Health in the green economy

Co-benefits to health of climate change mitigation

HEALTH CARE FACILITIES *Preliminary findings – initial review*

Key messages

Health gains/risks

- **While hospitals and health clinics are not a specific focus of mitigation assessment by the Intergovernmental Panel on Climate Change, adoption of safe and sustainable building measures by health facilities will offer more health co-benefits than the same measures applied to other commercial buildings.** This is partly due to health facilities' large demands for reliable energy, clean water and temperature/air flow control in treatment and infection prevention. Significant health gains also can be expected from specific interventions; for instance, the use of natural ventilation is both an effective energy-saving and infection-control measure.
- **Resilience of health care services may be enhanced through use of (clean) onsite energy co-generation** that ensures more reliable energy supply in cities where frequent energy outages occur, and in emergencies.
- **Access to health care can be enhanced and made more reliable through off-grid renewable energy systems.** Particularly in remote, resource-poor settings, renewable energy sources can supply basic electricity for life-saving procedures that might not otherwise be feasible.
- **Health risks to health workers, patients and communities will be reduced by improved management of health care and waste – and so will the carbon footprint.** Some 15–25% of health care waste is infectious waste; 3% is chemical or pharmaceutical waste; radioactive/cytotoxic waste accounts for less than 1%.[1] Scavenged needles and syringes from dump sites represent health threats, as do dioxins, furans and other toxic pollutants emitted by poor incineration. Better management of solid, liquid and gaseous health care products, as well as emissions from infectious, chemical and radioactive agents, can reduce exposure to risks of hepatitis B/C and HIV infections as well as to reproductive problems and cancers. Improved waste treatment measures can reduce the carbon footprint of such treatment and of energy required for water supply (resource extraction).
- **The health care sector is well-positioned to "lead by example"** in terms of reducing climate change pollutants and by demonstrating how climate change mitigation can yield tangible, immediate health benefits.

"Win-win" strategies for health care services and mitigation[a]

- **Water conservation, safe onsite water storage and rainwater harvesting.** Large quantities of water and special water treatment are required for many health care procedures, such as renal dialysis, burn care and cleaning of medical devices.[8] Many rural health facilities lack piped water. Water management is thus important to reduce health risks in care facilities, as well as water-borne disease in general.[9] Water efficiencies can help improve water access while reducing carbon-intensive water extraction and ecosystem degradation.[10] Rainwater harvesting is one conservation measure

[a] See also Table 1.

About Health in the Green Economy

Many strategies to reduce climate change have large, immediate health benefits. Others may pose health risks or tradeoffs. Examined systematically, a powerful new dimension of measures to address climate change emerges.

WHO's *Health in the Green Economy* series, to be published in spring 2011, is reviewing the evidence about expected health impacts of greenhouse gas mitigation strategies in light of mitigation options considered in the *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC).

The aim is to propose important health co-benefits for sector and health policy-makers, and for consideration in the next round of IPCC mitigation reviews (*Working Group III – Fifth Assessment Report* [AR5]). Opportunities for potential health and environment synergies are identified here for health care facilities.

World Health Organization

widely promoted in WHO's South-East Asia Region.[11,12] While rainwater, like other sources, may require treatment, harvested rainwater is used in a number of large urban hospitals recognized for "green" design.[13,14]

- **Improved recapture and reuse of waste anaesthetic gases can provide significant climate and health co-benefits.** Waste anaesthetic gases are not only powerful global warming pollutants, they are associated with reproductive risks (spontaneous abortion and congenital abnormalities), headache, nausea, fatigue and cognitive impairment for exposed health workers.[15–19] These gases need further review and discussion in mitigation analyses.
- **Well-designed telehealth schemes may reduce the travel-related carbon footprint of health care, and also improve access and outcomes for vulnerable groups.** Simple mobile phone applications supporting emergency assistance and long-distance consultation with health-care workers in remote areas are being used in many developing countries with good results.[20–24] Systematic review of telehealth, telecare and home monitoring schemes has found evidence of effective management of the frail and elderly for diabetes as well as effective management of mental health conditions, cardiac disease and high-risk pregnancy monitoring.[25–29] Meta-analysis also found evidence of health benefits for patients with lung diseases, diabetes and chronic wounds.[26] At the same time, telehealth should recognize the importance of direct contact between patients and their health-care providers.
- **Procurement of products that subsequently are not used**, particularly pharmaceuticals, was estimated to represent 60% of the carbon footprint of England's National Health Service (NHS).[2] Better-managed procurement saves health care resources as well as reducing unnecessary exposures to chemical and biological agents and their waste products. In the NHS case, it was estimated that a 10% reduction in pharmaceuticals procurement would lead to a 2% reduction in the system's carbon emissions.[2]

