Promoting Health While Mitigating Climate Change

Technical Briefing for the World Health Organization Conference on Health and Climate

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DISCUSSION DRAFT

Scope and purpose of the paper

This is one of two technical background papers prepared as a basis for discussion at the WHO Health and Climate Conference. It provides a brief summary of the available evidence on the health impacts (co-benefits and risks) of climate change mitigation strategies, and an outline of the necessary health sector responses that may contribute to optimizing co-benefits while mitigating risks.

The accompanying paper provides a brief summary of the available evidence on the health impacts of climate change and responses needed to protect health from these evolving risks, including areas of health system strengthening.

Acknowledgements

This paper is a work in progress which will be refined following further and more extensive consultation during and after the conference. As it stands, the current draft provides a flavour of what could be achieved for public health from harnessing the wealth of information and experience on climate mitigation health co-benefits. The draft draws upon WHO's reviews of the health co-benefits of climate change mitigation measures discussed in the Fourth and Fifth Assessment Reports of the Intergovernmental on Climate Change (IPCC) *Mitigation of Climate Change* (IPCC, WGIII/AR5) and (IPCC, WGIII/AR4), as presented in the *Health in Green Economy* series (http://www.who.int/hia/green_economy/en/). The report also draws upon WHO work on health indicators of sustainable development http://www.who.int/hia/health_indicators/en/; a new report on *Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings* (WHO, 2014); forthcoming WHO paper on *Reducing Short Lived Climate Pollutants for Better Health – Early Responses*; and a forthcoming WHO EURO technical briefing on the health implications of the IPCC Fifth Assessment report (IPCC, WGIII/AR5). Direct quotations from the IPCC are indicated with the use of italics, and in-text references are provided to their location in WGIII.

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Executive summary

There is a very large, unrecognized potential to obtain health co-benefits from policies that reduce climate change. Moreover, many of these benefits can be enjoyed locally, by communities that adopt low-carbon development strategies.

Some of the most important health benefits include: reduced risks from air pollution-related diseases and fewer environmental health risks from transport, housing, and energy systems as well as health benefits from healthier lifestyles (e.g. more physical activity) and diets. Climate change mitigation policies can therefore prevent significant communicable and non-communicable disease caused by key economic sectors. This can translate into significant health cost-savings from averted deaths and diseases. Harnessing climate change actions for health benefits can play a transformative role in the climate debate – strengthening public and policymaker will for action.

Many health benefits of climate change mitigation can also often be enjoyed in the near- or mid-term – while reducing climate change's long-term risks (e.g. increased droughts, extreme weather, disease pattern changes, etc.). For example, well planned urban public transport policies that encourage walking and cycling, as preferred modes of transport, not only emit less climate change pollutants, they also reduce very immediately traffic injury deaths, promote increased physical activity, and air pollution-related mortality (from strokes, respiratory and heart disease).

Air pollution is a special example of the linkage between climate change and health. Outdoor (ambient) air pollution and household pollution ($PM_{2,5}$) from solid fuel cookstoves causes an estimated 1 in every eight premature deaths, or roughly 7 million a year. Inefficient fuel combustion of fossil fuels and biomass that creates particulate air pollution ($PM_{2,5}$) also generates climate pollutants (e.g. $CO_{2,}$). A significant proportion of particulate pollution may include black carbon, which is a short-lived climate pollutant.

This report covers the evidence about health co-benefits from key measures to reduce climate change in a range of economic sectors, including: energy, housing, industry, waste management, agriculture, and urban settings and in the health sector itself. Examples of measures that are good for climate and for health are given in this briefing and include:

- **Electricity generation** that is powered by clean energy sources such as solar, wind or hydro power, reduce both climate and pollution emissions, created by coal and diesel fuels. Coal and diesel fuel are carcinogens (as classified by IARC) and a major source of particulates ($PM_{2,5}$) and CO_2. Energy efficiencies such as from co-generation of heat and power (CHP) can capture heat otherwise lost as waste in conventional grid electricity production, thus reducing air and climate pollution. In regions with no grid or unreliable grid electricity "mini-grid" energy networks can often harness new renewable energy technologies, producing electricity at points of greatest need, and as substitutes for stand-alone diesel generators and kerosene lighting.
- **The use of clean fuels and household cookstoves**, including liquefied petroleum gas (LPG), biogas, biofuels (e.g. ethanol) and/or advanced combustion cookstoves that comply with emission rates recommended by new WHO *Indoor air quality guidelines for household fuel combustion*, can dramatically reduce deaths from household air pollution, one of the largest environmental health risk among women and children in low income countries. Insofar as these cookstoves reduce emissions of black carbon, a short-lived climate pollutant, produced by inefficient coal and biomass cookstoves, they can offer a climate benefit as well.

- **Smart urban policies and investments in transport, land use, buildings**, waste management and industry, are under the influence of local authorities and stakeholders. This package of measures offers great potential for the health of city populations. Particularly in the transport sector, where emissions are now amongst the most rapidly growing, modal shifts to low-carbon rapid transit, walking and cycling systems can yield multiple benefits for climate as well as health – particularly when cities are built around these modes of travel.
- **Housing and buildings designed to be energy-efficient and climate-adapted** (e.g. using minimal energy for heating, cooling, or lighting), and which make effective use of natural daylighting and natural ventilation with appropriate screening to prevent entry by insects), can reduce the morbidity and mortality related to heat and cold exposure, as well as risks of airborne infectious disease transmission; and acute and chronic respiratory diseases related to indoor air pollution risks, mould, and dampness. A more robust building envelope, also helps protects occupants not only from heat and cold, but storms and extreme weather, as well as diseases borne by pests and vectors.
- **In affluent countries, shifting to diets** richer in fresh, in-season vegetables, fruits and legumes can help reduce certain climate change emissions from agricultural systems – as well as risks of obesity, heart disease and cancers associated with excessive consumption of red meat and some processed foods. In low-income countries, it is also important to maintain the biodiversity of food systems, for healthy dietary diversity, as agricultural production industrializes.
- **Putting the health sector on a low-carbon trajectory can benefit health systems in power-intensive settings,** through greater energy efficiencies, greener forms of on-site power generation, through renewables and co-generation of heat and power, as well as shifting to greener procedures at every link in the health service procurement and delivery chain.
- **For resource-constrained and off-grid hospitals and clinics**, low-carbon energy solutions may also help improve access to energy for vital services. This can be essential to address the energy gap in rural areas and developing countries, a key constraint to the achievement of universal health coverage.

Such measures are available for implementation *today*. And yet, In spite of the obvious associated win-wins, knowledge about the above types of health co-benefits is rarely used to inform the selection of climate mitigation policies and the allocation of financing needed to implement them. The consequences of this omission are that low-cost opportunities to avoid ill health are being systematically overlooked.

The impact of climate mitigation policies on health is a result of corresponding changes in environmental and social determinants or root causes of health. The health sector has a critical role to play in elucidating those impacts, and by engaging with other sectors to inform and promote climate change mitigation measures that are most beneficial to health. An effective policy response must present an urgent and comprehensive framework which unites interventions in mitigation and adaptation with the ultimate aim of protecting the planet while simultaneously promoting the health and well-being of its inhabitants.

A focus on human health and wellbeing also ensures that these policies yield additional public health benefits often associated with the green economy. At a broader level, this is closely aligned with many of the pre-existing goals in development and global health pursued by the development community, national governments, the World Health Organization, and the United Nations.

To unlock these opportunities, the following crucial advances are required: enhanced global governance which fully accounts for the links between climate change and health in intergovernmental forums such as the UN Framework Convention on Climate Change; strengthening of the contributions of the health sector to climate change discussions including through a wider use of tools such health impact assessments and cost-benefit analysis that incorporates all relevant health co-benefits and risks; monitoring of health trends associated with measures taken; and provision of effective climate change interventions in improving health, all designed to identify the local health risks and benefits of any given mitigation policy; and overall strengthen inter-sectoral collaboration of national and local level policy implementation, to ensure any response improves health and health equity.

This mandate is reflected strongly in the 2013 World Health Assembly resolution on health and climate change, and supported at the regional level through member state declarations such as the Libreville Declaration on Health and Environment in Africa, the European Parma Declaration on Environment and Health, and the South East Asian New Delhi Declaration on the Impacts of Climate Change on Human Health.

The following central messages emerge from this briefing, each with important policy implications:

1. The long-term cost of global mitigation efforts needed to stabilise global warming at an acceptable level is relatively small over the long-term when compared to the cost-savings from the health benefits of these policies. In addition the health benefits are often realised in the short-term, and should be considered as offsets from initial cost of investment;
2. Many of the largest and best understood health benefits are seen in transport policy, in interventions to improve air quality which can often be used in urban settings. Such measures will reduce the millions of deaths globally which occur as a result of household (indoor) and outdoor air pollution – currently one in 8 premature deaths;
3. Climate change exacerbates poverty and affects the socially disadvantaged first and most severely. Mitigation measures and sustainable development counteracts this effect, and should be seen as an opportunity to combat health inequities and to contribute to sustainable development.
4. Partnerships between health and other sectors are essential in achieving policies benefit health and climate. These are facilitated by a proactive engagement of the health sector for health in all policies, for example by providing health impact assessments and by linking data on health trends, economic costs, and evidence of effective interventions.
5. Interventions to reduce climate change offer some of the largest opportunities for improving the health of local populations through health in all policies approaches. These health benefits can quickly follow mitigation measures and can be enhanced and documented by a proactive role of the health sector, using tested tools.
6. Given the central role of health professionals and the health system in protecting and promoting the wellbeing of the public, there is a compelling argument for the health sector to lead by example in implementing mitigation measures. Not only that, but there is also a major opportunity for the health sector to harness climate mitigation finance to support critical health facility infrastructure improvements, particularly for clean and more reliable energy and power systems, as well as healthier and more climate resilient buildings.

At the current pace of climate emissions, temperatures could rise by 4° Celsius or more over much of the globe by the year 2100. This would have major consequences for health. Low-lying areas where people live today could be lost forever due to rising sea levels. Rising temperatures could turn the warmest parts of the world into places where it is no longer safe to work or carry out physical activity outdoors.

Already, climate change is causing hundreds of thousands of deaths ever year from changing patterns of disease, weather events, such as heat-waves and floods, and degradation of water supplies, sanitation, and agriculture, according to the latest WHO data. Children, women and the poor are among those most vulnerable to climate-related impacts and consequent diseases, such as malaria, diarrhoea and malnutrition.

However along with the threats, that are very real, responding to climate change should be seen as a great opportunity -- to promote health and well-being through investment in smarter, more liveable, and more sustainable cities and rural environments for peoples worldwide.

What is now urgently needed is for the health sector to position itself to better advocate and leverage the above described opportunities for health and development.

1. Introduction

There is growing recognition of the many health co-benefits that may be realized from well-designed mitigation policies. Not only are health benefits from mitigation particularly large, there is also great potential health system cost-savings from averted deaths and diseases. Harnessing climate change actions for health benefits can also play a transformative role in the climate debate – strengthening public and policymaker will for action.

The health impacts of climate change are summarised in the first briefing – *Strengthening Health Resilience to Climate Change*. This thematic briefing, in contrast, describes the health impacts of mitigating climate change.[1] The many potential health co-benefits that could be realized from a low-carbon trajectory provide strong impetus for an urgent, ambitious and systematic transition to a low-carbon economy. These include:

Reduced death and diseases from household and outdoor (ambient) air pollution– from which 7 million people die annually – is likely to be one of the most direct and immediate benefits of many climate change mitigation actions.

Reduced environmental health risks in cities, homes, workplaces and rural settings. Large potential also exists for a range of more indirect health benefits from mitigation that address environmental risks to health in sectors such as energy, transport, housing and agriculture for example. Health gains from healthier diets rich in fresh fruits and vegetables and more active lifestyles are also a potential benefit.

In addition, the health sector, itself, can reap gains from rapid and early uptake of climate mitigation strategies that a) improve access to energy for health facilities especially in rural areas with limited infrastructure services through renewable energy and "green" or environmentally friendly building solutions, and b) reduce the long-term energy, building and operations costs of large urban health-care centres and hospitals – which is now very high – along with its carbon footprint.

There also are substantial synergies between strategies to adapt to climate change and those discussed here, which aim to reduce the level of climate change that will occur.

For instance, more sturdy and climate-resilient housing design can both reduce housing energy demand (now more than 17% of direct CO_2 emissions from energy combustion alone), but also make occupants less vulnerable to extreme heat, storms and flooding from climate change already occurring. Low-carbon climate-adapted housing also can help protect indoor air quality through good ventilation design as well as protecting against disease vectors through re-discovery of simple measures such as house screening.

[1] In this context, mitigation refers to policies and interventions which decrease GHG emissions and increase carbon sinks (a component of the natural environment which is able to absorb CO_2 from the atmosphere).

In health facilities, new energy technologies, ranging from large co-generation plants to small solar systems can help make health systems more resilient to grid interruptions, which sometimes occur daily in developing countries, and also occur in developed countries during extreme weather or other emergencies.

Responding to climate change should thus be seen as a great opportunity -- to promote health and well-being through investment in smarter, more liveable, and more sustainable cities and rural environments for peoples worldwide.

At the same time, reducing emissions is a priority of increasing urgency. In 2010, global emissions of greenhouse gases (GHG) reached their highest point in history – about 49 gigatonnes of carbon dioxide equivalents ($GtCO_2eq$) annually. Continuing on this trajectory for another decade means that global warming would likely exceed 2°C by the end of the century irrespective of mitigation actions taken later. Limiting global warming to 2°C has been the consensus target for policymakers and scientists concerned about accelerating environmental, health, economic and social impacts beyond that threshold, exceeding the limits of adaptation strategies, as described in Thematic Paper 1.[2]

"Decarbonization" (significantly reducing the carbon intensity of economic development) is central to any mitigation strategy which aims to achieve stabilization levels of around 450-530 ppm CO_2eq by 2100. This means strategies that lower carbon emissions in key sectors, are urgently needed.

This document is designed as background material for the World Health Organization (WHO) Conference on Health & Climate. It provides an overview of what is known about promoting health whilst mitigating climate change. It summarises health benefits (and, where relevant, potential risks) of mitigation measures in key economic sectors, as well as those in three key settings: cities, households, and health care facilities. It concludes with a discussion of actions that the health sector can take to advance health-enhancing mitigation measures, as well as cost considerations and governance mechanisms commonly employed to enact such policies.

2. Health impacts of mitigation – potential co-benefits and risks to be mitigated

This section considers the health risks and benefits associated with environmental measures proposed for each of the economic sectors considered in the Fourth and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC) Working Group III, *Mitigation of Climate Change* (IPCC, WGIII/AR5; IPCC, WGIII/AR5). When relevant, the companion IPCC *Summary for Policymakers* (IPCC, SPM/ WGIII /AR5) is also cited. These reports represent the broadest global body of scientific work on potential and feasibility of mitigation measures for key economic sectors, such as: energy, transport, buildings, industry, and agriculture. Also covered are key mitigation considerations of relevance in cities and the health sector.

In addition to CO_2 - the gas driving long-term climate change - a variety of other climate pollutants are also considered, as relevant to health impacts. These include shorter-lived climate pollutants (SLCPs) such as: black carbon, methane and hydrofluorocarbons (HFCs). These are of interest insofar as black carbon is a major component of particulate matter (PM), the air pollutant most closely associated with pre-mature mortality; methane is a contributor to ground-level ozone formation which is a factor in asthma related morbidity, and HFCs are used in refrigeration and air conditioning systems, the latter of which can contribute to "urban heat island" impacts described in Section 3.3,

[2] Should GHG emissions exceed 55 $GtCO_2eq$ in 2030, the world will be unable to generate a mitigation pathway which limits warming to 2°C by 2100 (IPCC WGIII, AR5).

"Health and sustainable cities." Whilst there are substantial health benefits that result from many climate mitigation strategies, some interventions also have the potential to produce unintended negative consequences for health. These are explored, as relevant.

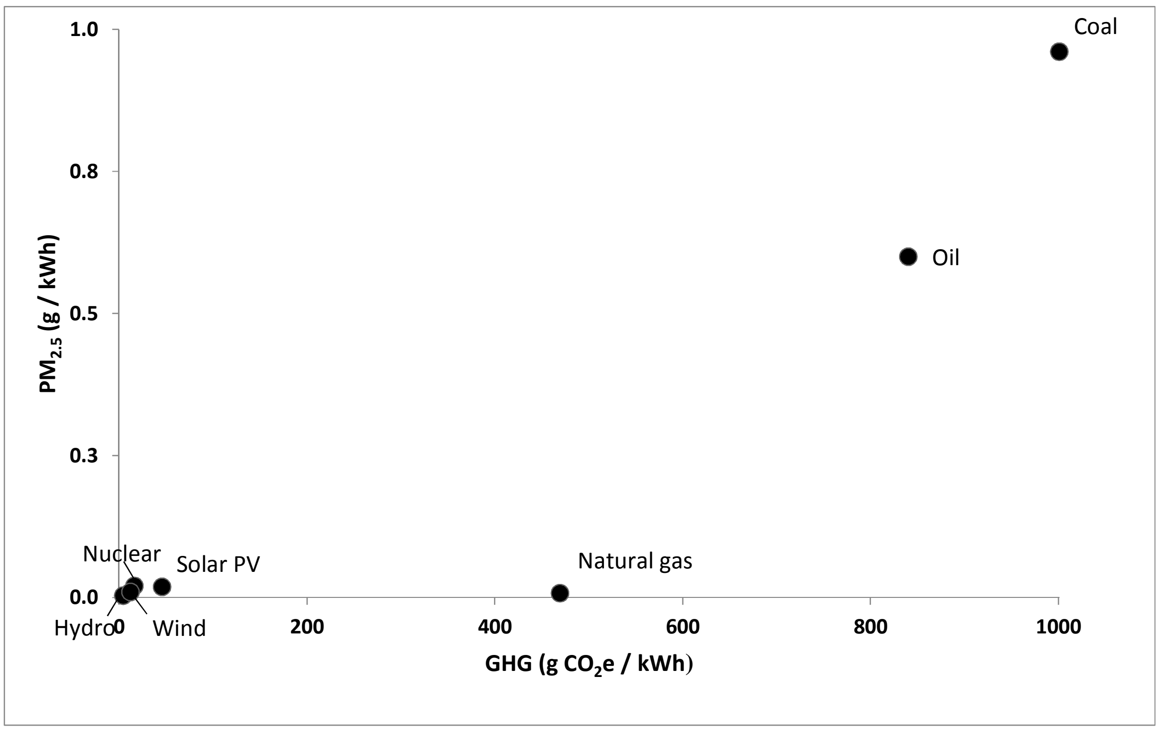
2.1 Energy and power supply

The energy sector[3] *is the largest contributor to global greenhouse gas emissions* (IPCC AR5/WGIII: 7), as well as a leading source of air pollution worldwide.

Energy sector emissions, including energy extraction, electricity generation, transmission and delivery to end users (industry, transport, buildings and agriculture) currently represents about 35% of total greenhouse gas emissions Based on current trajectories, direct GHG emissions from the energy supply sector are projected to triple by 2050 (based on 2010 levels). If stabilization of GHG emissions from the energy sector is to be achieved, low-carbon electricity sources, including renewable and nuclear energy, need to become the dominant source of the world's energy supply by 2050. At present, low-carbon energy sources make up only 30% of the global energy supply mix.

In many, if not most cases, the same energy sources that are low in CO_2, also produce far fewer emissions of health-harmful PM 2.5 particulates as illustrated below (Fig. 1).

Figure 1: Lifecycle GHG and $PM_{2.5}$ emissions of electricity generation technologies



Notes: Source data is (Sathaye J et al, 2011), covering lifecycle GHG and $PM_{2.5}$ emissions of electricity generation technologies. Data for GHGs is presented as the median reported value, and for $PM_{2.5}$, as the midpoint between the minimum and maximum reported value. PV = photovoltaic. Figure created by Noah Scovronick for an upcoming WHO report on health benefits short-lived climate pollutant mitigation).

Along with the fuels themselves, conventional power production is rife with inefficiencies in conversion, transmission and distribution processes – which significantly increase air pollution, per

[3] The energy supply sector as defined by IPCC comprises all energy extraction, conversion, storage, transmission and distribution processes that deliver final energy to end-use sectors (industry, transport, buildings, agriculture and forestry).

unit of power generated. For conventional fossil fuel plants, efficiency is estimated at only 37%, meaning that the majority of energy produced is lost as heat.

Clear health benefits can also be afforded from measures that reduce such energy losses, thus reducing air and climate pollutants per unit of energy generated. Combined heat and power plants, which utilize waste heat, have leads to much higher efficiency if best available technology is used, and district heat generation can be even more efficient. Decentralized systems, often called mini-grids –can also integrate well with local production of renewable energy and have lower costs than extending the main electricity grid. Some 70% of electricity expansion in developing countries would have to come from mini-grid or stand-alone off grid systems– in order to reach goals of universal access to electricity by 2030 estimates the International Energy Agency (IEA, 2011). Mini-grids also interface well with locally available renewable energy sources (e.g. water, sunlight, wind, geothermal).

At the same time, air pollution is not the only health risk from energy production, and health co-benefits are not uniform across all low-carbon technologies Impacts on health and health equity from fuels and energy production technologies used for mitigation as illustrated by Table 1 below.

Table 1. Health benefits and risks associated with decarbonizing energy systems

Energy supply technology:	Implications for health and social wellbeing:
Renewable/clean energy sources – wind, photovoltaic, hydro, geothermal	*Health benefits:* Significant reductions in air pollution. Health equity: Very suitable for more efficient forms of distributed energy generation; PV systems very suitable for household electricity provision in off-grid areas; Hybrid systems integrating renewables and off-grid diesel can increase power capacity, reliability and cost-efficiencies in public buildings, including health facilities. *Health risks:* Occupational dust and toxic exposures associated with solar PV panel production; Occupational injuries; Ecosystem disruption and population displacement from large dam construction.
Fossil fuel-based cogeneration of heat and power (CHP) and including carbon capture and storage of emissions (CCS).	*Health benefits:* Greatly-reduced air pollution in a CHP system as compared to conventional building heating systems or power plant electricity production. However climate benefits depend on carbon capture and storage of remaining emissions. *Health equity benefits:* Access to electricity. Less economic disruption in economies highly dependent on coal and oil. *Health risks:* Air pollution is higher, per unit of grid power generated, than other renewables and nuclear energy. In the case of stand-alone diesel generators, both Air pollution CO2 and long-lived climate emissions (black carbon) are even higher. *Health equity:* Occupational health risks associated with coal and oil extraction are particularly significant. Environmental damage and related health risks related to coal strip mining practices, oil pipeline sabotage, oil theft and oil leakage, in countries with poor environmental and regulatory regimes have been very significant, most often affecting vulnerable populations. *Health security*: Concerns regarding s potential CO_2 leakages and safety concerns regarding the transport and long-term storage of sequestered carbon.
Bio-energy (with co-generation of heat and power and carbon	*Health benefits:* Greatly reduced air pollution in a CHP system as compared to conventional building heating systems or power plant electricity production. Incineration of fuels such as biogas produced through anaerobic digestion (e.g.

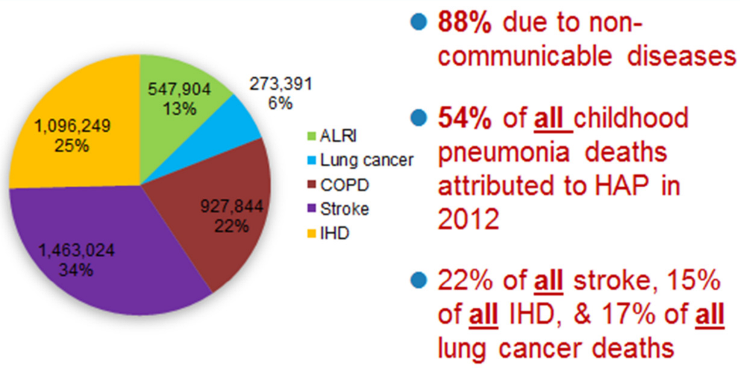
Energy supply technology:	Implications for health and social wellbeing:
capture and storage - BECCS)	of animal or human waste) further reduces both the pollution and GHG impacts bioenergy use. *Health risks:* Questions regarding true long-term sustainability of certain bioenergy sources, particularly biomass, such as deforestation impacts. *Health equity risks:* Substitution of food crops with bioenergy crop cultivation can further stimulate deforestation or threaten food security.
Natural gas (co-generation of heat and power, and onsite-building use)	*Health benefits*: Very low PM emissions, in comparison to oil and gas, particularly so when it is used to fuel CHP systems. Lower long-term climate emissions, but not as low carbon as renewables or nuclear. *Health equity:* Ready availability, including in some developing countries makes it an economic energy source, at least for interim. *Health risks*: Increased natural gas extraction through new technologies such as hydraulic fracturing, has raised concerns about long-term contamination of surface and ground water sources with benzene and other health-damaging carcinogens, either through poor wastewater disposal or the fracking process itself. This contamination can eventually make its way into the drinking-water supply or food chain. *Occupational and public health risks*: Flaring, industrial processes associated with extraction, and the risk of methane leaks also effects local air quality, increasing rates of methane, BETEX chemicals (benzene, toluene, ethyl benzene, and xylene), and radon. Many of these chemicals are known to cause chronic respiratory disease and lung cancer in these settings.
Nuclear power	*Health benefits:* reduced air pollution (corresponding to reduced rates of ischaemic heart disease and chronic obstructive pulmonary disorder, to name a few) and occupational hazards from coal mining. A shift to nuclear energy would also increase energy security (resulting from reductions in fuel price volatility). *Health risks:* Public health risks from potential nuclear accidents; occupational health risks of radiation exposure, and long-term public health and occupational health risks from nuclear waste storage and treatment. *Health security risks:* unintended security risks associated with nuclear proliferation, and nuclear sabotage and terrorism. ,

Source: Compiled from: IPCC, WGIII/AR5 (IPCC, 2014); IPCC, WGIII/ AR4 (IPCC, 2007); Dora et al (Lancet, 2014); and Health in the Green Economy – co-benefits to health of climate change mitigation strategies (http://www.who.int/hia/green_economy/en/).

2.2 Household energy

Close to 3 billion people worldwide rely primarily on the inefficient use of solid fuels (e.g. wood, charcoal, dung, crop waste, coal) for cooking, resulting in high levels of air pollution in and around the home. In 2012, an estimated 4.3 million deaths annually were attributed to such household air pollution, including over one-half of all pneumonia deaths in children under the age of five, one-third of all deaths to chronic-obstructive pulmonary disease, one-quarter of all deaths to stroke, and around 15% of all lung cancer and ischaemic heart disease deaths. Most occur in low and middle income countries (Fig. 2). Along with health impacts from inefficient cookstove emissions, there is an unquantified disease burden from other household energy end-uses, including: space heating and lighting with candles and kerosene.

Figure 2. Health impacts from primary solid fuel use for cooking



Notes: Other unquantified health impacts include: Injuries - from burns, fuel collection and poisonings cataract, low birth weight, cancer of upper aero-digestive tract; cervical cancer.

In addition to being one of the leading environmental health risk factors worldwide, household biomass burning in rudimentary cookstoves or over open fires is one of the largest sources globally of black carbon emissions, a short lived climate pollutant (SLCP).

Recent climate modelling of short-lived climate pollutants by sector indicates that reducing the inefficient use of biomass fuels in household cooking –may be one of the most effective near-term mitigation strategies and could help avert some 0.5º C of temperature change by 2050. In light of the pollution reductions achieved, the case for obtaining health co-benefits from such mitigation strategies is particularly compelling. What remains challenging, however, is the identification of advanced biomass cookstove technologies that can reach health-optimal emissions reductions.

Switching from inefficient biomass stoves to cleaner and more efficient fuels and technologies like liquefied petroleum gas (LPG), biogas, ethanol, or electric induction stoves are among the best options available for reducing household air pollution and yielding health benefits. These technologies are increasingly being used in urban areas of low and middle income countries – although a careful comparison of the relative climate impacts from different technologies, in terms of short- and long-lived emissions, depends on what energy source is used and how it is produced.

Clean household electricity access is another area where low-carbon strategies could yield strong health and climate co-benefits. Today, millions of people still lack access to electricity, reinforcing reliance upon dangerous and pollution lighting solutions such as kerosene. In off-grid areas as well as cities with unreliable grid electricity, millions of people use standalone diesel generators as a primary or backup power source. These produce high levels of PM and CO_2 emissions, per kWh of power produced, as well as creating risks of burns, and fires.

Increased uptake of household or mini-grid electricity solutions for lighting, communications, appliances, based upon solar, wind or diesel-solar/wind hybrid systems are increasingly affordable. Along with expanding electricity access to millions of households in unconnected rural areas, as per IEA projections, these approaches hold the potential to significantly reduce the future trajectory of air pollution, including CO_2 and black carbon emissions from household electricity demand. Not only is particulate pollution reduced, but so other health risks associated with diesel generators like injuries and carbon monoxide (CO) poisonings.

Table 2. Health Implications of Mitigation Measures for Household Energy

Mitigation measure	Implications for health and social wellbeing:
Sustained adoption of clean fossil fuels, biogas, and/or ethanol for cooking and space heating (e.g. liquefied petroleum gas)	*Health benefits (clean fuels):* lower emissions of health-damaging CO and PM pollution, including black carbon, is released, and resulting in fewer premature deaths from exposure to household air pollution. *Health benefits (biogas):* Can lead to improved sanitation waste management due to anaerobic digestion of household and animal excrement, as well as production of fertilizer digestate for crop production. *Health equity benefits*: Time needed to collect solid fuels such as firewood is reduced, thereby minimizing the safety and violence risks posed to women and children during fuel collection. These time savings allow for income-generation and education. *Health risks* – appropriate equipment and containers are needed to ensure safety, otherwise ethanol and liquefied petroleum gas (LPG) could lead to explosions, fires and burns.
Advanced combustion stoves that meet emission rates set forth by the WHO guidelines for household fuel combustion	*Health benefits:* for improved solid fuel stoves that meet WHO guidelines emission rate standards, health benefits from household air pollution risk reduction *Health equity benefits*: Time needed to collect solid fuels such as firewood is reduced, thereby minimizing the safety and violence risks posed to women and children during fuel collection. These time savings allow for income-generation and education.
Renewable or hybrid power generation at household, building or community mini-grid level	*Health benefits* – reduced household and outdoor air pollution; greater safety due to replacement of kerosene, associated with burns and injuries. *Health equity benefits* – Greater access in off-grid areas can lead to more productive uses of electricity, to education and to other benefits from electrification *Health risks* – appropriate technologies /connection are required to avoid safety risks (e.g. electrification), shortages, and overheating.

Source: Compiled from: IPCC, WGIII/AR5 (IPCC, 2014); IPCC, WGIII/ AR4 (IPCC, 2007); (Dora et al, Lancet, 2014) and Health in the Green Economy – co-benefits to health of climate change mitigation strategies (http://www.who.int/hia/green_economy/en/).

2.3 Transport

Transport energy consumption reached 27.4% of total end use energy consumption in 2010, of which around 40% was used in urban transport. (IPCC, WGIII/AR5.8

Over the past decade transport also has been one of the fastest growing sectors globally in terms of energy demand. Despite this trend, there remain substantial opportunities to reduce final energy demand by as much as 40% and CO2 emissions by 15 – 40% by 2050, according to the most recent IPCC assessment report. A key health opportunity associated with sustainable transport is reduction in air pollution exposures, and thus risks of cardiovascular disease, chronic lung diseases, as well as some cancers (Table 3). But increased physical activity through active transport and reducing traffic injury are other pathways to health gains.

Table 3. Health Outcomes Associated with Transport-Related Air Pollutants

Outcome	Associated transport-related pollutants
Mortality	Black smoke, ozone, $PM_{2.5}$
Respiratory disease (non-allergic)	Black smoke, ozone, nitrogen dioxide, VOCs, CAPs, diesel exhaust
Respiratory disease (allergic)	Ozone, nitrogen dioxide, PM, VOCs, CAPs, diesel exhaust
Cardiovascular diseases	Black smoke, CAPs
Cancer	Nitrogen dioxide, diesel exhaust
Adverse reproductive outcomes	Diesel exhaust; also equivocal evidence for nitrogen dioxide, carbon monoxide, sulphur dioxide, total suspended particles

PM: particulate matter; $PM_{2.5}$: PM < 2.5μm in diameter; VOCs: Volatile Organic Compounds (including benzene); CAPs: Concentrated Ambient Particles

Source: adapted from Krzyzanowski *et al*., 2005

Modal shifts towards low-carbon public transport and walking/cycling, or "active transport," represents an area potentially rich with population health benefits including: less air pollution and noise exposures, more physical activity, and greater equity of access to critical health, education and income-earning activities, as well as green spaces. (Table 4). Key to modal shift is investment in dedicated bus rapid transit, tram or rail transit in cities and metropolitan areas and for interurban journeys efficient and high-speed rail to reduce dependence on short-haul aviation (as well as car and truck traffic).

More sustainable urban land use is critical to encourage modal shift strategies that also support optimized health benefits. This involves compact and pedestrian/cycle-friendly cities where key destinations can be efficiently linked by transit and active transport routes. Mixed business and residential neighbourhoods allow basic services to be accessed without motorized transport at all. Finally, these measures need to be supported by a range of economic incentives such as: congestion pricing; parking pricing; safe walking and efficient bus routes to schools; and preferential pricing of public transport as well as of low-emissions fuels and vehicles.

Table 4. Health Implications of Mitigation Measures in the Transport Sector

Transport mitigation measures:	Implications for health and social wellbeing:
Modal shift of motorized traffic to dedicated BRT, light-rail and rail, complemented by dedicated walking and cycling infrastructure.	*Air and noise pollution exposures:* Less air pollution emissions per km/passenger travel results in fewer air pollution related disease risks and mortality (heart disease, stroke, lung disease, and some cancers); reduced urban noise pollution, reduces stress and sleep-related illness, and may improve mental health and well-being. *Traffic injury*: Investment in dedicated walking and cycling systems, easier road crossings and more contiguous sidewalks, leads to more physical separation of motor vehicles and non-motorized travellers, and less risk of injury. *Physical activity:* Increased uptake of active transport leads to more physical activity, which can reduce obesity as well as risks of diseases related to physical inactivity, including diabetes, cancer, and cardiovascular disease. *Health equity*; Provision of faster, safer, more efficient and more low-cost public transport increases access to services, jobs, education and leisure, for poor people as well as other social groups with less access to private cars (e.g. older people, disabled, women, children, etc.).

Transport mitigation measures:	Implications for health and social wellbeing:
	Health risks: Increased active transport may see potentially higher exposures to urban air pollution and traffic by pedestrians and cyclists if not accompanied by lower levels of car use and investments in safe non-motorized networks.
Compact urban planning and neighbourhoods with safe walking/cycling routes to reduce trip length and carbon intensity of journeys	*Air pollution and noise exposures; physical activity and traffic injury*: same as those above. *Health equity*: Safer, easier mobility for children, the elderly, the disabled, and people without cars. Space saved in urban road infrastructure and parking can be shifted to green spaces, particularly benefitting urban residents with less green space access.
High-speed interurban rail replacing short-haul aviation, passenger car and diesel truck journeys.	*Air pollution and noise exposures:* Potentially lower air pollution exposures for metropolitan and rural households along major road arteries and around airports, with disease risk reductions as per above. *Health equity:* Rail network expansion including metropolitan areas and rural communities can lead to potentially greater access to markets, jobs and services for the rural poor; greater access to jobs and services for women, children, disabled and elderly in suburban households without access to cars; and lower stress levels for commuters.
Improved vehicle and engine efficiencies along with uptake of low-carbon fuel sources (electricity, hydrogen, biofuels, CNG, etc.)	*Air pollution exposures:* Reductions particularly in particulate exposures. However, these may be offset by emissions from increased grid electricity demand in the case of electric vehicles. For CNG vehicles, oxides of nitrogen emissions still contribute to ozone. *Noise exposures*: In the case of electrified vehicles, there is significantly less urban noise exposure, which may lead to less noise-related stress, mental health and cardiovascular disease (among other things). On the other hand, completely silent electric vehicles may pose injury risks. *Health risks:* There is no improvement in physical activity or risks of traffic injury. *Health equity:* There is no improvement in access for groups without cars. Health risks: Historically, vehicle and fuel improvements have been outpaced by increases in the car fleet, meaning that modal shift and better urban design remain the primary measures through which long-term reductions in climate emissions can be achieved.

Source: Compiled from: IPCC, WGIII/AR5 (IPCC, 2014); IPCC, WGIII/ AR4 (IPCC, 2007); and Health in the Green Economy – co-benefits to health of climate change mitigation strategies – transport sector (http://www.who.int/hia/green_economy/en/).

2.4 Buildings and residential housing

In 2010, the building sector accounted for around 32% of final energy use with energy demand projected to approximately double and CO_2 emissions to increase by 50-150% by mid-century in baseline scenarios. (IPCC, WGIII/AR5, SPM.5.1) Projected emissions growth is linked to economic development (and increased private wealth), very rapid global urbanisation and thus expansion of offices and housing (without adequate attention to potential building or energy system efficiencies); poor urban planning, which also increases the carbon footprint of housing; and rapid uptake of energy-demanding office and household appliances, again without adequate attention to potential efficiencies.

Considering the very fast pace of construction in developing cities and the fact that buildings constructed today will "lock in" emissions for decades to come, these projections are of great concern. Meanwhile, one-third of today's population lives in slums, which create significant health impacts today, in terms of lack of access to safe shelter, water, transport and energy services, as well as potential future climate impacts (e.g. in terms of sprawl, energy-inefficient buildings, and unplanned urban expansion) that will need to be mitigated.

Mitigation measures generally involve: a) climate-adapted building design, including roofs, floors, joints, window treatment, insulation, etc. to reduce the need for heating in temperate countries and for air conditioning in warm countries; b) selective use of daylighting and natural ventilation to reduce cooling requirements; c) energy-efficient building heating systems and cooling systems, including: district heating, solar assisted hot water and space heating, electric or geothermal heat pumps; advanced bioenergy heating systems (e.g. wood pellets); and d) energy efficient building appliances. IPCC has estimated that use of such measures together can reduce the energy needs of buildings by 50-75% (IPCC, 2007, 6.4.7.) Health impacts of some of these design-based measures are briefly catalogued below.[4] For residential housing, this also builds upon the discussion of household energy in developing countries, covered in the *Energy* section.

Table 5. Health Implications of Selected mitigation measures for buildings

Interventions to reduce building emissions: (IPCC, 2007: 6; IPCC, 2014, x)	**Implications for health and social wellbeing:**
Low-energy building design and retrofits- including walls, insulation; joints, windows; shading; and (green) roofs improved thermal performance	*Thermal comfort:* Reduced heat stress and risk of heat-related stroke; less cold-related disease risks, including respiratory infections, and better mental health; less exposure to damp also reduces allergy risks – particularly in poor neighbourhoods/slums. *Health risks*: Thermal envelope improvements need to be accompanied by adequate ventilation.
Low-carbon heating and cooling systems, including district heating for large buildings; advanced renewable fuel systems; heat pumps and geothermal heating, and for smaller users, passive solar hot water and passive or PV solar-supported space heating.	*Air pollution and injury risks:* less exposure to air pollution from intermediate heating technologies such as stand-alone gas, electric and kerosene heaters. Less risk of burns and injuries (e.g. from kerosene spills). *Equity impacts:* Less risk of excessive heat and cold exposures and fuel-poverty, particularly in slums, and consequent heat and cold related morbidity; greater access to no-cost passive heating solutions; more control over thermal comfort.
Greater reliance on natural ventilation, with mechanical support, as needed, for effective cooling, and screens to prevent vector incursions.	*Indoor air pollution exposures to toxic chemicals and radon:* Better ventilation can reduce indoor air pollution exposure to a range of toxic chemicals that may be emitted by building materials including building materials, decorations and furnishings, as well as radon; *Infectious disease transmission:* Better ventilation can reduce risks of airborne disease transmission, asthma risks related to build up of dust and mites, and well as risks of microbial infections from faulty air conditioning ventilation systems. Screens are needed, however, to protect from vector-borne diseases.

[4] Note, a more complete treatment can be found in the Housing report of WHO's Health in the Green Economy series (WHO, 2011).

Interventions to reduce building emissions: (IPCC, 2007: 6; IPCC, 2014, x)	**Implications for health and social wellbeing:**
	Health risks: If air outside is heavily polluted then health risks from outdoor air pollution exposure would increase. Also, open windows can increase noise and security risks, particularly in densely populated neighbourhoods /slums.

Source: Compiled from: IPCC, WGIII/AR5 (IPCC, 2014); IPCC, WGIII/ AR4 (IPCC, 2007); and Health in the Green Economy – co-benefits to health of climate change mitigation strategies- housing sector (http://www.who.int/hia/green_economy/en/).

2.5 Industry

Industrial activities constitute a particularly diverse economic sector, covering a wide variety of processes from food production to materials manufacturing. This means that reducing sectoral emissions is often particularly difficult. As a whole, the sector account for 28% of final energy use and 31 % of global GHG emissions (if indirect emissions from heating and electricity are included), totalling 13 $GtCO_2$ in direct and indirect emissions in 2010.

Improvements in energy efficiency and reductions in emissions intensity of industrial processes have the positive side-effect of reducing the burden of disease from ambient air pollution. In the case of those involved in the process of aluminium production, these benefits extend to non-CO_2 emissions, with per fluorocarbons (PFCs) presenting a significant occupational hazard with health implications for the cardiovascular and nervous systems. Other social and health based co-benefits stem from increased local job security and working conditions.

Fossil fuel extraction and processing is a major source of methane emissions and is regularly identified as a key climate change mitigation opportunity [3, 159]. Specific actions include the recovery of methane from coal mines, the storage, recovery (or use) of gas released in oil and natural gas extraction processes, and reducing leakages during pipeline distribution [3, 159]. Climate mitigation benefits could be large. Public health benefits could include less ecosystem contamination from leakage of fuels into the environment as well as methane reductions that lead to less ground-level ozone (for which methane is a precursor) [3]. Some industries also emit considerable smokestack pollution, when that pollution contains heavy concentrations of black carbon, then reductions would yield a dual climate and health benefit. One example, brick kilns, is considered here:

Box 1: Reducing short-lived climate pollutants from brick kilns

Every year, billions of bricks are produced globally, with China and India the two top producers [146, 147]. In India alone, there are an estimated 100,000 kilns that employ around 10 million people [147]. Kiln designs vary widely, but in many low-income countries, bricks are often fired in traditional (artisanal) kilns that release high levels of heath relevant pollutants including $PM_{2.5}$ and BC, worsening local air quality and leading to high occupational exposures [146, 148-151]. The kiln fuel is generally wood or coal. In one study of Dhaka, Bangladesh, kilns were cited as the major source of particulate air pollution in the city and responsible for about 750 premature deaths annually [151]. Improved kiln designs, with more efficient combustion and chimney systems can reduce black carbon emissions and thus generate mutual climate and health benefits. A number of countries have promoted programmes and policies for improved brick kilns, but these generally have high capital costs [3, 146]. Lower-tech (and cost) options include the use of alternative fuels or educational measures to facilitate adoption of improved operating practices [153].

2.6 Agriculture and forestry and other land use

Agriculture, forestry and other land use (AFOLU) represents the only sector with declining emissions over the past decade. Deforestation and agricultural emissions (from livestock and soil and nutrient management) account for a majority of the sector's emissions, totalling roughly 25% of global emissions.

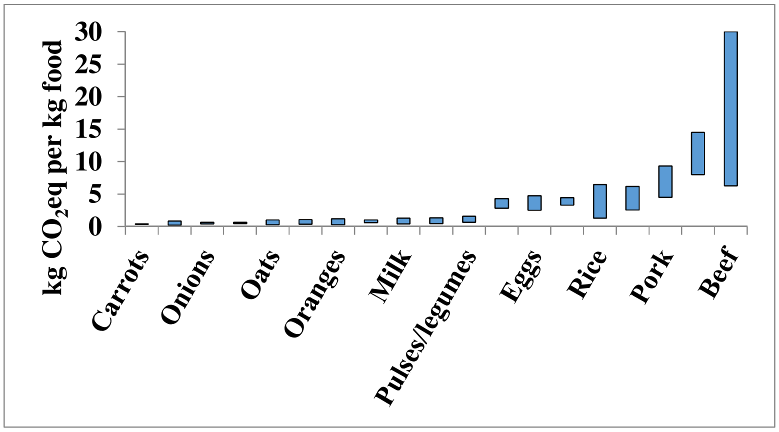
The sector is important, firstly because of its emissions reductions so far from which lessons learned can be drawn – although these are concentrated principally in high-income countries. Secondly, food production plays a central role in food security and thereby adequate nutrition in low -income countries. In high-income countries, in contrast, food production policies have come under scrutiny in terms of their association with obesity related risks, Type 2 diabetes, cardiovascular disease, cancers and other impacts arising from low fruit and vegetable consumption, overconsumption of meats, processed foods and sugary drinks, and generally poor dietary balance.

Technical mitigation policies are often conceptualised as being either supply-side or demand-side in nature.

The supply-side measures tackle emissions from livestock, forestry, land-based agriculture, and bioenergy production. Some approaches most directly relevant to health involve "sustainable intensification" of food production to generate more combined crop/animal and food/fuel energy resources per land unit at a lower carbon cost and "soil carbon sequestration" -- enriching soil carbon through incorporation of organic and inorganic material that also improves agricultural productivity and food security. Better manure management can reduce livestock emissions of methane, a short-lived climate pollutant, and improve health. In peri-urban poultry and pig farms, large untreated quantities of manure often accumulate posing severe environmental and occupational risks. Strategies involve improved composting or the conversion of manure via anaerobic digestion to methane-rich biogas, a clean cooking fuel. The biogas residue (digestate) may be more easily transportable, and can be used as high quality fertilizer, improving food production. Such strategies can also lead to local employment opportunities, e.g. in biogas or bioenergy production.

Demand-side measures encourage changes in human diets, improved supply chains, and reduced food waste. Assessing the "embodied" GHGs of foods is not straightforward. For fruits and vegetables, for instance, this depends on: whether the food was produced in an energy-intensive hothouse or open field; in-season or not; using irrigation or rainfall; chemical fertilizer and pest applications or composted nutrients and integrated pest management (IPM); and finally whether it was sold fresh locally or processed and air freighted further away. For livestock, the calculation may be even more complex, depending on their feed sources as well. But very generally, animal-sourced foods – and ruminants in particular – tend to be GHG-intense when compared to many fruits, vegetables, grains and beans, particularly those cultivated locally and in season (Fig. 2).

Figure 3: GHG intensity of select foods based on four European studies



Source: Compiled by Noah Scovronick for a forthcoming WHO report on health benefits of reducing short-lived climate pollutants, based upon data in: Berners-Lee et al, 2012; Carlsson-Kanyama, Gonzalez, 2009); Wallen, Brandt & Wennensten, 2004; Audsley, et al, 2009. CO_2-eq = carbon dioxide equivalents is a measure that includes non- CO_2 climate forcers such as methane, produced by livestock

In light of the health evidence about the beneficial qualities of diets rich in fruits, vegetables and fibres, there may be considerable potential for health co-benefits from demand-side climate mitigation strategies, particularly in higher income countries, where obesity and processed foods consumption are significant concerns. In lower-income countries, animal-based foods remain a more indispensable source of protein and micronutrients. However, here too, preserving local dietary diversity of traditional micronutrient-rich grains, fruits, legumes, seeds and nuts can be important both to nutrition and to the livelihoods of smallholder farmer, who cannot easily compete with the monocultures of large-scale producers. Potential health co-benefits associated with both demand and supply side measures are briefly described in table 6 below.

Table 6. Health Implications of AFOLU-Related Mitigation Measures

AFOLU mitigation measures:	Implications for health and social wellbeing:
Transformation of agro crop waste to bioenergy.	*Air pollution exposures*: Reduced open burning practices decreases local air pollution exposures, providing that the waste is processed as a high-grade biofuel or biogas, rather than burnt in rudimentary cookstoves. *Health equity risks:* Large-scale deployment of bioenergy also can incentivize farmers to shift from food to bio-energy crops.
Sustainable intensification through alternating wet-dry irrigation, agro-forestry, etc.	*Nutrition benefits increased food production, e.g. fish breeding in rice paddies or draining paddies in winter to produce a second food crop.* *Vector-borne disease control: e.g. alternating wet-dry rice paddy irrigation reduces vector breeding in flooded fields.* *Health equity: healthier livelihoods of rural communities through preservation of water resources; biodiversity (e.g. of agro-forestry systems), etc.*
Carbon enrichment of soils	*Health benefits – nutrition security - Enhances soil quality, water retention and thus food production capacity and nutrition security* *Health equity risks –"Low till" carbon enrichment measures are technologically demanding and thus most suitable to large landowners – and may also require more fertilizer, pesticides or crop variants to fend off weeds, offsetting their total benefit. Low-impact strategies for smallholders, who produce about 70% of foods*

AFOLU mitigation measures:	Implications for health and social wellbeing:
	globally, need more policy support. .
Manure management replacing excessive chemical fertilizer inputs	*Food security* -- from composted manure or biogas digestate *Sanitation: Reduction of large manure stockpiles through biogas production.* *Indoor air pollution exposures: biogas is a much cleaner fuel than biomass.*
Demand-side food measures: increased efficiency of supply chains and dietary changes; fostering bio-diverse peri-urban and local foods production.	*Noncommunicable disease:* Increased consumption of fruit and vegetables (locally sourced, where available), as well as a reduction in the consumption rates of red meat can help reduce cardiovascular disease and colorectal cancer. *Obesity-related conditions:* Dietary reliance on fresh, local fruits, vegetables, and legumes in-season, may reduce reliance carbohydrate-heavy processed foods and drinks. *Health equity:* fostering bio diverse diets can support smallholder farmers, urban access to fruits and vegetables, and in developing countries, the production of bio-diverse foods, including indigenous foods rich in micronutrients.
Demand side measures for sustainable apparel and forestry products	*Occupational health*: e.g. better worker health due to lower pesticide exposures, e.g. in sustainably cultivated cotton fields. *Health equity:* Conservation and sustainable management of forests has been shown to have benefits for the resilience of local communities and cultures.

Source: Compiled from: IPCC, WGIII/AR5 (IPCC, 2014); IPCC, WGIII/ AR4 (IPCC, 2007); (Dora et al, Lancet 2014); and Health in the Green Economy – co-benefits to health of climate change mitigation - agriculture sector (WHO, forthcoming).

3. Building healthy and sustainable cities

Cities concentrate economic sectors, and therefore opportunities both for livelihoods as well as health risks. The rapid rate of urbanisation occurring around the world, and the potential for locked-in emissions makes them of particular importance to any international mitigation strategy. In 2011, *more than half of the world population* (52%) *live in urban areas and each week the global urban population increases by 1.3 million* (IPCC, WGIII/AR5:12). By 2050, as much as two thirds of the world's population is expected to live in cities. Cities also were responsible for some 71-76% of energy-related CO_2 emissions (in 2006), also accounting for 80% of global gross domestic production (GDP). As such, they hold the greatest potential for the promotion of public health through climate mitigation.

Policy responses that drive the development of healthy and sustainable cities are most cost-effective when they integrate human development needs, economic needs and good environmental urban design. Examples of such packaged policies include: *co-locating high residential with high employment densities, achieving high diversity and integration of land uses, increasing accessibility and investing in public transport and other demand management measures,* (IPCC, WGIII/AR5, SPM.4.2.5) as per the principles already outlined in the transport and housing sections of this paper. Cities also are often hot-spots of inequality, and many of the interventions referenced above have important health equity dimensions to their implementation.

City-level mitigation is currently one of the more active and exciting governance spaces at the moment, with thousands of cities enacting policies to reduce their emissions and increase social wellbeing. However, many of these policies focus on relatively small emissions savings from energy efficiency, and few have begun to tackle difficult questions such as effective land-use design and policies to reduce urban sprawl. At the same time, socially disadvantaged groups such as the urban poor often experience the worst of the health impacts of climate change. Hence, achieving improvements in health equity must be an underlying focus and principle of any climate mitigation policy. Fostering low-carbon, sustainable urban development so as to broaden the range of health and health equity benefits in cities helps localise climate change issues, making them relevant to individuals, and overcoming psychological gaps which often impede progress.

Of particular note, the WHO *Health in the Green Economy* series has provided much of the foundations for work in sustainable and healthy cities. Building upon that, this section overviews three of the better understood and more important health co-benefits to be derived from low-carbon development: air quality improvements; more equitable and active transport; and urban design measures that can reduce the urban heat island effect. It will then conclude by exploring some of the governance challenges and enablers which determine the success of policies aiming to develop healthy and sustainable cities.

3.1 Air pollution

As noted, indoor and outdoor air pollution combined was responsible for as many as one in eight deaths in 2012. Air pollution is a key factor in the development of a range of disease conditions, including: ischaemic heart disease, hypertension, chronic obstructive pulmonary disease, asthma, and cancer of the upper and lower airways. Some of the most important (and best quantified) health co-benefits that can be obtained from reducing climate change are due to measures that reduce indoor and outdoor air pollution – particularly airborne emissions of fine particulate matter ($PM_{2.5}$), which are most closely associated with air pollution-related premature mortality.

In today's cities, outdoor levels of air pollutants are often dangerously high. According to the most recent data covering more than 1600 cities in 91 countries compiled by WHO, only an estimated 12% of urban dwellers globally live in cities that meet WHO guidelines levels for small and fine particulate (PM_{10}/$PM_{2.5}$)concentrations. Urban air pollution emissions typically include traffic emissions (e.g. also including considerable dust kicked up from roads in developing cities); household biomass emissions (still used among about one-quarter of households in developing cities); fossil-fuel power plants and industry; as well as open burning in landfills and peri-urban agriculture. Low and middle-income cities typically had the highest average annual air pollution concentrations – as much as 2-4 times higher than WHO Guideline levels. However, notable exceptions in some Latin American cities indicate that alternative development pathways are indeed possible. Correspondingly, it is hence not surprising that the IPCC concludes that the largest co-benefits for health in terms of climate mitigation could be in countries and cities where air quality regulations were previously lax.

Despite this, the sub-national policy context is possibly one of the most exciting areas of climate and public health policy, with a variety of synergistic solutions being trialled around the world. