are likely to have smaller per capita environmental impacts.

3.2.3. Patient knowledge and participation

Further, the environmental impact of a health system may also be shaped by levels of patient knowledge and participation. The hypothesis here is that informed, empowered patients use fewer health system resources because they are able to manage their health more effectively; communicate their needs and preferences to health professionals; and support the health of others in their community. Again, proving or disproving this hypothesis is beyond the scope of this report, and more research is needed in this area. Evidence is available, however, in specific areas. For example, several studies have found that support for self-management can reduce unplanned hospital admissions among people with long-term conditions, helping to reduce avoidable health system activity (De Silva, 2011). Similarly, shared decision-making tools can be used to identify the outcomes that individuals value most highly, and in doing so can help patients make informed choices (such as about medication) and avoid inefficiencies created by poor decisions (Elwyn et al., 2012).

3.3. THE ENVIRONMENTAL PRESSURES AND IMPACT OF HEALTH SYSTEMS

This section provides evidence about the environmental impacts and pressures of health systems – positive and negative. Its structure uses categories similar to the impact categories commonly used in “lifecycle assessments” (for example, see Stranddorf, Hoffmann & Schmidt (2005)), giving particular emphasis to those areas where health sector-specific evidence was found. The focus is on health systems in the WHO European Region, but evidence from elsewhere is also included where appropriate.

3.3.1. Global warming

Health systems contribute to global climate change through the generation of carbon dioxide (CO₂) and other greenhouse gases. The data available to estimate what proportion of the European Region’s overall carbon footprint is attributable to health system activities are limited, although in England the National Health Service (NHS) is estimated to be responsible for around 4% of total emissions (NHS Sustainable Development Unit, 2010a).

Health systems generate greenhouse gases through a wide range of activities. These include:

- direct energy use in health care facilities, in the form of electricity or local combustion of fossil fuels;
- patient/staff travel, by public or private transport;
- procurement of goods and services whose production generates emissions, including pharmaceuticals, medical devices and food.

A number of studies conducted in the United Kingdom have attempted to measure the relative impact of these three sources of greenhouse gas emissions. Although the exact figures vary, a common finding is that emissions related to procured goods are particularly high (see Table 2). The most significant contribution is made by pharmaceuticals, the manufacture of which is often a highly energy-intensive process with a large carbon footprint (NHS Sustainable Development Unit, 2010a).

Table 2. Relative impact of direct energy use, travel and procurement

Service	Proportion of carbon footprint (%)			Country	Source
	Direct energy use	Transport	Procurement		
Entire health system	19	16	65	England	NHS Sustainable Development Unit (2010a)
General acute hospital	30	23	47	England	Brockway (2009)
Cataract services	36	10	54	England	Morris et al. (2013)
Renal services	13	15	72	England	Connor, Lillywhite & Cooke (2010)
Dental services	18	45	36	Scotland	Duane et al. (2012) travel, waste and water)

To date, the NHS in England is the only European health system for which a systematic carbon footprinting exercise has been published. Its overall carbon footprint in 2012 was 24.7 million tonnes of CO₂ equivalent (CO₂e) (NHS Sustainable Development Unit, 2013). To put this figure in context, this is comparable to the entire carbon footprint of Croatia and exceeds the annual emissions from all passenger flights departing Europe's busiest airport, London Heathrow. Of all transport emissions in the United Kingdom, 5% are believed to be accounted for by health care-related journeys (Bond et al., 2009).

Several studies have attempted to measure the carbon footprint of specific aspects of health system activity, including some attempts to develop indicative carbon emissions for units of activity that can be used to estimate the carbon footprint of particular services or patient pathways. Table 3 lists the results identified in the literature, including some non-European studies where relevant. The lower half of the table gives some example carbon footprints from outside the health system, for comparison.

It should be noted that CO₂ is not the only gas that contributes to climate change. Several inhaled anaesthetics are also potent greenhouse gases, including sevoflurane, isoflurane and in particular desflurane (Ryan & Nielsen, 2010; Sherman et al., 2012). The contribution of these gases to the overall carbon footprint of health systems appears to be relatively small, however.

Table 3. Carbon emissions from health system activities and non-health comparators

Health system activity	CO ₂ e emissions	Country	Source
General acute hospital services per staff member per year	21.5 tonnes	United Kingdom	Brockway (2010)
Average inpatient admission	380 kg	United Kingdom	Tennison (2010)
Inpatient admission per day	80 kg	United Kingdom	Tennison (2010)
Outpatient appointment	50 kg	United Kingdom	Tennison (2010)
Renal admission per bed day	161 kg	United Kingdom	Connor, Lillywhite & Cooke (2010)
Renal outpatient appointment	22 kg	United Kingdom	Connor, Lillywhite & Cooke (2010)
Standard renal treatment per patient per year	7.1 tonnes	United Kingdom	Connor, Lillywhite & Cooke (2010)
Satellite haemodialysis unit per patient per year	10.2 tonnes	Australia	Lim, Perkins & Agar (2013)
Inpatient care in critical care unit per bed day (excluding travel and procurement)	9 kg	United Kingdom	Pollard et al. (2014)
Cataract operation	182 kg	United Kingdom	Morris et al. (2013)
Laparoscopic surgical procedure	29.2 kg	United States	Woods et al. (2015)
Laparoscopic surgical procedure (robotically assisted)	40.3 kg	United States	Woods et al. (2015)
NHS-related travel per patient per year (rural Scotland)	93.2 kg	United Kingdom	Wootton, Tait & Croft (2010)
Patient travel to a general practice surgery per registered patient per year	5.7 kg	United Kingdom	Andrews et al. (2013)
Total annual patient travel to a general practice surgery with 11 000 patients	62.8 tonnes	United Kingdom	Andrews et al. (2013)
Ambulance service per response	36.6 kg	United States	Blanchard & Brown (2011)
Smoking cessation support per lifetime quitter	636–2823 kg ^a	United Kingdom	Smith et al. (2013)
Hospital food per patient per day	5.1 kg	Spain	Vidal et al. (2015)
Clinical research trial per year for one trial	108–181 kg	United Kingdom	Subaiya, Hogg & Roberts (2011)

Return flight from Berlin to Moscow (including radiative forcing)	450 kg	N/A	
Car journey from Paris to Berlin (1055 km)	120 kg	N/A	

Annual carbon footprint per capita (2010)	7.4 tonnes	EU	United States Department of Energy
Annual carbon footprint per capita (2010)	7.6 tonnes	Europe and central Asia (all income levels)	United States Department of Energy
Annual carbon footprint per capita (2010)	5.3 tonnes	Europe and central Asia (developing economies only)	United States Department of Energy
Annual carbon footprint per capita (2010)	21.4 tonnes	Luxembourg	United States Department of Energy
Annual carbon footprint per capita (2010)	15.2 tonnes	Kazakhstan	United States Department of Energy
Annual carbon footprint per capita (2010)	1.2 tonnes	Kyrgyzstan	United States Department of Energy
Annual carbon footprint per capita (2010)	0.4 tonnes	Tajikistan	United States Department of Energy

^a depending on the intervention used.

3.3.2. Chemical hazards

Health systems generate waste (both wastewater and solid health care waste) that can contain hazardous chemicals. On release into the environment these can pose risks to nature and indirectly to human health: terrestrial and aquatic environments are affected. Use of hazardous chemicals in health care settings can also be dangerous for workers and patients. Chemical-containing waste is considered hazardous if it is toxic, corrosive, flammable, reactive, oxidizing or explosive, or any combination of these.

3.3.2.1. Wastewater generation

In aquatic environments, health systems contribute to water pollution in a number of ways – most directly through the discharge of contaminated wastewater. The research reviewed here largely relates to wastewater generated directly in health care facilities, but a number of additional mechanisms can be expected to have an impact through contamination of domestic wastewater by patients as a result of health system activities. As discussed in section 3.3.3, evidence also shows that disposal of health care waste creates risks of pollution of natural water systems.

The health sector produces large volumes of wastewater. For example, the NHS in England is estimated to generate around 34 billion litres of wastewater annually – equivalent to over 650 litres per person in the country each

year (Department of Health, 2013). Hospital wastewater contains a number of pollutants and these can affect the environment in a range of ways (see Table 4). Several studies have found that the overall ecological toxicity of hospital wastewater is several times greater than that of general urban effluents (Boillot et al., 2008; Orias & Perrodin, 2013).

Table 4. Pollutants in hospital wastewater

Pollutant type	Examples
Pharmaceutical products	Antibiotics, lipid regulators, analgesics, beta-blockers, anti-cancer drugs, anti-epileptics
Microbial hazards	Multidrug-resistant bacteria
Heavy metals	Mercury, copper, lead, zinc, arsenic
Cleaning products	Detergents, disinfectants
Other chemical hazards	Absorbable organic halogens, free chlorine

Sources: Pauwels & Verstraete (2006); Boillot et al. (2008); Orias & Perrodin (2013).

Many of these substances are not wholly removed by standard wastewater treatment processes and instead escape into surface waters, where they can disrupt ecological processes and, ultimately, have an influence on drinking-water quality (Pauwels & Verstraete, 2006).

3.3.2.2. Health care waste generation (solid)

The management of solid waste materials is a major environmental challenge; indeed, it is regarded as the most urgent environmental challenge facing some European countries (Marinkovic et al., 2008). Health care waste is a significant part of this problem, in terms of both the volume produced and the complexities involved in its handling. As an illustration of the scale of the issue, in the United States of America the health system generates more waste by weight than any other sector aside from the food industry (Lee & Mears, 2012a).

High-income countries produce more medical waste per capita but also tend to dispose of it more effectively and have a stronger regulatory framework for doing so (Marinkovic et al., 2008). Western European countries typically produce 3–6 kg of waste per bed day, whereas eastern European countries produce 1.4–2 kg per bed per day (Hossain et al., 2011). The trend for increasing use of disposable instruments and pre-packaged materials is one factor behind growing levels of waste generation, particularly in high-income countries.

Most of the waste produced in health care facilities is non-hazardous general waste; this typically accounts for between 75% and 90% (Chartier et al., 2014). Nevertheless, the volumes of hazardous waste are also substantial, including infectious, chemical, pathological, pharmaceutical, sharps, radioactive and other hazardous waste. In hospitals, surgical theatres produce particularly high volumes of waste (Lee & Mears, 2012a; Stall et al., 2013).

Volumes of waste generated per bed day vary widely between institutions, with little observable relationship between volume and hospital size or type (Komilis, Katsafaros & Vassilopoulos, 2011). Table 5 gives some illustrative evidence regarding the weight of waste produced in some health care facilities.

Table 5. Weight of solid waste produced through health system activities

Patient/procedure	Weight of waste produced (kg)	Country	Reference(s)
Inpatient per bed day	1.8–1.9	Serbia	Stankovic, Nikic & Nikolic (2008); Gavranic, Simic & Gavranic (2012)
Inpatient per bed day	2.4	Turkey	Eker et al. (2010)
Inpatient per bed day	8.4	Greece	Tsakona, Anagnostopoulou & Gidaracos (2007)
Haemodialysis patient per year	323	United Kingdom	James (2010)
Haemodialysis bed per year	1626	United Kingdom	James (2010)
Hip replacement surgery per procedure	13.6	United States	Lee & Mears (2012b)
Knee replacement surgery per procedure	15.1	United States	Lee & Mears (2012b)

Increasingly large volumes of medical waste are produced in community settings, including private households, as a result of the trend for delivering more care outside hospital settings. Evidence shows that, in some countries, waste disposal practices have not kept up with this change in the delivery of clinical services, resulting in an increasing risk of medical waste materials being disposed of improperly (Blenkharn, 2008).

The failure to manage health care (and other) waste materials properly has direct consequences for both environmental and human health. There is evidence that the health of populations in a number of low and middle-income countries has been adversely affected by this failure (Harhay et al., 2009). One review concluded that at least half of the world's population is threatened by environmental and public health risks attributable to poor health care waste management (Caniato, Tudor & Vaccari, 2015).

3.3.2.3. Methods of disposal

The environmental impacts of health care waste are various and depend on the method of disposal – all approaches to disposal come with some level of environmental risk. Landfill is typically the cheapest option, but it creates both environmental and health risks when not properly managed (Hossain et al., 2011). Incineration is often regarded as the least environmentally damaging way of disposing of hazardous waste, but this too has its drawbacks. Ash from the incineration of medical waste has been found in a number of European countries to contain high levels of heavy metals such as mercury (Valavanidis et al., 2008; Kougemitrou et al., 2011; Gielar & Helios-Rybicka, 2013), along with variable levels of other pollutants including polycyclic aromatic hydrocarbons (Singh & Prakash, 2007) and absorbable organic halogens (Durmusoglu et al., 2006). In one Portuguese study, mercury levels in hospital incinerator ash were found to be 226 times the legal limit (Alvim-Ferraz & Afonso, 2003). The high concentrations of heavy metals and other pollutants in incinerator ash is a concern: unless stabilized appropriately (for example, in cement) these leach readily into water supplies and affect aquatic ecosystems.

3.3.2.4. Chemicals of concern

A wide range of chemicals is used in health care practice, including disinfectants, cleaning products, pharmaceuticals and many more. Some are hazardous, and improper use can result in health disorders and

environment impact. The main pathways of human exposure to hazardous chemicals are inhalation of contaminated dusts or aerosols, absorption through skin, ingestion of contaminated food and ingestion as a result of bad practice (such as controlling liquid orally via a pipette). Exposure may occur during handling and disposal of waste and chemicals and during preparation of or treatment with drugs or chemicals.

3.3.2.5. Laboratory chemicals and disinfectants

A number of active ingredients/chemicals are commonly used for disinfectant production and in laboratory practice in health care settings. Their toxic effects are well known. For example, glutaraldehyde is a severe skin irritant and can cause dermatitis; formaldehyde is an irritant and possible carcinogen. Other toxic chemicals include xylene, toluene, methanol, ethylene oxide, quaternary ammonium compounds, chloroform, phenols, barium compounds, herbicides, pesticides, hydrochloric acid, concentrated acetic acid, sodium hydroxide, ammonium hydroxide and metals in nanoforms.

Widely used chlorine bleach may result in burns and respiratory effects; it may also react with strong acids, resulting in release of chlorine gas. Safe management of these chemicals is important to protect not only worker and patient health but also the environment.

3.3.2.6. Pharmaceutical compounds

The presence and impact of pharmaceutical compounds has been a particular focus for research, owing to the harmful effects of these compounds on aquatic ecosystems. Some pharmaceutical compounds are only partially metabolized by the body and are therefore released via human excretion into wastewater systems. The main groups of pharmaceuticals discussed in scientific papers dealing with discharges from health care facilities are endocrine-disrupting chemicals (see section 3.3.2.8); antibiotics; and anti-inflammatory, hormonal and antidepressant drugs.

An additional source of contamination is the improper disposal of pharmaceutical products, with patients disposing of unwanted medications via the drain or toilet. Several studies have found that hospital effluents contain relatively high concentrations of a number of pharmaceutical compounds (Verlicchi et al., 2012; Frédéric & Yves, 2014), although domestic wastewaters also contain many of these substances. Conventional water treatment plants are unable to remove all of the pharmaceutical compounds found in wastewater (Al Aukidy, Verlicchi & Voulvoulis, 2014), so some of these chemicals escape into the wider environment.

The evidence shows clearly that a number of compounds can have harmful effects on aquatic ecosystems when present in sufficient concentrations – including a range of effects on aquatic animals (Fabbri, 2015) – and that they can reach groundwater and drinking-water (Mullot et al., 2010). A large number of studies have also been conducted by the MistraPharma programme in Sweden, which aims to generate new evidence about the environmental risks associated with pharmaceutical products (Brandt et al., 2012).

Research from this programme and elsewhere highlights a number of classes of drug that may pose a particular risk. These include antibiotics (such as ciprofloxacin, ofloxacin, erythromycin and sulfamethoxazole), diclofenac (an anti-inflammatory drug) and synthetic estrogen from oral contraceptive pills, which is known to interfere with the reproductive function of fish (Thomas et al., 2007; Escher et al., 2011; Brandt et al., 2012; Al Aukidy, Verlicchi & Voulvoulis, 2014). Although in most cases the concentrations required to cause harm are higher than those typically measured in the environment, the MistraPharma research suggests that there are a number of grounds for continued caution – not least the fact that the ecotoxicity of many drugs remains unknown (Brandt et al., 2012).

The recently adopted resolution by the International Conference on Chemicals Management, regarding environmentally persistent pharmaceutical pollutants in the context of the Strategic Approach to International

Chemicals Management outlined a number of measures that stakeholders should take to prevent pharmaceuticals having a negative impact on natural ecosystems.

3.3.2.7. Genotoxic chemicals and chemotherapeutic waste

Health care waste contaminated with chemotherapy drugs is considered to be highly hazardous because of its potential genotoxic properties. Genotoxic chemicals and chemotherapeutic waste include cytotoxic drugs used in cancer treatment and their metabolites, antineoplastic drugs and alkylating agents, intravenous sets containing chemotherapy drugs and gloves and gauze contaminated with chemotherapy drugs.

The severity of hazard of chemotherapeutic waste depends on substance toxicity and duration of exposure, but generally they are highly mutagenic, teratogenic and/or carcinogenic. They are extremely irritative for humans, with harmful local effects on skin and eyes, and they may cause dizziness, nausea, headache or dermatitis. For example, mitoxantrone, carmustine, cyclophosphamide, dacarbazine, ifosfamide, melphalan, streptozocin, thiotepa and teniposide are classified as irritants. Further, aclarubicin, chlormethine, cisplatin, mitomycin, amsacrine, dactinomycin, daunorubicin, doxorubicin, epirubicin, pirarubicin, vinblastine, vincristine, vindesine, viorelbine and zorubicin are vesicant drugs.

3.3.2.8. Endocrine-disrupting chemicals

A number of substances used in health care settings, including chemicals in medical devices and pharmaceuticals, are believed to affect the hormone systems of humans and other mammals. In sufficient concentrations these endocrine-disrupting chemicals (EDCs) can interfere with the formation and growth of organs, leading to birth defects and developmental disorders, as well as affecting other processes such as sexual maturation (Bergman et al., 2013). They pose potential risks to patients and to the environment, on release through wastewater or with solid health care waste.

Particular concern has been raised about the use of bisphenol A and phthalates in medical settings and elsewhere (Amaral, 2014). These are widely used as additives in plastic products, including medical tubing, catheters and blood bags; they are also present in cleaning fluids and other products.

A number of research studies have concluded that exposure to equipment containing EDCs in neonatal units is associated with higher levels of these chemicals in infants' bodies. For example, urinary concentrations among infants exposed to high levels of products containing EDCs are several times higher than levels in the general population or in infants in neonatal units exposed to fewer of these products (Weuve et al., 2006; Calafat et al., 2009; Duty et al., 2013) we evaluated urinary concentrations of several phenols, including bisphenol A (BPA. There is also evidence of high levels of exposure to EDCs among adults in intensive care units (Huygh et al., 2015).

Debate is ongoing regarding safe levels of exposure to EDCs; the extent to which observed increases in the prevalence of hormone-related diseases can be attributed to the widespread use of these chemical is unclear. The relative contribution made by the use of EDCs in medical versus other settings also remains to be established. A review of the evidence of health risks related to neonatal exposure concluded that while there is evidence of associations with a range of developmental and other disorders, most of this is based on animal or observational studies and further research is needed (Fischer et al., 2013). Nevertheless, several countries in the European Region – including France and Denmark – have adopted a precautionary approach, phasing out the use of specific EDCs in medical equipment, with a particular focus on their use in paediatric, neonatal and maternity wards (Amaral, 2014).

3.3.2.9. Heavy metals

Heavy metals such as mercury form a further category of hazardous chemicals whose presence in the environment can be linked to the activities of health systems. Mercury is used for a variety of purposes in health care settings

(such as in thermometers, sphygmomanometers and dental fillings), and as a result health systems are believed to be one of the main sources of environmental mercury pollution. Estimates suggest that in some countries health systems account for 10% of all mercury air releases and over a third of mercury releases in wastewater (WHO, 2005; Rustagi & Singh, 2010).

The human and environmental impact of heavy metals is well established. Exposure to mercury can have toxic effects on the nervous, digestive and immune systems (WHO, 2016). Even if present in small amounts in the environment, it can biomagnificate in the food-chain through the process of “bioaccumulation” in fish and plants (Vinodhini & Narayanan, 2008).

The use of mercury in health care settings has come under particular criticism, given that alternatives are available for most uses (Health Care Without Harm, 2011). The United Nations Minamata Convention on Mercury, agreed in 2013, commits signatories to reducing mercury pollution through control measures on air emissions and a ban on new mercury mines (UNEP, 2013). At the time of writing 128 countries have signed the convention, including the majority of countries in the WHO European Region.

3.3.2.10. Hazardous chemicals in building materials

A number of substances commonly formerly used in building construction are known to be hazardous to human health and can pose risks when released into the environment. Prominent examples include asbestos, lead and polychlorinated biphenyl (PCB). Although these have largely been phased out and encapsulation has been used to prevent exposure and release to the environment, they continue to pose a risk – for example, when buildings are renovated or decommissioned.

Asbestos was widely used in the construction of hospitals and other health facilities, particularly in the 1960s and 1970s. Health care professionals working in these buildings are at risk of developing chronic lung disease (asbestosis) and cancer (mesothelioma) if steps are not taken to remove or encapsulate materials containing asbestos. As there can be a considerable lag time between exposure and development of disease, some health professionals are developing these conditions now as a consequence of exposure several decades ago, prior to protective action being taken. If not contained, asbestos dust can contaminate air and watercourses, and can be spread through the environment causing health problems for humans and other animals at considerable distances from the original source.

3.3.3. Resource consumption

As outlined in section 3.1, the scale and diversity of health system activities makes it inevitable that large volumes of resources are used by the sector. This applies to a wide range of resources including food, energy and materials of all kinds – many of which are in finite supply.

The resource that has been the subject of most research in this area is water. Water scarcity is a significant environmental problem in several parts of the world. In the WHO European Region water supplies are projected to come under increasing pressure in parts of the Mediterranean and in central Asian countries. Access to reliable supplies of clean water in health care facilities is essential to meet acceptable standards of sanitation and hygiene, and as yet this cannot be guaranteed in all countries (WHO, 2015a).

Health systems make a relatively minor but nonetheless important contribution to water consumption. For example, the NHS in England consumes 39 billion litres of water per year – equivalent to an Olympic-size swimming pool every 34 minutes, or around 1.3% of the country’s total water use (Department of Health, 2013). This does not include indirect or “embedded” water consumption – for example, relating to electricity generation (water consumption for

cooling of power plants) or production of materials used in health care. This embedded water consumption is likely to be significant. For example, in one analysis of the environmental impacts of disposable materials used in hospitals, the largest impact was attributable to cotton products, with cotton being a highly water-intensive crop to grow (Campion et al., 2015).

Some health care treatments have particularly high water requirements. For example, a typical haemodialysis session uses around 500 litres of water, most of which could potentially be (but typically is not) reused for other purposes (Agar, 2010). Water consumption also adds to the carbon footprint of health systems, since the purification and transportation of water requires energy and generates associated greenhouse gas emissions. Emissions attributable to water consumption accounted for between 4% and 12% of the carbon footprint of haemodialysis services in an Australian study (Lim, Perkins & Agar, 2013).

Health systems are also major consumers of food for patients and staff. For example, hospitals in the United Kingdom serve approximately 300 million patient meals each year – around 250 000 meals per hospital (Towers et al., 2002). Environmental impacts linked to food production and consumption are large and multiple; it is thus outside the scope of this report to review them in full. Overall, food consumption is estimated to be responsible for between 20% and 30% of all the environmental impacts caused by humans in developed economies (Reynolds et al., 2014). To illustrate one of the many issues involved – that of “food miles” – one study found that collectively the ingredients used in a single hospital meal had been transported over 30 000 km, with associated emissions of CO₂ and other pollutants (Jochelson et al., 2005).

3.3.4. Other negative impacts

Given the scale and breadth of health system activities, and the extensive supply chains on which they rely, it is inevitable that the health sector also contributes to other forms of environmental degradation, including the following.

- Acidification of soils and freshwater through emissions of nitrogen oxides and sulfur oxides; this is largely a result of burning fossil fuels (for example, in the process of electricity generation or from motorized vehicles). Soil acidification can make it difficult for some plants to grow successfully, and acidification of freshwater can be harmful for fish, shellfish and other animals, leading to reduced biodiversity.
- Creation of photochemical oxidants – for example, in the form of smog and harmful levels of ozone in the troposphere (the lowest atmospheric level); this is caused by reactions between nitrogen oxides and volatile organic compounds, with combustion of fossil fuels again the major source. Photochemical oxidants can be harmful for both plant and animal life.
- Ozone depletion in the higher atmosphere, leading to increasing risk of exposure to harmful ultraviolet radiation from the sun; this has been attributed to the release of halocarbons such as chlorofluorocarbons (CFCs). Halocarbons are used within the health sector as cleaning solvents and refrigerants and in plastic products.
- Eutrophication, where freshwaters become enriched with high levels of nitrogen- and phosphorus-based nutrients, leading to excessive growth of algae and plankton and the decline of other species (including aquatic animals); this is a result of overcrowding and depletion of oxygen in the water. Substances known to cause eutrophication are found in wastewaters from a wide range of sources, including health care facilities – for example, in the form of phosphorus-based detergents.
- Changes to land use: health systems use significant areas of land both directly (through the construction of health care facilities) and indirectly (as a result of supply chain operations). Any form of construction can involve alteration of natural habitats, and if not done sensitively this can threaten ecological niches and potentially lead to reduced biodiversity.

The relative importance of health systems as contributors to these global environmental challenges is unclear, but given that they typically account for 8–10% of gross domestic product in the European Region, it can be assumed that the contribution made by the sector is far from negligible. Taking vehicle emissions as an example, it is estimated that 5% of road traffic in the United Kingdom is attributable to health care (NHS Sustainable Development Unit, 2010a). From this it can be concluded that the health sector makes a modest but nonetheless important contribution to emissions of nitrogen oxides and sulfur oxides, implicated in acidification, creation of photochemical oxidants and other forms of environmental damage.

3.3.5. Positive environmental impacts

The sections above describe how health systems can have an adverse impact on the environment. Nevertheless, it should not be assumed that the effects of health systems on the environment are entirely negative. There are clear examples of health system activities that have an important positive effect on the environment. This particularly relates to health protection and health promotion activities.

3.3.5.1. Health protection

A critical purpose of health systems is to protect the population from exposure to health risks. Importantly, this includes minimizing exposure to environmental factors that can be damaging both to human health and to natural ecosystems. Key activities in the field of environmental health protection include the introduction and enforcement of regulatory requirements concerning indoor and outdoor air pollution, purity of drinking-water, treatment of wastewater, protection of freshwater and coastal waters and soil contamination.

While the core function of environmental health protection is to protect human health, health system activities in this area have also achieved some significant environmental benefits. For example, in order to reduce the burden of respiratory and other diseases, WHO has developed air quality guidelines that give maximum advised levels of atmospheric particulate matter, ozone, nitrogen dioxide and sulfur dioxide (WHO, 2006). Increasingly widespread application of these kinds of guidelines and standards since the 1980s has led to significant reductions in emissions. For example, most European countries reduced sulfur emissions by more than 60% between 1990 and 2004 (Vestreng et al., 2007). This has in turn delivered environmental benefits by helping to mitigate acid rain and acidification of soil and freshwater reserves, an area where measurable improvements have been seen in most regions of Europe since 1990 (Skjelkvåle et al., 2005). Nevertheless, enforcement of regulatory frameworks relating to environmental health protection remains a problem in many countries.

Similarly, occupational health protection may also confer environmental benefits. In particular, regulations controlling exposure to hazardous chemicals in the workplace often also have the effect of reducing the release of these chemicals into the environment. No specific evidence was found quantifying the scale of these benefits.

3.3.5.2. Health promotion

Promotion of healthy lifestyles and behaviours is another core role of health systems that can be expected to deliver positive environmental benefits. A prima facie connection exists between some of the lifestyles and behaviours encouraged on health grounds and actions that can be taken to minimize an individual's environmental footprint. Perhaps most obviously, evidence shows that promoting active transport (such as cycling and walking) and low-meat diets could help to reduce the burden of cardiovascular and other noncommunicable diseases, while also helping to mitigate global climate change. For example, modelling suggests that switching from motorized to active and from high- to low-carbon forms of transport would have beneficial effects on the environment while also potentially leading to a significant reduction in the burden of cardiovascular and other diseases (Haines et al., 2009). The reduced disease burden would result from the combined effects of increased levels of physical activity and reduced air pollution, and also potentially from decreased injury risk.

There is also reason to believe that the natural environment itself has a public health value. A systematic review found some evidence to suggest that participating in physical activity in outdoor natural environments has a greater beneficial effects on self-reported measures of mental well-being than does indoor physical activity – although it concluded that further research is needed to confirm this hypothesis conclusively (Thompson Coon et al., 2011). Some evidence shows that programmes aiming to expand and improve urban green spaces may deliver health and environmental benefits. A literature review found that most studies report a beneficial effect on health, although often the effect sizes are small and the causal relationships involved are complex (Lee & Maheswaran, 2011). The potential environmental benefits are clearer, with plant life acting as a sink for atmospheric CO₂ and also capturing airborne particulate matter.

In the case of diet, a number of researchers have explored the question of whether diets can be both healthier and more environmentally sustainable at the same time (Macdiarmid et al., 2012; Macdiarmid, 2014). A review of the literature found that while it is not necessarily the case that all healthy diets have a smaller environmental footprint, most studies support the conclusion that reduced consumption of meat and dairy products, and increased consumption of fruit and vegetables, would have a positive impact on both the environment and health (Reynolds et al., 2014). For example, meat-based meals were found to generate on average nine times higher greenhouse gas emissions than plant-based meals, per meal (Carlsson-Kanyama, 1998).

To the extent that health systems succeed in modifying these kinds of behaviour through health promotion activities, they are likely to have a positive impact on the environment. As these activities involve shaping the behaviours of entire populations, the scale of the potential health and environmental benefits could be significant – modelling suggested that in the United Kingdom more active transport and lower consumption of animal products could reduce the burden of disease by 7400 and 2900 disability-adjusted life-years per million population, respectively (Haines et al., 2009). Given the relatively modest investment in health promotion in most countries, however, it is reasonable to assume that any beneficial environmental effects are not currently sufficient to outweigh the negative environmental impacts described in the foregoing sections.

3.4. BENEFITS OF FOSTERING ENVIRONMENTAL SUSTAINABILITY IN HEALTH SYSTEMS

The notion of fostering environmental sustainability in health systems incorporates three related objectives:

- reducing the negative environmental impacts of health system activity;
- strengthening those areas where health systems have a positive impact on the environment;
- improving the resilience of health systems to environmental change.

The following sections examine the evidence regarding the potential benefits of actions within each of the four health system functions (resource generation, service delivery, stewardship and financing) outlined in WHO's *World health report 2000* (WHO, 2000). They include environmental, financial, health, access/quality and workforce benefits and improved climate resilience.

- Environmental benefits: section 3.3 presented compelling evidence that health systems have considerable negative effects on the environment, as well as some positive effects through health protection and health promotion activities. Given this, it is clear that opportunities exist to reduce negative environmental impacts and strengthen the positives. The precise extent of these opportunities is difficult to quantify on the basis of the evidence reviewed.

- Financial benefits: evidence shows that opportunities exist in some areas to save money through more efficient use of energy and other resources. There is also some evidence from other sectors that sustainability can confer reputational gains among potential customers. Benefits in the form of access to new sources of funding – such as environmental subsidies – may also be available but no research was found relating to this.
- Health benefits: evidence shows that in some countries improved management of waste materials and reduced emissions from health care facilities would lead to significant health benefits for local communities. There is also evidence that behaviour change measures (such as active transport and low-carbon diets) and interventions aimed at improving environmental quality (such as urban greening and curbing air pollution) improve public health (see section 3.3.5).
- Access/quality benefits: a number of research studies indicate that access to health services and quality of care could both be improved – for example, by using eHealth technologies to reduce the need for patient travel, or through changes to lighting use in inpatient wards.
- Workforce benefits: some evidence from other sectors suggests that fostering environmental sustainability can be associated with improved staff morale, increased levels of organizational commitment and improvements in recruitment and retention.
- Improved climate resilience: the WHO definition of a climate-resilient health system is one that is “capable to anticipate, respond to, cope with, recover from and adapt to climate-related shocks and stress, so as to bring sustained improvements in population health, despite an unstable climate” (WHO, 2015b). Relevant beneficial effects highlighted below include reduced population vulnerability to the health impacts of climate change, preparedness for extreme weather events and future-proofing the supply chains on which health systems depend. While improved resilience offers clear potential benefits, no research was identified assessing the scale of these.

Table 6 lists some of the areas where opportunities to seize these benefits may exist. The list is not intended to be exhaustive but is based on the main areas identified in the research literature. The following sections provide a summary of the evidence regarding the potential benefits in each of these areas. It is worth stressing that even in the areas that appear to have been researched most extensively, only a small number of empirical research studies have typically been conducted. The conclusions drawn about the benefits of fostering environmental sustainability in health systems are therefore tentative at best. Despite this caveat, the evidence that does exist points to some significant potential benefits.

Table 6. Areas where potential benefits may exist in each of the health system functions

Service delivery	Resource generation	Stewardship	Financing
Digital health/eHealth Using alternative medical devices Assessing treatment options Service reconfiguration Waste management strategies Health protection and promotion activities (see section 3.3.5)	Facilities design and operation Workforce education Pharmaceutical manufacturing Staff engagement and commitment	Intersectoral advocacy	Procurement processes Access to alternative sources of income Reputational benefits Responsible investment

3.4.1. Service delivery

Health systems have the most direct effect on the environment through the delivery of services, and most of the research conducted relates to this health system function. Both clinical and non-clinical aspects of service delivery

present opportunities to foster environmental sustainability. This section reviews evidence on the delivery of clinical care (such as the use of eHealth technologies) and considers non-clinical aspects such as waste management.

3.4.1.1. Reducing travel through telehealth and telemedicine

Telehealth, telemedicine and other forms of eHealth are one of the more widely studied interventions that have been assessed for environmental and other benefits, largely as a result of the potential they offer to reduce substantially the need for patient and staff travel. Research on the possible carbon and cost savings has been conducted in Canada, Sweden, the United Kingdom and the United States (see Table 7).

Table 7. Selected research evidence on the carbon and cost impact of telehealth and telemedicine

Intervention	Country	Carbon saving	Cost saving	Source
Teleconsultation for assessment of minor injury and suspected cancer	Scotland	59 tonnes/year		Wootton, Tait & Croft (2010)
Teleconsultation for rehabilitation care	Sweden	40–70-fold decrease in emissions		Holmner et al. (2014)
Videoconferencing for multidisciplinary team meetings	Wales	31.1 tonnes/year		Lewis, Tranter & Axford (2009)
Teleconsultation for outpatient appointments	Canada	370 tonnes/year	€262 000/year	Masino et al. (2010)
Teleconsultation for outpatient appointments	United States	340 tonnes/year		Yellowlees et al. (2010)
Teleconferencing to replace 5% of all business miles in the NHS (modelled)	England	6827 tonnes/year	€18.8 million/year	NHS Sustainable Development Unit (2010b)

While Table 7 focuses on those studies that report carbon savings, a much wider evidence base is available for the potential cost savings from telehealth and telemedicine. The largest randomized controlled trial conducted to date – the United Kingdom’s “whole system demonstrator” programme – found that telehealth interventions were associated with reduced emergency admissions and mortality (Steventon et al., 2012). The magnitude of any financial benefits stemming from these technologies remains unclear, however.

3.4.1.2. Using alternative medical devices

In addition to the eHealth interventions described above, a number of other medical devices have been evaluated in terms of their environmental and other benefits. Technologies for haemodialysis have been one target for research, in part because of the significant environmental impacts associated with this treatment. Home-based dialysis equipment offers the prospect of reducing carbon emissions associated with travel, but it is not yet clear what the net environmental impact of these technologies might be: using currently available technologies, patients remaining

at home often needs to dialyse more frequently and for longer than in-centre patients (Connor, Lillywhite & Cooke, 2011). Research on technologies supporting water conservation in renal dialysis indicates that new equipment designs could help reduce water consumption, carbon emissions and costs (Agar et al., 2009; Agar, 2010). In one Australian renal service 100 000 litres of water that were previously discarded each week are now captured for reuse (Agar, 2010).

Research on medical devices used in surgical procedures shows that automated control of anaesthetic gases reduced the costs of anaesthesia by 27% and greenhouse gas emissions by 44% (Tay et al., 2013). It is also possible, of course, for new technologies to lead to increased environmental impacts. For example, one study found that robotically assisted laparoscopic surgery generated 38% more greenhouse gas emissions than conventional laparoscopy (Woods et al., 2015).

3.4.1.3. Assessing treatment options

Clinicians often have to choose between multiple possible treatment options and are increasingly encouraged to consider their relative cost–effectiveness. From a global perspective, the costs included in such cost–effectiveness assessments do not typically include the full set of relevant costs, because those related to environmental damage and depletion of natural resources are externalized.

A small number of research studies have compared the “full” (including environmental) costs and benefits of different treatment options. These provide illustrative examples, including those listed below, of how clinical decision–making could be influenced if environmental costs and benefits were to be included in the evaluation of different treatment options.

- Smoking cessation: text message, telephone and group counselling remained cost–effective interventions when the analysis was revised to include the environmental and economic cost of damage from carbon emissions, whereas individual face–to–face counselling did not (Smith et al., 2013).
- Social prescribing for mental health was found to be highly cost–effective and had a smaller carbon footprint than cognitive behavioural therapy or antidepressant medication (Maughan et al., 2015).
- Reflux control: surgical treatment has lower financial and carbon costs than medical treatment in the medium to long term (Gatenby, 2011).
- Inhaled anaesthetics: desflurane is several times more potent as a greenhouse gas than sevoflurane or isoflurane (Ryan & Nielsen, 2010; Sherman et al., 2012).
- Prescribing: some pharmaceuticals are metabolized much more effectively by the body and are therefore less likely to be excreted into the environment, so there is scope for clinicians to prescribe drugs preferentially that are more extensively metabolized (Daughton, 2014).

3.4.1.4. Service reconfiguration

The overall pattern or configuration of services across a geographical area has an important effect on financial and environmental costs, as well as on quality of care. By including environmental considerations in decisions about service reconfiguration, it may be possible to optimize all three of these outcomes. For example, one study reported development of a modelling tool to support service reconfiguration decisions that allows options to be identified that maximize clinic utilization rates while minimizing financial and carbon costs (Duane et al., 2014).

The limited available research conducted on this shows that in some examples clinical, financial and environmental interests are aligned. For example, using mobile breast screening clinics instead of centralized services was found to reduce greenhouse gas emissions by around 75 tonnes per year, while also improving the patient experience (Bond et al., 2009). Equally, in some situations tensions may arise between the most clinically, financially and environmentally beneficial configuration of services. For example, one study estimated that concentrating services

for myocardial infarction in a smaller number of tertiary care centres (on clinical and cost grounds) had tripled travel-related carbon emissions (Zander et al., 2011). Nevertheless, this needs to be set against the potential environmental benefits of removing overcapacity in the system and matching supply more closely to demand.

3.4.1.5. Waste management strategies

A large research literature examines the effectiveness of various ways of reducing the environmental impact of health care waste. This reflects the fact that environmental considerations are already often (although not always) embedded in this area of health system activity. Extensive technical guidance is available to support safe and sustainable management of health care waste (including both solid waste and wastewater) – for example, in the WHO handbook *Safe management of wastes from health-care activities* (Chartier et al., 2014).

The environmental benefits of improved waste management are clear. In many countries, improved waste management can also be assumed to confer direct public health benefits, given the evidence reviewed in section 3.3.2 indicating that inadequate management of health care waste creates significant health risks. Importantly, evidence shows that health care waste can be managed effectively and affordably even in low- and middle-income settings. For example, an evaluation of a new national health care waste management system introduced in Kyrgyzstan found that as well as improving the management of waste materials, hospitals achieved on average 33% annual cost savings relative to previous systems (Toktobaev et al., 2015).

Table 8 summarizes the evidence on the environmental benefits of specific waste management interventions commonly described in the literature identified. The greatest benefits are likely to come through tackling waste “at source”: by preventing or reducing its creation and by reusing (where safe to do so) and recycling, rather than by focusing exclusively on developing more sustainable approaches to disposal (although these are also needed) (Chartier et al., 2014). Sustainable procurement (see section 3.4.4.1) can play an important role in reducing volumes of waste by using a “lifecycle” approach that takes account of final disposal and the costs associated with this when making procurement decisions.

Table 8. Effects of commonly researched waste management interventions

Intervention	Findings from research	Sources
Switching to reusable medical products	Switching can significantly reduce lifetime environmental costs, as well as the financial costs of waste disposal. For example, one study showed that lifetime greenhouse gas emissions attributable to reusable sharps were 36% those of disposable alternatives, although the precise figure depends on the source of electricity used in the hospital for reprocessing.	Conrardy et al. (2010); Eckelman et al. (2012); Grimmond & Reiner (2012); McGain et al. (2012)
Recycling general waste	Most non-hazardous waste from operating rooms and elsewhere could be safely recycled.	(McGain, Hendel & Story, 2009)
Enhanced treatment of hospital wastewater	Additional treatment – such as using membrane bioreactor technology, nanofiltration, reverse osmosis and/or advanced oxidation processes can be an efficient way of removing pollutants from hospital wastewater.	Beier et al. (2010; 2012); Verlicchi, Al Aukidy & Zambello (2015)

3.4.2. Resource generation

Some evidence illustrates the benefits that could result from incorporating environmental sustainability within the resource generation function of health systems, particularly in relation to facilities design, workforce education and manufacturing of pharmaceuticals.

3.4.2.1. Facilities design and operation

A large evidence base exists on sustainable building and plant design, including extensive volumes devoted specifically to health care buildings such as the *Green guide for health care* (Health Care Without Harm & Center for Maximum Potential Building Systems, 2002). A systematic review of this evidence is beyond the scope of this report.

A modelling exercise conducted for the NHS Sustainable Development Unit in England identified actions with the greatest environmental and financial effects, including a number of measures related to the design and operation of facilities:

- installing combined heat and power generation in hospitals;
- improving heating and lighting controls, and switching to energy-efficient lighting;
- reducing thermostat temperature settings by 1° C in winter.

The combined impact of the 29 actions included in the modelling exercise (most but not all of which related to the design of buildings and associated engineering technologies) would be a predicted carbon saving of 823 000 tonnes of CO₂ per year, accompanied by a cost saving of over €214 million per year (NHS Sustainable Development Unit, 2010b).

Similarly, an analysis of five hospitals in the United States estimated that if implemented nationwide, a package of interventions designed to improve the environmental impact of hospitals (including measures on waste and energy use) could generate financial savings exceeding US\$5.4 billion over five years and US\$15 billion over 10 years (Kaplan et al., 2012).

The environmental footprints of different health care facilities vary widely. This gives some indication of the benefits that might be achievable through adoption of best practice. In one comparative study, selected Scandinavian hospitals used 40% less energy per square foot per year than matched hospitals in the United States, despite comparable climate conditions (Burpee & McDade, 2014). This was attributed to a number of architectural, mechanical and energy production strategies, which collectively improve the efficiency of heating and cooling.

3.4.2.2. Workforce education

As in any workplace, the environmental impact of a health system is shaped by the behaviours of those working within it. While the impact of clinical behaviours is discussed above, non-clinical behaviours (such as turning off electrical equipment when not in use) are also important. Changing these behaviours through workforce education provides an opportunity to achieve environmental and cost savings.

Radiology departments have been a particular focus for research of this kind, given the high energy requirements of the equipment involved. One piece of research estimated that a radiology department in a hospital in the United States could save almost US\$10 000 annually by turning off workstations and monitors when not in use overnight (Prasanna, Siegel & Kuncze, 2011). Similar cost savings were calculated for a radiology department in Ireland, in addition to carbon savings equivalent to the annual emissions from 10 passenger cars (McCarthy et al., 2014). In another radiology department, computerized tomography (CT) scanners were found to consume many times more electricity while idle than while in active use (Esmaeili et al., 2015).

A behaviour change project operating in six hospitals in London, United Kingdom, evaluated the impact of a workforce education programme that encouraged staff to turn off equipment when not in use, switch off lights where possible and close doors and windows. Over two years, the programme was estimated to have reduced CO₂ emissions by 1900 tonnes and reduced energy costs by around US\$650 000. The evaluation also reported benefits for patients – for example, in terms of fewer sleep disruptions – and to staff, in the form of improved team spirit and collaboration (Global Action Plan, 2015).

3.4.2.3. Pharmaceutical manufacturing

The production of pharmaceutical products is a highly energy-intensive process, involving a number of ecologically toxic chemicals. A carbon footprinting exercise in the United Kingdom found that pharmaceuticals accounted for 21% of the carbon footprint of the NHS in England (NHS Sustainable Development Unit, 2013). This suggests that there may be considerable scope to reduce environmental impacts through adoption of more energy-efficient, sustainable manufacturing processes in the pharmaceutical industry. Further research is needed to assess the scale of these potential benefits and the financial costs involved.

3.4.3.4. Staff engagement and commitment

Evidence from other sectors shows that fostering environmental sustainability through an organizational commitment to corporate social responsibility is associated with improved levels of employee commitment and engagement (Brammer, Millington & Rayton, 2007; Ali et al., 2010; Kim et al., 2010). There is also some evidence that this can help with recruitment and retention: talented employees being attracted to organizations with a strong ethos around sustainable business practices (Bhattacharya, Sen & Korschun, 2008; Bode, Singh & Rogan, 2015). This research has largely been conducted within the context of profit-making firms operating in various industries; little evidence yet exists on whether this association also exists within the health sector. Surveys in some countries, however, indicate high levels of support for fostering environmental sustainability among health care professionals (NHS Sustainable Development Unit, 2010a).

3.4.3. Stewardship and governance

Global challenges such as the epidemic of noncommunicable diseases and climate change have led policy-makers in both the health and environmental sectors to the realization that, in order to achieve their objectives, they need to influence policy and decision-making beyond their own sectors. As a result, both health and environmental policy-makers are advocating “horizontal” or “whole-of-government/whole-of-society” approaches to governance, whereby they work to further their respective policy agendas across a number of sectors, including construction and urban planning, transportation, agriculture, finance, education and social affairs. As such, there may be considerable benefit in forging alliances between health and environmental policy-makers, in view of pursuing their respective objectives through common governance mechanisms. For example, research confirms that a number of aspects of urban planning – including land use patterns and transport networks – influence levels of active and motorized transport in the local population, and thus have an impact on both the environment and health (Frank et al., 2010).

While the mechanisms that enable stewardship and governance have been documented (see, for example, McQueen et al., 2012), as yet only a few examples have documented instances where health and environmental policy-makers use these mechanisms together or form an alliance to advocate their establishment. As such, it is too early to draw conclusions about the extent to which governance partnerships between the health and environmental sectors can be effective.

Inclusion of environmental concerns in intersectoral advocacy could also include consideration of improving community resilience to climate change. Climate change is predicted to have a number of public health impacts across the European Region (Menne et al., 2008), and the resilience of health systems to these changes will depend

in part on the ability to reduce population vulnerability to the associated health impacts. A review of the literature in this area concluded that there is scope to support simultaneous improvements in public health and community resilience by promoting social capital and local economic development and building other community-level assets – all of which requires partnership working between the health system and other sectors (Bajayo, 2012). The size of these potential benefits has yet to be quantified.

Intersectoral partnership is also needed to increase the preparedness of health systems and other public services for extreme weather events such as heatwaves, drought, storms and flooding. Again, no empirical evidence regarding the effectiveness or benefits of this kind of partnership working was identified.

3.4.4. Financing

3.4.4.1. Procurement processes

Procurement processes could be used to secure improvements in both the environmental impact and the resilience of health system supply chains (in relation to resilience, this includes the important concept of energy security). Sustainable procurement is increasingly used by public sector organizations in a wide range of countries (Brammer & Walker, 2011): where effective, it can improve the environmental impact of supply chains.

The adoption of sustainable procurement practices in the hospital sector in France was perceived to have succeeded in having a positive impact on supplier management (Oruezabala & Rico, 2012). In the Netherlands a qualitative study found that sustainability considerations were seen as relevant by decision-makers involved in procuring medical equipment, but that in practice they came second to cost (Lindgreen et al., 2009). Research on sustainable procurement practices in health and social care in Northern Ireland found that, although sustainability criteria were increasingly embedded in procurement processes, limited official guidance was available and widespread skills gaps were evident in terms of the competencies of procurement teams – for example, in whole-life costing (Erridge & Hennigan, 2012). Another piece of research reported on the development in Sweden of a decision-making tool designed to support reductions in the carbon footprint of material goods consumed by the health system. This concluded that considerable environmental benefits could be achieved by using green purchasing and preventing inefficient consumption patterns (Karlsson & Pigretti Öhman, 2005).

A key challenge for implementing sustainable procurement practices is measurement. Procurement teams need criteria and monitoring tools that allow them to hold suppliers to account. An ongoing “green procurement index health” project being conducted by the United Nations Development Programme aims to address this challenge through a number of supporting actions, including the development of guidelines and tools (UNDP, 2016).

Overall, limited research literature was identified quantifying the benefits of including environmental concerns in the procurement practices of health systems (excepting the literature on disposable versus reusable medical devices described above). This is an important finding in itself, given the evidence reviewed earlier indicating that the carbon footprint of goods and services procured by health systems exceeds the footprint related to direct service delivery. The paucity of research on procurement was also identified by a previous literature review on sustainable hospitals (McGain & Naylor, 2014). A particularly striking gap is the apparent absence of research on the use of procurement processes to drive sustainable practices in the manufacturing of pharmaceuticals (see section 3.4.2.3).

3.4.4.2. Other potential benefits related to financing

A number of further potential benefits could follow from fostering environmental sustainability within the financing function of health systems. The scale of these could not be quantified on the basis of available research evidence, but opportunities can be assumed to exist to some extent.

- New sources of funding not previously available to health sector organizations could be accessed – for example, in the form of environmental subsidies or grants.
- Responsible investment: health sector organizations have access to significant investment holdings, and opportunities exist for them to secure environmental benefits through their investment and divestment decisions. An example is the decision in 2015 by the World Medical Association to call on national association members to consider disinvesting in fossil fuels.
- Reputational benefits: health care providers could gain a competitive advantage over rivals by demonstrating to potential customers the importance they attach to operating in a sustainable way.

In the case of reputational benefits, some evidence from other sectors supports the hypothesis that fostering environmental sustainability can help organizations to secure a competitive advantage in the market (Schnietz and Epstein, 2005; Du, Bhattacharya & Sen, 2007; Heslin & Ochoa, 2008; Dangelico & Pujari, 2010; Sprinkle & Maines, 2010). Indeed, this has often been a key motivator for corporate social responsibility programmes. The relevance of these findings is not limited to market-based health systems, as a health care provider that succeeds in building a positive reputation may benefit from higher patient satisfaction and improved relations with patients and the public, regardless of competition from other providers.

3.5. BARRIERS AND ENABLERS

This section describes factors that may either enable or inhibit the goal of fostering environmental sustainability, drawing again on the relevant research evidence where available.

3.5.1. Individual-level barriers and enablers

The most commonly described barrier to sustainable practices in the literature was a lack of knowledge or awareness among those working in health systems. This was observed in a large number of case studies and surveys conducted in a range of settings, including both high- and low-income countries (Ferreira & Teixeira, 2010; Manzi, Nichols & Richardson, 2014; Vogt & Nunes, 2014). It applies to knowledge of best practice in relation to waste disposal and segregation, energy conservation and water use. For example, surveys of health care professionals in Croatia (Janev Holcer, Maricevic & Miodic-Juran, 2012) and Ireland (McKeon, 2009) found limited understanding among nursing staff of the risks posed by mercury toxicity, and over half of all mercury waste in Ireland is disposed of incorrectly.

Education and training programmes have been found to be an effective means of improving staff knowledge and behaviours (such as compliance with waste management regulations) in several countries including Portugal (Botelho, 2012), Spain (Mosquera et al., 2014), Turkey (Ozder et al., 2013) and the United Kingdom (Charlesworth et al., 2012).

Psychological research suggests, however, that barriers at the individual level are not solely a question of knowledge and awareness. A study of psychological factors limiting engagement with sustainability in health care settings identified a number of barriers, including using denial of the problem as a coping strategy; diffusion of responsibility (“someone else will solve the problem”); and the so-called “moral offset” (“I’m doing enough good just by being a doctor/nurse”). Overall, the research suggested that hospital environments can be disempowering places to work,

which encourage environmental “numbness” (Topf, 2005). A culture of being reactive and prioritizing immediate concerns may also make it harder to engage with questions regarding the longer-term sustainability of one’s actions (Anåker et al., 2015). These psychological barriers need to be addressed, given that a consistent finding from research on sustainability in other sectors is that employee engagement at all levels is critical to embed a concern for sustainability within an organization (Fenwick, 2007; Smith & Sharicz, 2011).

3.5.2. Organizational barriers and enablers

Organizational factors can make it harder for individuals to act on environmental considerations, even if they would like to. For example, in relation to waste management, the evidence suggests that some hospitals use inappropriate containers for medical waste collection that do not permit correct segregation and disposal (Birpinar, Bilgili & Erdogan, 2009; Eker et al., 2010). The evidence is clear that this is a problem in lower-income countries, but some evidence also shows that standards of waste management in higher-income countries continue to fall short of regulatory expectations. An audit of 16 hospitals in the United Kingdom, for example, found that medical waste carts and the areas dedicated to their storage were often “in a poor state of repair” (Blenkharn, 2007).

Organizations can be slow to respond when requirements of them change. For example, the growing proportion of health care delivered in patients’ own homes creates new responsibilities for municipal authorities in terms of ensuring that medical waste from domestic properties is disposed of properly. An audit of local authorities in the United Kingdom suggested that many have not adequately responded to these growing responsibilities (Blenkharn, 2008).

A number of organizational characteristics have been found to be associated with successful adoption of sustainable practices. Research from other sectors suggests that organizational culture and leadership styles are critical, and that the most sustainable businesses are those that devolve responsibility for sustainability to individual employees and teams; allow improvisation and experimentation; and create conditions for learning (Fenwick, 2007; Smith & Sharicz, 2011).

Health care organizations may have a number of motivations for promoting environmental sustainability, as demonstrated by the range of potential benefits discussed in section 3.4. Financial considerations inevitably play a critical part. Outside the health sector, research increasingly points to businesses adopting sustainability as a core part of their strategies as a means of outperforming rivals and gaining a competitive advantage (Mahler et al., 2009; Nidumolu, Prahalad & Rangaswami, 2009; Dangelico & Pujari, 2010). These intrinsic motivations could be strengthened by creating new incentives at the system level (see below).

3.5.3. System barriers and enablers

The literature review also identified a number of system-wide barriers. These vary by country, but in many cases include weak governance at the national level, a lack of appropriate regulatory frameworks and/or weak enforcement of whatever legislation and regulation does exist. For example, an evaluation of waste management practices at three hospitals in Serbia found poor performance at every stage of management, underlined by the lack of any specific regulations for the segregation of medical waste and an absence of any training courses on hospital waste management (Stankovic, Nikic & Nikolic, 2008). This situation is reported to have improved markedly with the implementation of a national waste management strategy in Serbia in 2009 (Caniato, Tudor & Vaccari, 2015; Gavrancic, Simic & Gavrancic, 2012).

A range of incentives (financial or non-financial) could be used to encourage health system stakeholders to incorporate environmental sustainability in their work. Financial incentives could include low-interest financing,

tax incentives and seed funding to support innovation. No specific evidence was found regarding the use of these kinds of incentives within the health sector, but there is a large body of wider research that could be drawn on. For example, the successes and shortcomings of the emissions trading scheme developed in the EU demonstrates that the effectiveness of such measures depends critically on the design of the incentive structures and the exact values and prices used (Ellerman, Convery & de Perthuis, 2011).



4. DISCUSSION

Drawing firm conclusions from the evidence reviewed in this report is challenging as a result of two constraints. First, the evidence base has significant gaps and weaknesses, meaning that some hypotheses regarding the environmental sustainability of the health systems have not yet been the subject of adequate empirical investigation (see the section on knowledge gaps below). Second, the nature of the subject means that the breadth of the relevant evidence is necessarily very wide, and the depth with which any one area can be explored is, as a result, constrained.

Nonetheless, some important conclusions can be drawn. Foremost among these is that there is no room for doubt about the central premise that health systems have a substantial impact on the environment, that and in their current form they are highly dependent on access to energy and other natural resources. In the context of wider pressures on environmental systems and increasing concerns about energy security and the cost and availability of a range of natural resources, this provides reason enough for pursuing efforts to foster environmental sustainability in health systems.

The review gives good reason to believe that at least some attempts to reduce the negative environmental impacts of health systems will also deliver financial and health co-benefits. What is not yet clear is the scale and extent of these. It cannot be assumed that including environmental considerations in health system decision-making will always lead to win-win scenarios. Indeed, it is likely that trade-offs will exist and that frameworks will be required to support decision-makers in reaching optimal decisions that balance competing considerations in the best possible way.

While minimizing adverse impacts is important, clear opportunities are also available to strengthen those areas where health systems have a positive impact on the environment – notably through investment in health promotion and environmental health protection activities. Making the most of these opportunities to create “shared value” should be a focus for further work.

More generally, the environmental impact of a health system depends crucially on the overall characteristics of the system, including the efficiency and effectiveness of health services; the health status of the population; and levels of patient knowledge and participation (see section 3.2). Making progress on these characteristics may achieve as much as action that is explicitly “environmental” in its objectives.

It is clear, therefore, that integrating environmental concerns into health systems has implications for all four of the health system functions recognized by WHO – service delivery, resource generation, stewardship and financing. While the environmental impacts attributable to service delivery are perhaps the most tangible and obvious, the available evidence indicates that the environmental footprint associated with resource generation processes is probably larger. The stewardship and financing functions would certainly need to play a role in facilitating the adoption of sustainable practices – for example, through intersectoral advocacy or the use of procurement processes or financial incentives. Little health-specific evidence is yet available to suggest how these functions can be exercised to greatest effect, however.

4.1. KNOWLEDGE GAPS

The extent of the evidence base relating to environmentally sustainable health systems is highly variable. In some areas, such as health care waste management, an established research community and a sizeable body of evidence

are available to draw on. In contrast, research examining the carbon footprint of health systems is an emerging field, and most of the available evidence relates to a relatively narrow set of countries.

The quality of the evidence reviewed is also variable. In some cases well designed experimental research studies include randomized controlled trials and systematic reviews of the literature. Much of the evidence presented here, however, is based on single observational studies, albeit ones often repeated in a number of countries. This means that a proportion of the data reported is illustrative and suggestive rather than definitive.

Overall, the available evidence gives an incomplete picture of both the full range of environmental impacts of health system activities (see section 1) and the benefits of promoting sustainable practices. Critically, while it may be sufficient for the purposes of advocacy, it does not currently give policy-makers and others the information needed to guide decision-making.

A scoping review of environmentally sustainable health and social care published by the United Kingdom National Institute for Health Research (Naylor & Appleby, 2012) mapped out the research needs across a number of areas. It concluded that more progress is needed in the following areas:

- developing standard metrics and research methods for assessing the environmental costs and benefits of health system activities;
- calculating the environmental costs and benefits of discrete components of activity, which could be used to build models for estimating the impacts of different options and pathways;
- embedding environmental sustainability in wider health research, with environmental costs and benefits treated as an outcome measure or a dimension of quality akin to access or equity;
- research focused on supporting implementation – for example, understanding the barriers to change or assessing the co-benefits of sustainable approaches;
- interdisciplinary research, supported by collaborative funding between research funders in health and other sectors;
- international coordination of research efforts across countries.

In addition to these overarching issues, a number of specific research gaps have been identified by this summary. In particular, there is a need for:

- identifying and quantifying the specific aspects of health system activity that have the greatest environmental impact – for example, in terms of the carbon footprint of different forms of care, the volume and toxicity of substances emitted or the amount of natural resources consumed;
- measuring the environmental, health, financial and other benefits associated with promising interventions, including:
 - telehealth, telecare and other digital health technologies;
 - promotion of active transport (such as walking and cycling) and dietary change;
 - environmental and occupational health protection measures;
- evaluating the effectiveness of different mechanisms for fostering environmental sustainability in health systems, including:
 - intersectoral partnerships between the health and environmental sectors;
 - using procurement processes to drive sustainable practices in supply chains;
 - engaging the health workforce and promoting behaviour change among professionals;
- understanding the feasibility of different options in low- and middle-income settings;
- assessing the “soft” benefits of fostering environmental sustainability within health care organizations, such as reputational benefits and staff engagement.

5. CONCLUSIONS

Overall, the evidence reviewed in this report illustrates the compelling rationale for fostering environmental sustainability in health systems: there is no room for doubt about the central premise that health systems have a substantial impact on the environment, and that in their current form they are highly dependent on access to energy and other natural resources. As concerns mount worldwide regarding environmental change and efforts to counter this gather momentum, all sectors will increasingly be expected to operate in a sustainable way. What is not yet clear is how this ambition could best be put into practice in health systems. While minimizing adverse impacts is important, clear opportunities are also available to strengthen areas where health systems have a positive impact on the environment, such as health promotion and environmental health protection activities. Policy-makers and others need comprehensive, reliable information regarding the environmental costs and benefits of alternative courses of action, as well as insight into how to foster environmental sustainability effectively. Investment in relevant research and coordination of research efforts across countries and sectors are therefore vital.



REFERENCES

- Agar JWM (2010). Conserving water in and applying solar power to haemodialysis: “green dialysis” through wiser resource utilization. *Nephrology (Carlton)*. 15(4):448–53. doi:10.1111/j.1440-1797.2009.01255.x.
- Agar JWM, Simmonds RE, Knight R, Somerville CA (2009). Using water wisely: new, affordable, and essential water conservation practices for facility and home hemodialysis. *Hemodial Int*. 13(1):32–7. doi:10.1111/j.1542-4758.2009.00332.x.
- Al Aukidy M, Verlicchi P, Voulvoulis N (2014). A framework for the assessment of the environmental risk posed by pharmaceuticals originating from hospital effluents. *Sci Total Environ*. 493:54–64. doi:10.1016/j.scitotenv.2014.05.128.
- Ali I, Rehman K, Ali S, Yousaf J, Zia M (2010). Corporate social responsibility influences, employee commitment and organizational performance. *Afr J Bus Manag*. 4(12):2796–801.
- Alvim-Ferraz MCM, Afonso SAV (2003). Incineration of different types of medical wastes: emission factors for particulate matter and heavy metals. *Environ Sci Technol*. 37(14):3152–7.
- Amaral MJ (2014). Non-toxic health care: alternatives to phthalates and bisphenol A in medical devices. Brussels: Health Care without Harm Europe (<https://noharm-europe.org/edcs-report>, accessed 17 June 2016).
- Anåker A, Nilsson M, Holmner Å, Elf M (2015). Nurses’ perceptions of climate and environmental issues: a qualitative study. *J Adv Nurs*. 71(8):1883–91. doi:10.1111/jan.12655.
- Andrews E, Pearson D, Kelly C, Stroud L, Rivas Perez M (2013). Carbon footprint of patient journeys through primary care: a mixed methods approach. *Br J Gen Pract*. 63(614):e595–603. doi:10.3399/bjgp13X671579.
- Bajayo R (2012). Building community resilience to climate change through public health planning. *Health Promot. J. Austr*. 23(1):30–6.
- Beier S, Cramer C, Mauer C, Koster S, Schroder HF, Pinnekamp J (2012). MBR technology: a promising approach for the (pre-)treatment of hospital wastewater. *Water Sci Technol*. 65(9):1648–53. doi:10.2166/wst.2012.880.
- Beier S, Koster S, Veltmann K, Schroder H, Pinnekamp J (2010). Treatment of hospital wastewater effluent by nanofiltration and reverse osmosis. *Water Sci Technol*. 61(7):1691–8. doi:10.2166/wst.2010.119.
- Bergman A, Heindel J, Jobling S, Kidd K, Zoeller RT, editors (2013). State of the science of endocrine disrupting chemicals – 2012. An assessment of the state of the science of endocrine disruptors prepared by a group of experts for the United Nations Environment Programme (UNEP) and WHO. Geneva: World Health Organization (<http://www.who.int/ceh/publications/endocrine/en/>, accessed 17 June 2016).
- Bhattacharya C, Sen S, Korschun D (2008). Using corporate social responsibility to win the war for talent. *MIT Sloan Manag Rev*. 49(2):37–44.

- Birpinar ME, Bilgili MS, Erdogan T (2009). Medical waste management in Turkey: a case study of Istanbul. *Waste Manag.* 29(1):445–8. doi:10.1016/j.wasman.2008.03.015.
- Blanchard IE, Brown LH (2011). Carbon footprinting of North American emergency medical services systems. *Prehospital Emer. Care.* 15(1):23–9. doi:10.3109/10903127.2010.519818.
- Blenkharn JI (2007). Standards of clinical waste management in hospitals: a second look. *Public Health.* 121(7):540–5. doi:10.1016/j.puhe.2006.12.005.
- Blenkharn JI (2008). Clinical wastes in the community: local authority management of clinical wastes from domestic premises. *Public Health.* 122(5):526–31. doi:10.1016/j.puhe.2007.08.004.
- Bode C, Singh J, Rogan M (2015). Corporate social initiatives and employee retention. INSEAD Working Paper No. 2015/34/STR/EFE. doi:10.2139/ssrn.2439609.
- Boillot C, Bazin C, Tissot-Guerraz F, Droguet J, Perraud M, Cetre JC et al. (2008). Daily physicochemical, microbiological and ecotoxicological fluctuations of a hospital effluent according to technical and care activities. *Sci Total Environ.* 403(1–3):113–29. doi:10.1016/j.scitotenv.2008.04.037.
- Bond A, Jones A, Haynes R, Tam M, Denton E, Ballantyne M et al. (2009). Tackling climate change close to home: mobile breast screening as a model. *J Health Serv Res Policy.* 14(3):165–7. doi:10.1258/jhsrp.2009.008154.
- Botelho A (2012). The impact of education and training on compliance behavior and waste generation in European private health care facilities. *J Environ Manage.* 98:5–10. doi:10.1016/j.jenvman.2011.12.003.
- Brammer S, Millington A, Rayton B (2007). The contribution of corporate social responsibility to organizational commitment. *Int J Hum Resour Manag.* 18(10):1701–19.
- Brammer S, Walker H (2011). Sustainable procurement in the public sector: an international comparative study. *Int J Oper Prod Manag.* 31(4):452–76. doi:10.1108/0144357111119551.
- Brandt I, Breitholtz M, la Cour Jansen J, Liljelund K, Larsson J, Rudén C et al., editors (2012). *Pharmaceuticals in a healthy environment: MistraPharma research 2008–2011.* Stockholm: MistraPharma.
- Brockway P (2009). Carbon measurement in the NHS: calculating the first consumption-based total carbon footprint of an NHS Trust. Leicester: De Montfort University.
- Brockway P (2010). NHS at forefront of carbon modelling. *Health Estate.* 64(9):33–8.
- Burpee H, McDade E (2014). Comparative analysis of hospital energy use: Pacific Northwest and Scandinavia. *HERD.* 8(1):20–44. doi:10.1177/193758671400800104.
- Calafat AM, Weuve J, Ye X, Jia LT, Hu H, Ringer S et al. (2009). Exposure to bisphenol A and other phenols in neonatal intensive care unit premature infants. *Environ Health Perspect.* 117(4):639–44. doi:10.1289/ehp.0800265.
- Campion N, Thiel CL, Woods NC, Swanzy L, Landis AE, Bilec MM (2015). Sustainable health care and environmental life-cycle impacts of disposable supplies: a focus on disposable custom packs. *J Clean Prod.* 94:46–55. doi:10.1016/j.jclepro.2015.01.076

- Caniato M, Tudor T, Vaccari M (2015). International governance structures for health-care waste management: a systematic review of scientific literature. *J Environ Manage.* 153:93–107. doi:10.1016/j.jenvman.2015.01.039.
- Carlsson-Kanyama A (1998). Climate change and dietary choices: how can emissions of greenhouse gases from food consumption be reduced? *Food Policy.* 23(3–4):277–93. doi:10.1016/S0306-9192(98)00037-2.
- Charlesworth KE, Ray S, Head F, Pencheon D (2012). Developing an environmentally sustainable NHS: outcomes of implementing an educational intervention on sustainable health care with UK public health registrars. *N S W Public Health Bull.* 23(1–2):27–30. doi:10.1071/NB11018.
- Chartier Y, Emmanuel J, Pieper U, Prüss A, Rushbrook P, Stringer R et al., editors (2014). *Safe management of wastes from health-care activities, second edition.* Geneva: World Health Organization (http://www.who.int/water_sanitation_health/medicalwaste/wastemanag/en/, accessed 16 June 2016).
- Chevalier F, Levitan J, Garel P (2009). *Hospitals in the 27 Member States of the European Union.* Paris: Dexia Editions.
- Connor A, Lillywhite R, Cooke MW (2010). The carbon footprint of a renal service in the United Kingdom. *QJM.* 103(12):965–75. doi:10.1093/qjmed/hcq150.
- Connor A, Lillywhite R, Cooke MW (2011). The carbon footprints of home and in-center maintenance hemodialysis in the United Kingdom. *Hemodial Int.* 15(1):39–51. doi:10.1111/j.1542-4758.2010.00523.x.
- Conrardy J, Hillanbrand M, Myers S, Nussbaum GF (2010). Reducing medical waste. *AORN J.* 91(6):711–21. doi:10.1016/j.aorn.2009.12.029.
- Dangelico RM, Pujari D (2010). Mainstreaming green product innovation: why and how companies integrate environmental sustainability. *J Bus Ethics.* 95(3):471–86. doi:10.1007/s10551-010-0434-0.
- Daughton CG (2014). Eco-directed sustainable prescribing: feasibility for reducing water contamination by drugs. *Sci Total Environ.* 493:392–404. doi:10.1016/j.scitotenv.2014.06.013.
- Department of Health (2013). *Health Technical Memorandum 07-04: Water management and water efficiency – best practice advice for the healthcare sector.* London: The Stationery Office.
- De Silva D (2011). *Evidence: helping people help themselves.* London: The Health Foundation.
- Duane B, Hyland J, Rowan JS, Archibald B (2012). Taking a bite out of Scotland’s dental carbon emissions in the transition to a low carbon future. *Public Health.* 126(9):770–7. doi:10.1016/j.puhe.2012.05.032.
- Duane B, Taylor T, Stahl-Timmins W, Hyland J, Mackie P, Pollard A (2014). Carbon mitigation, patient choice and cost reduction—triple bottom line optimization for health care planning. *Public Health.* 128(10):920–4. doi:10.1016/j.puhe.2014.08.008.
- Durmusoglu E, Bakoglu M, Karademir A, Kirli L (2006). Adsorbable organic halogens (AOXs) in solid residues from hazardous and clinical waste incineration. *J Environ Sci Health A Tox Hazard Subst Environ Eng.* 41(8):1699–1714. doi:10.1080/10934520600754193.

- Du S, Bhattacharya C, Sen S (2007). Reaping relational rewards from corporate social responsibility: The role of competitive positioning. *Int J Res Mark.* 24(3):224–41. doi:10.1016/j.ijresmar.2007.01.001.
- Duty SM, Mendonca K, Hauser R, Calafat AM, Ye X, Meeker JD et al. (2013). Potential sources of bisphenol A in the neonatal intensive care unit. *Pediatrics.* 131(3):483–9. doi:10.1542/peds.2012–1380.
- Eckelman M, Mosher M, Gonzalez A, Sherman J (2012). Comparative life cycle assessment of disposable and reusable laryngeal mask airways. *Anesth Analg.* 114(5):1067–72. doi:10.1213/ANE.0b013e31824f6959.
- Eker HH, Bilgili MS, Sekman E, Top S (2010). Evaluation of the regulation changes in medical waste management in Turkey. *Waste Manag Res.* 28(11):1034–8. doi:10.1177/0734242X10366158.
- Elkington J (1994). Towards the sustainable corporation: win-win-win business strategies for sustainable development. *Calif Manage Rev.* 36:90–100.
- Ellerman AD, Convery FJ, de Perthuis BK (2011). Pricing carbon: the European Union emissions trading scheme, first edition. Cambridge: Cambridge University Press.
- Elwyn G, Frosch D, Thomson R, Joseph-Williams N, Lloyd A, Kinnersley P et al. (2012). Shared decision-making: a model for clinical practice. *J Gen Intern Med.* 27(10):1361–7. doi:10.1007/s11606-012-2077-6.
- Erridge A, Hennigan S (2012). Sustainable procurement in health and social care in Northern Ireland. *Public Money Manag.* 32(5):363–70. doi:10.1080/09540962.2012.703422.
- Escher BI, Baumgartner R, Koller M, Treyer K, Lienert J, McArdell CS (2011). Environmental toxicology and risk assessment of pharmaceuticals from hospital wastewater. *Water Res.* 45(1):75–92. doi:10.1016/j.watres.2010.08.019.
- Esmaeili A, Twomey JM, Overcash MR, Soltani SA, McGuire C, Ali K (2015). Scope for energy improvement for hospital imaging services in the USA. *J Health Serv Res Policy.* 20(2):67–73. doi:10.1177/1355819614554845.
- European Commission (2012). Commission Staff Working Document on an action plan for the EU health workforce. Strasbourg: European Commission (SWD(2012) 93 final; http://ec.europa.eu/health/workforce/policy/index_en.htm, accessed 16 June 2016).
- Fabbri E (2015). Pharmaceuticals in the environment: expected and unexpected effects on aquatic fauna. *Ann NY Acad Sci.* 1340:20–8. doi:10.1111/nyas.12605.
- Fenwick T (2007). Developing organizational practices of ecological sustainability: A learning perspective. *Leadersh Organ Dev J.* 28(7):632–45. doi:10.1108/01437730710823888.
- Ferreira V, Teixeira MR (2010). Health care waste management practices and risk perceptions: findings from hospitals in the Algarve region, Portugal. *Waste Manag.* 30(12):2657–63. doi:10.1016/j.wasman.2010.07.012.
- Fischer CJ, Bickle Graz M, Muehlethaler V, Palmero D, Tolsa JF (2013). Phthalates in the NICU: is it safe? *J Paediatr Child Health.* 49(9):E413–19. doi:10.1111/jpc.12244.

- Frank LD, Greenwald MJ, Winkelman S, Chapman J, Kavage S (2010). Carbonless footprints: promoting health and climate stabilization through active transportation. *Prev Med.* 50(Suppl 1):S99–105. doi:10.1016/j.ypmed.2009.09.025.
- Frédéric O, Yves P (2014). Pharmaceuticals in hospital wastewater: their ecotoxicity and contribution to the environmental hazard of the effluent. *Chemosphere.* 115:31–9. doi:10.1016/j.chemosphere.2014.01.016.
- Gatenby PAC (2011). Modelling the carbon footprint of reflux control. *Int J Surg.* 9(1):72–4. doi:10.1016/j.ijsu.2010.09.008.
- Gavrancic T, Simic A, Gavrancic B (2012). Medical waste management at the Oncology Institute of Vojvodina: possibilities of successful implementation of medical waste regulation in Serbia. *Waste Manag Res.* 30(6):596–600. doi:10.1177/0734242X12448832.
- Gielar A, Helios-Rybicka E (2013). Environmental impact of a hospital waste incineration plant in Krakow (Poland). *Waste Manag Res.* 31(7):722–8. doi:10.1177/0734242X13485868.
- Global Action Plan (2015). Barts Health NHS Trust: Operation TLC. In: Global Action Plan [website]. London: Global Action Plan (<https://www.globalactionplan.org.uk/barts-health-nhs-trust>, accessed 20 June 2016).
- Grimmond T, Reiner S (2012). Impact on carbon footprint: a life cycle assessment of disposable versus reusable sharps containers in a large US hospital. *Waste Manag Res.* 30(6):639–42. doi:10.1177/0734242X12450602.
- Haines A, McMichael AJ, Smith KR, Roberts I, Woodcock J, Markandya A et al. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy-makers. *Lancet.* 374(9707):2104–14. doi:10.1016/S0140-6736(09)61759-1.
- Harhay MO, Halpern SD, Harhay JS, Olliaro PL (2009). Health care waste management: a neglected and growing public health problem worldwide. *Trop Med Int Health.* 14(11):1414–17. doi:10.1111/j.1365-3156.2009.02386.x.
- Health Care Without Harm (2011). Guide for eliminating mercury from health care establishments. Buenos Aires: Health Care Without Harm (<https://noharm-global.org/documents/mercury-elimination-guide-hospitals>, accessed 17 June 2016).
- Health Care Without Harm, Center for Maximum Potential Building Systems (2002). Green guide for health care [website]. Reston, Va: Health Care Without Harm & Center for Maximum Potential Building Systems.
- Heslin P, Ochoa J (2008). Understanding and developing strategic corporate social responsibility. *Organ Dyn.* 37(2):125–44.
- Holmner A, Ebi KL, Lazuardi L, Nilsson M (2014). Carbon footprint of telemedicine solutions—unexplored opportunity for reducing carbon emissions in the health sector. *PLoS One.* 9(9):e105040. doi:10.1371/journal.pone.0105040.
- Hossain MS, Santhanam A, Nik Norulaini NA, Omar AKM (2011). Clinical solid waste management practices and its impact on human health and environment: a review. *Waste Manag.* 31(4):754–66. doi:10.1016/j.wasman.2010.11.008.

- Huygh J, Clotman K, Malarvannan G, Covaci A, Schepens T, Verbrugghe W et al. (2015). Considerable exposure to the endocrine disrupting chemicals phthalates and bisphenol-A in intensive care unit (ICU) patients. *Environ Int.* 81:64–72. doi:10.1016/j.envint.2015.04.008.
- James R (2010). Incineration: why this may be the most environmentally sound method of renal health care waste disposal. *J Ren Care.* 36(3):161–9. doi:10.1111/j.1755-6686.2010.00178.x.
- Janev Holcer N, Maricevic M, Miocic-Juran A (2012). The use of mercury-based medical devices across Croatian health care facilities. *Arh Hig Rada Toksikol.* 63(1):41–7. doi:10.2478/10004-1254-63-2012-2162.
- Jochelson K, Norwood S, Hussain S, Heer B (2005). Sustainable food and the NHS. London: The King's Fund (<http://www.kingsfund.org.uk/publications/sustainable-food-and-nhs>, accessed 17 June 2016).
- Kaplan S, Sadler B, Little K, Franz C, Orris P (2012). Can sustainable hospitals help bend the health care cost curve? Washington, DC: The Commonwealth Fund (<http://www.commonwealthfund.org/Publications/Issue-Briefs/2012/Nov/Sustainable-Hospitals.aspx>, accessed 14 September 2016).
- Karlsson M, Pigretti Öhman D (2005). Material consumption in the healthcare sector: strategies to reduce its impact on climate change – the case of Region Scania in South Sweden. *J Clean Prod.* 13(10):1071–81. doi:10.1016/j.jclepro.2004.12.012.
- Kim H, Lee M, Lee H, Kim N (2010). Corporate social responsibility and employee–company identification. *J Bus Ethics.* 95(4):557–69.
- Knapp M, McDaid D, Parsonage M (2011). Mental health promotion and prevention: the economic case. London: Personal Social Services Research Unit, London School of Economics and Political Science.
- Komilis D, Katsafaros N, Vassilopoulos P (2011). Hazardous medical waste generation in Greece: case studies from medical facilities in Attica and from a small insular hospital. *Waste Manag Res.* 29(8):807–14. doi:10.1177/0734242X10388684.
- Kougemitrou I, Godelitsas A, Tsabaris C, Stathopoulos V, Papandreou A, Gamaletsos P et al. (2011). Characterization and management of ash produced in the hospital waste incinerator of Athens, Greece. *J Hazard Mater.* 187(1–3):421–32. doi:10.1016/j.jhazmat.2011.01.045.
- Lee AC, Maheswaran R (2011). The health benefits of urban green spaces: a review of the evidence. *J Public Health (Oxf).* 33(2):212–22. doi:10.1093/pubmed/fdq068.
- Lee RJ, Mears SC (2012a). Greening of orthopedic surgery. *Orthopedics.* 35(6):e940–4. doi:10.3928/01477447-20120525-39.
- Lee RJ, Mears SC (2012b). Reducing and recycling in joint arthroplasty. *J Arthroplasty.* 27(10):1757–60. doi:10.1016/j.arth.2012.04.020.
- Lewis D, Tranter G, Axford AT (2009). Use of videoconferencing in Wales to reduce carbon dioxide emissions, travel costs and time. *J Telemed Telecare.* 15(3):137–8. doi:10.1258/jtt.2009.003010.

- Lim AEK, Perkins A, Agar JWM (2013). The carbon footprint of an Australian satellite haemodialysis unit. *Aust Health Rev.* 37(3):369–74. doi:10.1071/AH13022.
- Lindgreen A, Antico M, Harness D, van der Sloot R (2009). Purchasing and marketing of social and environmental sustainability for high-tech medical equipment. *J Bus Ethics.* 85(2):445–62. doi:10.1007/s10551-008-9740-1.
- Macdiarmid JI, 2014. Seasonality and dietary requirements: will eating seasonal food contribute to health and environmental sustainability? *Proc Nutr Soc.* 73(3):368–75. doi:10.1017/S0029665113003753
- Macdiarmid JI, Kyle J, Horgan GW, Loe J, Fyfe C, Johnstone A et al. (2012). Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *Am J Clin Nutr.* 96(3):632–9. doi:10.3945/ajcn.112.038729.
- Mahler D, Barker J, Belsand L, Schulz O (2009). Green winners: the performance of sustainability-focused companies during the financial crisis. Chicago, IL: AT Kearney.
- Manzi S, Nichols A, Richardson J (2014). A non-participant observational study of health and social care waste disposal behaviour in the South West of England. *J Health Serv Res Policy.* 19(4):231–5. doi:10.1177/1355819614538780.
- Marinkovic N, Vitale K, Janev Holcer N, Dzakula A, Pavic T (2008). Management of hazardous medical waste in Croatia. *Waste Manag.* 28(6):1049–56. doi:10.1016/j.wasman.2007.01.021.
- Masino C, Rubinstein E, Lem L, Purdy B, Rossos PG (2010). The impact of telemedicine on greenhouse gas emissions at an academic health science center in Canada. *Telemed J E Health.* 16(9):973–6. doi:10.1089/tmj.2010.0057.
- Maughan DL, Patel A, Parveen T, Braithwaite I, Cook J, Lillywhite R et al. (2015). Primary-care-based social prescribing for mental health: an analysis of financial and environmental sustainability. *Prim Health Care Res Dev.* 7(2):114–21. doi:10.1017/S1463423615000328.
- McCarthy CJ, Gerstenmaier JF, O’Neill AC, McEvoy SH, Hegarty C, Heffernan EJ (2014). “EcoRadiology” – pulling the plug on wasted energy in the radiology department. *Acad Radiol.* 21(12):1563–6. doi:10.1016/j.acra.2014.07.010.
- McGain F, Hendel SA, Story DA (2009). An audit of potentially recyclable waste from anaesthetic practice. *Anaesth Intensive Care.* 37(5):820–3.
- McGain F, McAlister S, McGavin A, Story D (2012). A life cycle assessment of reusable and single-use central venous catheter insertion kits. *Anesth Analg.* 114(5):1073–80. doi:10.1213/ANE.0b013e31824e9b69.
- McGain F, Naylor C (2014). Environmental sustainability in hospitals – a systematic review and research agenda. *J Health Serv Res Policy.* 19(4):245–52. doi:10.1177/1355819614534836.
- McKeon M (2009). The uses of mercury equipment and products in Irish health care. *Ir Med J.* 102(1):10–12.

- McQueen DV, Wismar M, Lin V, Jones CM, Davies M, editors (2012). Intersectoral governance for health in all policies: structures, actions and experiences. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/about-us/governance/regional-committee-for-europe/past-sessions/sixty-second-session/documentation/background-documents/intersectoral-governance-for-health-in-all-policies-structures,-actions-and-experiences>, accessed 14 September 2016).
- Menne B, Apfel F, Kovats S, Racioppi F, editors (2008). Protecting health in Europe from climate change. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/pre-2009/protecting-health-in-europe-from-climate-change>, accessed 16 June 2016).
- Merkur S, Sassi F, McDaid D (2013). Promoting health, preventing disease: is there an economic case? Copenhagen: WHO Regional Office for Europe (OBS policy summary 6; <http://www.euro.who.int/en/about-us/partners/observatory/publications/policy-briefs-and-summaries/promoting-health,-preventing-disease-is-there-an-economic-case>, accessed 16 June 2016).
- Morris DS, Wright T, Somner JEA, Connor A (2013). The carbon footprint of cataract surgery. *Eye (Lond)*. 27(4):495–501. doi:10.1038/eye.2013.9.
- Mosquera M, Andres-Prado MJ, Rodriguez-Caravaca G, Latasa P, Mosquera MEG (2014). Evaluation of an education and training intervention to reduce health care waste in a tertiary hospital in Spain. *Am J Infect Control*. 42(8):894–7. doi:10.1016/j.ajic.2014.04.013.
- Mullot JU, Karolak S, Fontova A, Levi Y (2010). Modeling of hospital wastewater pollution by pharmaceuticals: first results of Mediflux study carried out in three French hospitals. *Water Sci Technol*. 62(12):2912–9. doi:10.2166/wst.2010.986.
- Naylor C, Appleby J (2012). Environmentally sustainable health and social care: scoping review. London: National Institute for Health Research Service Delivery and Organization Programme.
- NHS Sustainable Development Unit (2010a). Saving carbon, improving health: Update – NHS carbon reduction strategy update. Cambridge: NHS Sustainable Development Unit (<http://www.sduhealth.org.uk/policy-strategy/engagement-resources/nhs-carbon-reduction-strategy-2009.aspx>, accessed 14 September 2016).
- NHS Sustainable Development Unit (2010b). Save money by saving carbon: decision making in the NHS using marginal abatement cost curves. Cambridge: NHS Sustainable Development Unit (<http://www.sduhealth.org.uk/delivery/measure/finance.aspx>, accessed 14 September 2016).
- NHS Sustainable Development Unit (2013). Carbon footprint update for NHS in England 2012. Cambridge: NHS Sustainable Development Unit (<http://www.sduhealth.org.uk/policy-strategy/reporting/nhs-carbon-footprint.aspx>, accessed 14 September 2016).
- Nidumolu R, Prahalad CK, Rangaswami MR (2009). Why sustainability is now the key driver of innovation. *Harv Bus Rev*. 87(9):57–64.
- Orias F, Perrodin Y (2013). Characterization of the ecotoxicity of hospital effluents: a review. *Sci Total Environ*. 454–5:250–76. doi:10.1016/j.scitotenv.2013.02.064.

- Oruezabala G, Rico JC (2012). The impact of sustainable public procurement on supplier management – the case of French public hospitals. *Ind Mark Manag.* 41(4):573–80. doi:10.1016/j.indmarman.2012.04.004.
- Ozder A, Teker B, Eker HH, Altindis S, Kocaakman M, Karabay O (2013). Medical waste management training for health care managers – a necessity? *J Environ Health Sci Eng.* 11(1):20. doi:10.1186/2052-336X-11-20.
- Pauwels P, Verstraete W (2006). The treatment of hospital wastewater: an appraisal. *J Water Health.* 4(4):405–16.
- Pollard AS, Paddle JJ, Taylor TJ, Tillyard A (2014). The carbon footprint of acute care: how energy intensive is critical care? *Public Health.* 128(9):771–6. doi:10.1016/j.puhe.2014.06.015.
- Porter ME, Kramer MR (2006). The link between competitive advantage and corporate social responsibility. *Harv Bus Rev.* 84(12):78–92.
- Prasanna PM, Siegel E, Kuncze A (2011). Greening radiology. *J Am Coll Radiol.* 8(1):780–4. doi:10.1016/j.jacr.2011.07.017.
- Reynolds CJ, Buckley JD, Weinstein P, Boland J (2014). Are the dietary guidelines for meat, fat, fruit and vegetable consumption appropriate for environmental sustainability? A review of the literature. *Nutrients.* 6(6):2251–65. doi:10.3390/nu6062251.
- Rustagi N, Singh R (2010). Mercury and health care. *Indian J Occup Environ Med.* 14(2):45–8. doi:10.4103/0019-5278.72240.
- Ryan SM, Nielsen CJ (2010). Global warming potential of inhaled anesthetics: application to clinical use. *Anesth Analg.* 111(1):92–8. doi:10.1213/ANE.0b013e3181e058d7.
- Schnietz K, Epstein M (2005). Exploring the financial value of a reputation for corporate social responsibility during a crisis. *Corp Reput Rev.* 7(4):327–45. doi:10.1057/palgrave.crr.1540230.
- Sherman J, Le C, Lamers V, Eckelman M (2012). Life cycle greenhouse gas emissions of anesthetic drugs. *Anesth Analg.* 114(5):1086–90. doi:10.1213/ANE.0b013e31824f6940.
- Singh S, Prakash V (2007). Toxic environmental releases from medical waste incineration: a review. *Environ Monit Assess.* 132(1–3):67–81. doi:10.1007/s10661-006-9503-3.
- Skjelkvåle BL, Stoddard JL, Jeffries DS, Tørseth K, Høgåsen T, Bowman J (2005). Regional scale evidence for improvements in surface water chemistry 1990–2001. *Environ Pollut.* 137(1):165–76. doi:10.1016/j.envpol.2004.12.023.
- Smith AJB, Tennison I, Roberts I, Cairns J, Free C (2013). The carbon footprint of behavioural support services for smoking cessation. *Tob Control.* 22(5):302–7. doi:10.1136/tobaccocontrol-2012-050672
- Smith PAC, Sharicz C (2011). The shift needed for sustainability. *Learn Organ.* 18(1):73–86. doi:10.1108/09696471111096019.
- Sprinkle GB, Maines LA (2010). The benefits and costs of corporate social responsibility. *Bus Horiz.* 53(5):445–53. doi:10.1016/j.bushor.2010.05.006.

- Stall NM, Kagoma YM, Bondy JN, Naudie D (2013). Surgical waste audit of 5 total knee arthroplasties. *Can J Surg.* 56(2):97–102. doi:10.1503/cjs.015711.
- Stankovic A, Nikic D, Nikolic M (2008). Report: treatment of medical waste in Nisava and Toplica districts, Serbia. *Waste Manag Res.* 26(3):309–13.
- Steventon A, Bardsley M, Billings J, Dixon J, Doll H, Hirani S et al. (2012). Effect of telehealth on use of secondary care and mortality: findings from the whole system demonstrator cluster randomized trial. *BMJ.* 344:e3874. doi:10.1136/bmj.e3874.
- Stranddorf H, Hoffmann L, Schmidt A (2005). Impact categories, normalization and weighting in LCA. Copenhagen: Danish Environmental Protection Agency.
- Subaiya S, Hogg E, Roberts I (2011). Reducing the environmental impact of trials: a comparison of the carbon footprint of the CRASH-1 and CRASH-2 clinical trials. *Trials.* 12:31. doi:10.1186/1745-6215-12-31.
- Tay S, Weinberg L, Peyton P, Story D, Briedis J (2013). Financial and environmental costs of manual versus automated control of end-tidal gas concentrations. *Anaesth Intensive Care.* 41(1):95–101.
- Tennison I (2010). Indicative carbon emissions per unit of health care activity. Cambridge: Eastern Region Public Health Observatory.
- Thomas KV, Dye C, Schlabach M, Langford KH (2007). Source to sink tracking of selected human pharmaceuticals from two Oslo city hospitals and a wastewater treatment works. *J Environ Monit.* 9:1410–18. doi:10.1039/b709745j.
- Thompson Coon J, Boddy K, Stein K, Whear R, Barton J, Depledge MH (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental well-being than physical activity indoors? A systematic review. *Environ Sci Technol.* 45(5):1761–72. doi:10.1021/es102947t.
- Toktobaev N, Emmanuel J, Djumalieva G, Kravtsov A, Schüth T (2015). An innovative national health care waste management system in Kyrgyzstan. *Waste Manag Res.* 33(2):130–8. doi:10.1177/0734242X14565209.
- Topf M (2005). Psychological explanations and interventions for indifference to greening hospitals. *Health Care Manage Rev.* 30(1):2–8.
- Towers A, Eastwood M, Castles H, Cosgrove P (2002). Sustainable food procurement in the NHS. London: Sustainable Development Commission (<http://www.sd-commission.org.uk/publications.php?id=38>, accessed 17 June 2016).
- Tsakona M, Anagnostopoulou E, Gidaracos E (2007). Hospital waste management and toxicity evaluation: a case study. *Waste Manag.* 27(7):912–20. doi:10.1016/j.wasman.2006.04.019.
- UNDP (2016). Green Procurement Index Health (GPIH): phase 1 2015 project report. Istanbul: United Nations Development Programme (https://issuu.com/informal_int_task_team_sphs/docs/gpih_booklet-report-2015, accessed 20 June 2016).

- UNEP (2013). Minamata Convention on Mercury. Nairobi: United Nations Environment Programme (<http://www.mercuryconvention.org/Convention/tabid/3426/Default.aspx>, accessed 17 June 2016).
- Valavanidis A, Iliopoulos N, Fiotakis K, Gotsis G (2008). Metal leachability, heavy metals, polycyclic aromatic hydrocarbons and polychlorinated biphenyls in fly and bottom ashes of a medical waste incineration facility. *Waste Manag Res.* 26(3):247–55.
- Verlicchi P, Al Aukidy M, Galletti A, Petrovic M, Barcelo D (2012). Hospital effluent: investigation of the concentrations and distribution of pharmaceuticals and environmental risk assessment. *Sci Total Environ.* 430:109–18. doi:10.1016/j.scitotenv.2012.04.055.
- Verlicchi P, Al Aukidy M, Zambello E (2015). What have we learned from worldwide experiences on the management and treatment of hospital effluent? An overview and a discussion on perspectives. *Sci Total Environ.* 514:467–91. doi:10.1016/j.scitotenv.2015.02.020.
- Vestreng V, Myhre G, Fagerli H, Reis S, Tarrason L (2007). Twenty-five years of continuous sulphur dioxide emission reduction in Europe. *Atmos Chem Phys.* 7(12):3663–81. doi:10.5194/acp-7-3663-2007.
- Vidal R, Moliner E, Pikula A, Mena-Nieto A, Ortega A (2015). Comparison of the carbon footprint of different patient diets in a Spanish hospital. *J Health Serv Res Policy.* 20(1):39–44. doi:10.1177/1355819614553017.
- Vinodhini R, Narayanan M (2008). Bioaccumulation of heavy metals in organs of fresh water fish *Cyprinus carpio* (Common carp). *Int J Environ Sci Technol.* 5(2):179–82. doi:10.1007/BF03326011.
- Vogt J, Nunes KRA (2014). Recycling behaviour in health care: waste handling at work. *Ergonomics.* 57(4):525–35. doi:10.1080/00140139.2014.887786.
- Weuve J, Sánchez BN, Calafat AM, Schettler T, Green RA, Hu H et al. (2006). Exposure to phthalates in neonatal intensive care unit infants: urinary concentrations of monoesters and oxidative metabolites. *Environ Health Perspect.* 114(9):1424–31. doi:10.1289/ehp.8926.
- WHO (2000). The world health report 2000 – health systems: improving performance. Geneva: World Health Organization (<http://www.who.int/whr/2000/en/>, accessed 16 June 2016).
- WHO (2005). Mercury in health care: policy paper. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/medicalwaste/mercurypolpaper/en/, accessed 17 June 2016).
- WHO (2006). Air quality guidelines – global update 2005. Geneva: World Health Organization (http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/, accessed 17 June 2016).
- WHO (2015a). Water, sanitation and hygiene in health care facilities: status in low- and middle-income countries and way forward. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/wash-health-care-facilities/en/, accessed 17 June 2016).
- WHO (2015b). Operational framework for building climate resilient health systems. Geneva: World Health Organization (<http://www.who.int/globalchange/publications/building-climate-resilient-health-systems/en/>, accessed 14 September 2016).

- WHO (2016). Mercury and health: fact sheet. Geneva: World Health Organization (<http://www.who.int/mediacentre/factsheets/fs361/en/>, accessed 17 June 2016).
- WHO Regional Office for Europe (2010). Parma Declaration on Environment and Health. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/2010/protecting-health-in-an-environment-challenged-by-climate-change-european-regional-framework-for-action/parma-declaration-on-environment-and-health>, accessed 16 June 2016).
- WHO Regional Office for Europe (2013). Health 2020: a European policy framework and strategy for the 21st century. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/health-topics/health-policy/health-2020-the-european-policy-for-health-and-well-being/publications/2013/health-2020.-a-european-policy-framework-and-strategy-for-the-21st-century-2013>, accessed 16 June 2016).
- WHO Regional Office for Europe (2014). The case for investing in public health. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/health-topics/Health-systems/public-health-services/publications/2015/the-case-for-investing-in-public-health>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015a). European Health for All database [online database]. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/data-and-evidence/databases/european-health-for-all-database-hfa-db>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015b). Ambulatory care sensitive conditions in Germany. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/countries/germany/publications/ambulatory-care-sensitive-conditions-in-germany-2015>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015c). Ambulatory care sensitive conditions in Latvia. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/countries/latvia/publications/ambulatory-care-sensitive-conditions-in-latvia-2015>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015d). Ambulatory care sensitive conditions in Kazakhstan. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/countries/kazakhstan/publications3/ambulatory-care-sensitive-conditions-in-kazakhstan-2015>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015e). Ambulatory care sensitive conditions in Portugal. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/health-topics/Health-systems/health-service-delivery/publications/2016/ambulatory-care-sensitive-conditions-in-portugal-2016>, accessed 16 June 2016).
- WHO Regional Office for Europe (2015f). Ambulatory care sensitive conditions in the Republic of Moldova. Copenhagen: WHO Regional Office for Europe (<http://www.euro.who.int/en/countries/republic-of-moldova/publications2/ambulatory-care-sensitive-conditions-in-the-republic-of-moldova-2015>, accessed 16 June 2016).
- Woods DL, McAndrew T, Nevadunsky N, Hou JY, Goldberg G, Yi-Shin Kuo D et al. (2015). Carbon footprint of robotically-assisted laparoscopy, laparoscopy and laparotomy: a comparison. *Int J Med Robot.* 11(4):406–12. doi:10.1002/rcs.1640.
- Wootton R, Tait A, Croft A (2010). Environmental aspects of health care in the Grampian NHS region and the place of telehealth. *J Telemed Telecare.* 16(4):215–20. doi:10.1258/jtt.2010.004015.

Yellowlees PM, Chorba K, Burke Parish M, Wynn-Jones H, Nafiz N (2010). Telemedicine can make health care greener. *Telemed J E Health*. 16(2):229–32. doi:10.1089/tmj.2009.0105.

Zander A, Niggebrugge A, Pencheon D, Lyratzopoulos G (2011). Changes in travel-related carbon emissions associated with modernization of services for patients with acute myocardial infarction: a case study. *J Public Health (Oxf)*. 33(2):272–9. doi:10.1093/pubmed/fdq048.

ANNEX 1.

LITERATURE SEARCH STRATEGY

INCLUSION CRITERIA

- The main subject of the article had to relate to one or more of the three subjects described in the objectives:
 - the environmental impact of health systems in Europe;
 - potential benefits of fostering environmental sustainability in health systems;
 - barriers to and incentives for such action.
- “Health systems” are defined with reference to the WHO health system functions, and the scope of the review therefore included both the delivery of health care and the supply chains on which health care depends.
- Articles had either to introduce new empirical data or to reviews empirical research.
- Empirical articles could use any methodological approach.
- Articles must have been published within the last 10 years.
- They must be written in English.

EXCLUSION CRITERIA

- Journalistic articles and short comment pieces were excluded.
- Articles about the impact of global environmental change on human health were excluded.
- Articles focusing on health systems outside the WHO European Region were excluded unless they related to issues on which no or little European evidence had been identified.

PRIMARY SEARCH STRATEGY

- The PubMed database was used for the primary literature search. Two searches were conducted – one based on subject headings (using “MeSH” terms) and the other using free text searching.
- The table below lists the search terms used. For both searches, articles had to include (or be categorized with) one or more terms relating to environmental sustainability (group A), AND one or more term relating to health systems (group B).

Group A. Environmental sustainability	Group B. Health systems
<ul style="list-style-type: none"> ■ Environmental sustainability/impact/ protection/audit/ change/management ■ Sustainable development/buildings/ estates/facilities/ transport/procurement/ pathways/care ■ Climate change, global warming, greenhouse effect, greenhouse gas ■ Carbon dioxide/emissions/footprint/ reduction/ accounting/modelling/offset ■ Energy use/saving/efficiency ■ Renewable energy, sustainable energy ■ Water use/consumption/conservation/ management ■ Medical waste ■ Waste management/disposal/reduction/ minimization ■ Resource use/consumption ■ Recycling ■ Pollution, pollutant, hazardous, toxic, emissions, mercury ■ Green, greener, greening ■ Conservation ■ Habitat, biodiversity, land use ■ Acidification ■ Eutrophication 	<ul style="list-style-type: none"> ■ Health system/services/sector ■ Health care, health care ■ Medicine, medical ■ Primary care, community care, community services, ambulatory care, acute care, intensive care, critical care, surgery, surgical, hospital ■ Public health, health promotion, preventive health services, preventive medicine ■ Digital health, eHealth, mHealth, telehealth, telemedicine, telecare ■ Health facilities/financing/workforce/ planning/resources/communication

SUPPORTING STRATEGIES

The following strategies were used to augment the PubMed search:

- searching the ScienceDirect database using the same search terms to find additional articles not identified by the PubMed search;
- using citation indexes to find additional articles that have cited key articles identified by the primary search;
- using reference lists of key articles to identify additional articles.

GREY LITERATURE

Grey literature was identified through the following routes:

- searching using the Open Grey database;
- searching the websites of key organizations, including:
 - Health Care Without Harm
 - Centre for Sustainable Health Care
 - Sustainable Development Unit

- other relevant organizations acting at the European/global level;
- seeking recommendations from relevant experts, including within WHO;
- searching the website of the European Commission for relevant EU-funded research projects.

Grey literature was filtered for quality. The key criterion for inclusion was that it had to describe primary empirical evidence or draw systematically on secondary evidence published elsewhere. For primary evidence, the methods through which this was obtained had to be described in sufficient detail for an appraisal of the quality of the evidence. Where grey literature drew on secondary evidence, this had to be referenced in full.



The WHO Regional Office for Europe



The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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