Health equity

- **Siting of health-care facilities near major public transport arteries, and safe pedestrian/cycling routes** can improve safe and equitable access to facilities. Since hospitals are typically large employers, public transport and active travel routes can enhance opportunities for physical activity among health care workers and reduce emissions from travel to work.
- **Development of low-energy and no-energy medical devices can be expanded in tandem with use of renewable energy sources** (e.g. photovoltaic [PV] solar panels) to improve access to vital health services in poorly resourced settings. Examples of medical devices that can use solar power include: LED lights and lanterns, LED microscopes for improved tuberculosis diagnosis;[30,31] and solar-powered, direct current (DC) vaccine-storage refrigerators.[32] A wide array of rapid diagnostics require no energy at all to use. The US Department of Energy is currently sponsoring research on use and development of DC grids and devices for residential and small commercial applications.[33]

The climate footprint of health care facilities

Health care facility activities have been estimated to represent 3–8% of the climate change footprint in developed-country settings such as England's National Health Service and the United States of America.[2,3] While no such health sector estimates exist elsewhere at a national level, electricity access and hospital electricity consumption data in countries of South-East Asia and sub-Saharan Africa reflect far lower energy use rates.[4,5] At the same time, it has been estimated that between 200 000 and 400 000 hospitals and health clinics in developing countries have no electricity or have unreliable electric supplies.[6]

Health care procedures also generate other greenhouse gases, including nitrous oxide, refrigerants and waste anaesthetic gases. Inhaled anaesthetics (e.g. nitrous oxide, desflurane, isoflurane and sevoflurane) may have large global warming potentials (GWPs)[b 7] Health facility use of water and transport services, as well as health care waste disposal, all have a carbon footprint insofar as these consume energy and/or generate emissions of CO_2 as well as other climate change agents.

[b] Global warming potential (GWP) for a particular greenhouse gas is described by the United States Environmental Protection Agency (USEPA) as "the ratio of heat trapped by one unit mass of the greenhouse gas to that of one unit mass of CO2 over a specified time period." (www.epa.gov). For more detail see: *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.*

SCOPE AND METHODS

This analysis reviews mitigation measures relevant to health care facilities, as covered in assessments for commercial buildings and for industry by the Intergovernmental Panel on Climate Change (IPCC), *Working Group III – Fourth Assessment Report (2007).* Mitigation measures have been examined in terms of: their *direct* impacts on the delivery of health care services; on environmental and occupational health for health workers, patients and communities; and *indirect benefits* such as improved resilience of health care facilities and more reliable energy provision. In addition, this analysis looks at how health equity is impacted by certain mitigation strategies. For instance, in poor, off-grid rural clinics, more use of renewable energy sources, along with more efficient medical devices, may increase access to and reliability of health care. While most of the focus is on IPCC-assessed mitigation strategies, some strategies not explicitly noted by IPCC also are considered, when these take advantage of unique health care sector opportunities to generate health and environment co-benefits.

This report does not analyse the impact of climate change on health care delivery. While climate change has a significant impact on public health responses to changing patterns of disease transmission and natural disasters, this is largely an "adaptation" issue, covered by a considerable body of ongoing work both in WHO, the United Nations system and IPCC.[37,38,39] This review, in contrast, is focused on mitigation, which is less explored. Of course, where mitigation measures can also improve the health sector's adaptive response to climate change, these co-benefits are described.

Health sector activities considered

WHO defines the health care system as "all organizations, institutions, and resources that are devoted to producing health actions." A health action is defined as any effort, whether personal health care, public health service or inter-sectoral initiative, whose primary purpose is to improve health.[40] In practice, the health care sector includes such a wide variety of practices and activities that precise definition of the sector's boundaries across countries and cultures can probably never be conclusive.[41] This document focuses on health care facilities, including those that provide direct health treatment procedures for patients. This includes hospitals and health care clinics, but not health clubs, home-based health care or pharmaceutical manufacturing. The focus is largely on facility-based services and not outreach such as vaccine and bednet distribution campaigns, vector management and emergency relief. Health care facilities are examined because they represent a major part of the overall sectoral activities and of the sector's climate and environment impacts.

Mitigation strategies reviewed

The potential health impacts of key IPCC-reviewed strategies were appraised in the light of health-based evidence identified in a review of nearly 300 peer-reviewed articles and reports relating to health facility building design and energy efficiency, as well as to environmental/occupational health determinants in health facilities. The health effects of IPCC-reviewed mitigation strategies were assessed in terms of their impacts on:

- environmental and occupational determinants of health among health workers, patients and communities;
- improved health care facility access to reliable energy and, where relevant, other energy-linked resources vital to basic health care provision, particularly clean water;
- potential overall savings in health care resources that presumably provide resources for other health care purposes.

Integral to all measures was consideration of how mitigation measures can improve health equity through better access to care.

BACKGROUND AND RATIONALE

Health care is a major economic sector worldwide. In 2007, world health expenditures totaled US$ 5.3 trillion, or US$ 639 per person per year[34,35], or roughly 8–10% of global GDP.[36] Modern health care procedures also require many energy-intensive processes in terms of water, lighting, heating, cooling and ventilation as well as waste disposal. Mitigation measures that use resources more efficiently save health sector resources in the short and long term, and also enhance provision of health care services and benefit health directly and indirectly. Until now, IPCC-reviewed mitigation strategies for commercial buildings and industry have not specifically focused on the health care sector or its facilities. However, this sector is worthy of special attention due to its size, its growth, and its direct impacts on health. As perceived leaders in health-promoting activities and behaviour, health policy decision-makers also can be expected to lead initiatives that address global environmental health now and in the future.

WHO is thus undertaking a review of potential health co-benefits (and where relevant, risks) of mitigation strategies relevant to health care facilities. Many of the strategies are common to commercial buildings and industry, and were considered and documented by the IPCC's *Fourth Assessment Report* in those chapters. Certain strategies, however, apply in different ways to the health care sector due to its unique needs. Moreover, the health care sector offers some unique opportunities for mitigation overlooked by other reviews.

SUMMARY OF INITIAL FINDINGS

A range of mitigation measures common to buildings and industry may have special relevance to health care facilities for provision of improved services. Key messages reflect some of the most policy-relevant findings. Table 1 provides a more systematic summary of health impacts and co-benefits of IPCC-reviewed and other targeted measures, including:

- building-related energy efficiencies;
- on-site energy generation and storage;
- intensified development and use of low-energy medical devices;
- appropriate use of natural (mixed-mode) ventilation and natural daylighting;
- on-site rainwater capture and treatment, as appropriate;
- waste/sewage treatment as appropriate;
- siting of facilities to improve access to health care by mass transport and active transport;
- materials procurement and waste reduction/management strategies;
- expanded use of telehealth and other home-care strategies
- reduction, recapture/reuse of inhaled anaesthetics.

Finally, there is a need for more systematic measuring and benchmarking of health sector energy consumption and emissions, as well as of overall environmental performance in the context of "greener" facility designs and use of renewable energy sources. Systematic assessment of the actual health impacts and economic impacts of energy-saving technologies, designs and devices also is needed to identify the most cost-effective and practical strategies, particularly for low-resource settings.

Major health organizations, beginning with WHO, have affirmed that climate change is a public health concern. Given the health sector's leadership role, it must demonstrate to the world how climate change can and should be addressed. A full report on the review will be published in the spring of 2011.

Table 1: Mitigation strategies applicable to the health care sector

Mitigation strategy	Actions	GHG impact	Health co-benefits	Limitations and needs
Improve energy supply and distribution efficiency (IPCC chapters 4 & 6)[42,43]	Fuel switching; energy recovery; distributed generation;[44] combined heat and power	Reduced transmission losses; reduced emissions from energy use, fuel production and transport	Health systems: immediate energy savings; operational resilience/ reliability Environmental risks: reduced air pollution exposures Health equity: improved access to reliable health care	Infrastructure retrofit and financing
On-site renewable energy sources (IPCC chapters 4 & 6)[42,43]	Solar photovoltaics (electricity) Thermal solar energy (e.g. space/hot water heating) Wind; concentrating solar; advanced biomass; fuel cells; geothermal energy	Reduced emissions from energy use, fuel production and transport	Health systems: Improved operational resilience/reliability; long-term energy savings Environmental risks: Reduced ambient air emissions from on-site fuel oil and wood-burning furnaces, particularly in developing countries, and from the transport of fuel Health equity: Anecdotal evidence of improved access to reliable health care[45]	Financing Systematic review of impacts of energy poverty in health facilities and of health outcomes related to sustainable energy interventions in health clinics

Mitigation strategy	Actions	GHG impact	Health co-benefits	Limitations and needs
Reduced-energy devices (IPCC chapter 6)[42]	Non-electric medical devices (e.g. rapid diagnostics) Direct-current devices (e.g. direct current (DC) refrigerators and ultrasound devices, LED lights and microscopes) Energy efficient appliances: right-sizing, match and numbers; reduced standby losses	Reduced emissions from energy use, fuel production and transport	Health systems: Energy and operations savings, energy security, improved functionality at night (due to lighting) and device reliability[46,47] Environmental effects: Decreased CO_2 emissions from energy device/ appliance usage[42] Disease/injury risk reduction: Improved diagnosis of tuberculosis with low-energy LED microscopes, anecdotal evidence of improved management of rural childbirth and health clinics with solar powered-LED lights/lanterns[45,46,48] Health equity: Increased access to health care,[46] energy security	Health sector and medical device sector investment in R&D for DC-powered and low-energy devices Management capacity for energy efficiencies
Passive cooling, heating and ventilation strategies (IPCC chapter 6)[42]	Natural ventilation in health care settings[49] Evaporative cooling Desiccant dehumidification Underground earth-pipe cooling	Reduced direct emissions from on-site energy production; reduced emissions from energy use, fuel production and transport	Health systems: Energy and operations savings, energy security Environmental risks: Reduced emissions from energy usage,[42,47] improved indoor air quality Disease risk: Decreased transmission of airborne infections, including tuberculosis[49] Equity impact: Energy security, improved social welfare, productivity and patient health	Infrastructure retrofit and financing Installation and maintenance of window screening in facilities vulnerable to vector-borne disease
Facility wastewater and solid waste management (IPCC chapter 10)[50]	Advanced autoclaving of infectious health care waste to reduce volume and make it suitable for municipal disposal[51] On-site wastewater pre-treatment and sanitation improvements[52,54] High-heat incineration of pharmaceuticals with pollution scrubbers[53]	Reduced energy expenditure for waste and water treatment Reduced greenhouse gas (GHG) footprint from waste treatment processes (e.g. more efficient incineration) in some settings Reduced aquifer and ecosystem damage from sewage/waste disposal	Health systems: Savings in waste/ water disposal fees, reduced waste volumes, improved compliance with local air quality regulations/ guidelines Environmental risks: Improved hygiene around facility, reduced methane and other emissions[50,55] Disease risks and health equity: Reduced risks of exposure to infectious agents, and to diarrhoea and other water-borne diseases (cholera, etc.) for those living downstream of health facilities[56,57]	Infrastructure retrofit and financing Inadequate or absent community waste treatment and wastewater treatment systems downstream
Reduced GHG emissions from anaesthesia gas use and disposal[7]	Waste anaesthetic gas recapture and scavenging[16]	Reduced direct emissions from anaesthesia gas waste	Health systems: Anaesthesia cost savings with reuse Environmental risks: Reduced anaesthesia emissions Disease risk: Reduced health risks (reproductive, nervous system, cognitive disorders) for health workers exposed to gas Health equity: Improved health worker productivity	Infrastructure limitations, technology availability, limited expertise, ability to procure and secure financing

Mitigation strategy	Actions	GHG impact	Health co-benefits	Limitations and needs
Reduced procurement carbon footprint[58]	Better-managed procurement of pharmaceuticals, medical devices, business products and services, food/catering and other facility inputs	Reduced energy footprint in production and transport of unused/expired pharmaceuticals and products	Health systems: resource savings on unused/wasted products, estimated 10% reduction in pharmaceuticals procurement determined feasible by England's National Health Service[58] Disease risks: reduced risks from use of outdated/expired products, but increased risks if supply lines for refills of essential products are unreliable	Infrastructure and supply line reliability, administrative/IT capacity for precise inventories
Telehealth/ telemedicine[59]	Home patient telemonitoring and guidance Emergency response Health worker advice/ consultation/ collaboration via mobile phones	Reduced emissions from health care-related travel	Health systems: More cost-effective health care[59–61] Environmental risks: Reduced travel-related emissions and risk of travel-related injuries, particularly to frail and vulnerable populations Disease risks: Improved management of chronic conditions, such as diabetes and heart disease, as well as emergency response Health equity: Better access to health care advice in poorly-resourced remote locations	Infrastructure limitations; limited expertise
Health facilities in proximity to public transport and safe walking/cycling (IPCC Chapter 4)[62]	Public transport options mapped during planning of buildings to locate new facilities nearby Employee incentives for public active transport use and facilities	Reduced transport-related emissions from health worker and hospital visitor travel	Environmental risks: reduced transport-related emissions Health risks: reduced traffic injury risk for health workers and hospital/clinic visitors travelling to health facilities,[63,64] Potential for active transport by health care workers to reduce risks of hypertension, cardiac disease and diabetes[65,66] Health equity: Improved facility access for health workers and visitors who do not have cars[67–69]	Infrastructure, land availability and use limitations
Conserve and maintain water resources[70]	Water-efficient fixtures, leakage management, water safety[71,72] Onsite water treatment and safe water storage in health facilities[8] Rainwater harvesting,[72] greywater recapture/ recycling[73]	Reduced energy use for water extraction from surface/aquifer sources Reduced truck transit of water resources Reduced aquifer and ecosystem damage from water extraction	Health systems: Improved performance due to better access to safe water,[8,75] savings in water fees Environmental risks: Reduced water contamination from health facility activities Disease risk: Reduced disease transmission from unsafe water and drinking water[74] Health equity: Improved access to safe, potable water in poorly resourced health facilities[75]	Infrastructure and financing in poorly resourced settings Building codes in developed countries may require use of piped water only

SELECTED REFERENCES

1. *Safe healthcare waste management*. Geneva, World Health Organization, 2004. (http://www.healthcarewaste.org/en/160_hcw_policy.html)
2. *NHS England Carbon Footprinting Report*. London, National Health Service / Sustainable Development Unit, 2008.
3. Chung J, Meltzer D. Estimate of the carbon footprint of the US health care sector. *Journal of the American Medical Association*, 2009, 302(18):1970–1972.
4. *Energy efficiency in hospitals – best practice guide*. New Delhi, USAID/India, 2009. (http://eco3.org/energy-efficiency-in-hospitals-best-practice-guide-2/)
5. *Electricity access data in hospitals, health centres and community clinics in two counties serving 500,000 people*. Liberian Biomedical Research Institute, personal communication to UBS Optimus Foundation, 2010.
6. *Estimate of health clinics lacking electricity access based on International Energy Agency data on lack of electricity access in the general population and distribution of health care facilities globally*. We Care Solar, personal communication to the UBS Optimus Foundation, 2010.
7. Ryan SM, Nielsen C. Global warming potential of inhaled anesthetics: application to clinical use. *Anesthesia & Analgesia*, 2010, 111(1):92–98.
8. Drinking-water quality in health care facilities. In: *WHO Guidelines for drinking-water quality, third edition, incorporating first and second addenda*. Geneva, World Health Organization, 2008:102.
9. *Combating waterborne disease at the household level*. Geneva, World Health Organization, 2007.
10. Jordan, water is life. In: *Health and Environment: managing the linkages for sustainable development*. Geneva, World Health Organization, 2008.
11. *Sustainable Development and Healthy Environment: Water, Sanitation and Health: Rainwater Harvesting*. World Health Organization, Regional Office for South-East Asia, 2010. (http://www.searo.who.int/en/Section23/Section1000_15437.htm)
12. Regional high-level meeting on rainwater harvesting, 28–30 June 2009. Kathmandu, Government of Nepal & World Health Organization, 2009. (http://www.moppw.gov.np/rainwater.html)
13. Sambhavna Trust Clinic, Bhopal, India. In: Guenther R, Vittori, G. *Sustainable healthcare architecture*. Hoboken, John Wiley & Sons, 2008:57.
14. *Kohinoor is a LEEDing light*. Mumbai, Indian Express Healthcare, July 2010. (http://www.expresshealthcare.in/201007/strategy02.shtml)
15. Shiraishi Y, Ikeda K. Uptake and biotransformation of sevoflurane in humans: a comparative study of sevoflurane with halothane, enflurane, and isoflurane. *Journal of Clinical Anesthesia*, 1990, 2:381–386.
16. Krajewski W et al. Occupational exposure to nitrous oxide: the role of scavenging and ventilation systems in reducing the exposure level in operating rooms. *International Journal of Hygiene and Environmental Health*, 2007, 210(2):133–138.
17. Hemminki K, Kyyrönen P, Lindbohm ML. Spontaneous abortions and malformations in the offspring of nurses exposed to anesthetic gases, cytostatic drugs, and other potential hazards in hospitals, based on registered information of outcome. *Journal of Epidemiology & Community Health*, 1985, 39(2):141–147.
18. *Waste anesthetic gases: occupational hazards in hospitals*. Cincinnati, US Centers for Disease Control and Prevention / National Institute for Occupational Safety and Health, 2007.
19. Tompa A et al. Chemical safety and health conditions among Hungarian hospital nurses. *Annals of the New York Academy of Sciences*, 2006, 1076:635–48.
20. Wooten R et al., eds. *Telehealth in the developing world*. London & Ottawa, Royal Society of Medicine Press & International Development Research Center, 2009.
21. Chib A et al. Midwives and mobiles: using ICTs to improve healthcare in Aceh Besar, Indonesia. *Asian Journal of Communication*, 2008, 18(4):348–364.
22. Meso P, Mbarika V, Sood S. An overview of potential factors for effective telemedicine transfer to sub-Saharan Africa. *Institute of Electrical and Electronics Engineers: Transactions on Information Technology in Biomedicine*, 2009, 13(5):734–739.
23. Foster KR. Telehealth in sub-Saharan Africa: Lessons for humanitarian engineering. *Institute of Electrical and Electronics Engineers Technology and Society Magazine*, 2010, 29(1):42–49.
24. Pal A et al. Telemedicine diffusion in a developing country: the case of India. *Institute of Electrical and Electronics Engineers Transactions on Information Technology in Biomedicine*, 2005, 9(1):59–65.
25. Barlow J et al. A systematic review of the benefits of home telecare for frail elderly people and those with long-term conditions. *Journal of Telemedicine and Telecare*, 2007, 13:172–179.
26. Dang S, Dimmick S, Kelkar G. Evaluating the evidence base for the use of home telehealth remote monitoring in elderly with heart failure. *Telemedicine Journal and E-Health*, 2009, 15(8):783–796.
27. Kovalski N et al. Effect of remote orthopedic consultation on hospital referrals in a community-based urgent care facility. *Israeli Journal of Emergency Medicine*, 2008, 8(3):29–33.
28. Polisena J et al. Home telemonitoring for congestive heart failure: a systematic review and meta-analysis. *Journal of Telemedicine and Telecare*, 2010, 16:68–76.
29. Stroetmann KA et al. *How can telehealth help in the provision of integrated care?* Permanand G et al., eds. Copenhagen, WHO Regional Office for Europe, 2010:7–9 (WHO Policy Brief Series, No. 13).
30. Ramsay A et al. New policies, new technologies: modelling the potential for improved smear microscopy services in Malawi. *PloS ONE*, 2009, 4(11):e7760.
31. *Approaches to improve sputum smear microscopy for tuberculosis diagnosis*. Expert group meeting report. Geneva, World Health Organization, 2009.
32. *Pre-qualification of cold chain-related products under the PQS system: A guideline for manufacturers of solar power systems (PQS/E003)*. Geneva, World Health Organization, 2010.
33. Van Buskirk R, Marnay C. *Direct DC power systems for efficiency and renewable energy integration with a residential and small commercial focus*. Washington, US Department of Energy, 2009.
34. "Composition of World Health Expenditures, 2007." National Health Accounts. World Health Organization. Sept. 2010. (http://www.who.int/nha/en/) (http://www.who.int/nha/use/pie_2007-full.pdf)
35. "Spending on health, a global overview." *Fact sheet*. Geneva, World Health Organization. (http://www.who.int/mediacentre/factsheets/fs319.pdf)
36. *Global GDP in US dollars, not adjusted for inflation*. World Bank, 2010. (http://www.google.com/publicdata?ds=wb-wdi&met=ny_gdp_mktp_cd&idim=country:USA&dl=en&hl=en&q=gdp#met=ny_gdp_mktp_cd&tdim=true)
37. Barker T et al. Summary for Policymakers. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York, Cambridge University Press, 2007:1–23.
38. Secretary-General's Advisory Group on Energy and Climate Change. *Energy for a sustainable future: report and recommendations*. New York, United Nations, 2010.
39. *Protecting health from climate change: connecting science, policy and people*. Geneva, World Health Organization, 2009.
40. *World Health Report 2000 – Health systems: improving performance*. Geneva, World Health Organization, 2000.
41. International Hospital Federation and the World Health Organization. *The performance of hospitals under changing socioeconomic conditions: A global study on hospital sector reform*. Geneva: World Health Organization, 2007. (http://www.ihf-fih.org/en/Publications/IHF-Publications/Other-publications/Hospital-Performance-The-performance-of-hospitals-under-changing-socioeconomic-conditions)

42. Levine M et al. Residential and commercial buildings. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York, Cambridge University Press, 2007:387–446
43. Sims REH et al. Energy supply. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York, Cambridge University Press, 2007:251–322.
44. *Distributed Generation Program.* California Environmental Protection Agency Air Resources Board, 2010. (http://www.arb.ca.gov/energy/dg/dg.htm)
45. *Mission statement*, We Care Solar. (http://www.wecaresolar.com/mission)
46. *Affordable technology: Blood pressure measuring devices for low-resource settings*. Geneva, World Health Organization, 2005.
47. *Global forum to improve developing country access to medical devices*. Geneva, World Health Organization, 2010. (http://www.who.int/mediacentre/news/notes/2010/medical_devices_20100908/en/print.html)
48. *Journey towards a billion*. A quarterly newsletter of the Lighting a Billion Lives Campaign. TERI, 2:3, July 2010. (http://labl.teriin.org/pdf/July2010.pdf)
49. Atkinson J et al. *Natural ventilation for infection control in health-care settings*. Geneva, World Health Organization, 2009.
50. Bogner, JM et al. Waste management. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York, Cambridge University Press, 2007; 585–618. (http://www.ipcc-wg3.de/publications/assessment-reports/ar4/.files-ar4/Chapter10.pdf)
51. Emmanuel J. *Best environmental practices and alternative technologies for medical waste management*. Botswana, Institute of Waste Management of Southern Africa, Botswana Chapter, 2007.
52. Franceys R, Pickford J, Reed R. *Guide to the development of on-site sanitation*. Geneva, World Health Organization, 1992.
53. Prüss A, Giroult E, Rushbrook P. *Safe management of wastes from health-care activities*. Geneva, World Health Organization, 1999.
54. WHO *guidelines for the safe use of wastewater, excreta and greywater.* Geneva, World Health Organization & United Nations Environment Programme, 2006. (http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html)
55. Health Care Waste Management, Geneva, World Health Organization. (http://www.healthcarewaste.org/en/115_overview.html)
56. *Essential environmental health standards in health care*. Geneva, World Health Organization, 2008.
57. *Water safety in buildings*. Geneva, World Health Organization, 2010 (in press). (http://www.who.int/water_sanitation_health/hygiene/settings/water_safety_buildings_march2010.pdf)
58. *NHS England carbon emissions: carbon footprinting study*. London, Sustainable Development Commission / Stockholm Environment Institute, 2008.
59. Johnston K et al. The cost-effectiveness of technology transfer using telemedicine. *Health Policy and Planning*, 2004, 19(5):302–309.
60. Fuhr J, Pociask S. *Broadband services: economic and environmental benefits*. Washington, American Consumer Institute, 2007.
61. Beale S, Sanderson D, Kruger J. *Evaluation of the telecare development programme*. Edinburgh, Scottish Government, 2009.
62. Kahn Ribeiro S et al. Transport and its infrastructure. In: *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York, Cambridge University Press, 2007:323–385.
63. Nantulya V, Reich M. The neglected epidemic: road traffic injuries in developing countries. *British Medical Journal*, 2002, 324(7346):1139–1141.
64. Peden M et al., eds. *World report on road traffic injury prevention*. Geneva, World Health Organization, 2004.
65. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *Journal of Science and Medicine in Sport*, 2004, 7(1):6–19.
66. *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva, World Health Organization, 2009.
67. Dora C, Phillips M, eds. *Transport, environment and health*. Copenhagen, World Health Organization Regional Office for Europe, 2000.
68. *Hidden cities: unmasking and overcoming health inequities in urban settings*. Kobe, World Health Organization / WHO Centre for Health Development & United Nations Human Settlements Programme, 2010.
69. *Healthy transport in developing cities, Health and Environment Linkages Initiative*. Geneva, World Health Organization & United Nations Environment Programme, 2009. (http://www.who.int/heli/risks/urban/urbanenv/en/index.html)
70. *Water in a changing world*. Paris, United Nations Educational Scientific and Cultural Organization, 2009.
71. *Water safety in buildings*. World Health Organization, 2010. (http://www.who.int/water_sanitation_health/hygiene/settings/water_safety_buildings_march2010.pdf)
72. Farley M. *Leakage management and control: A best practice training manual*. Geneva, World Health Organization, 2001.
73. Rainwater harvesting. In: *WHO Guidelines for drinking-water quality, third edition, incorporating first and second addenda*. Geneva, World Health Organization, 2008:120e.
74. *Overview of greywater management, health considerations. regional consultation on national priorities and plans of action on management and reuse of wastewater*. Amman, World Health Organization, Regional Office for the Eastern Mediterranean, Center for Environmental Health Activities (CEHA) 2006. (http://www.emro.who.int/ceha/pdf/Greywter%20English%202006.pdf)
75. Esrey S. Water, waste and well-being: a multi-country study. *American Journal of Epidemiology*, 1996, 143 (6): 608–623.

Public Health & Environment Department (PHE)
Health Security & Environment Cluster (HSE)
World Health Organization (WHO)
Avenue Appia 20, CH-1211 Geneva 27, Switzerland
www.who.int/phe/en/
www.who.int/hia/green_economy/en/index.html

Photo:
A nurse unpacks a solar suitcase that provides LED lights for maternal deliveries in a Nigerian health clinic.
(©We Care Solar, *www.wecaresolar.com)*

Design by Inís Communication – www.iniscommunication.com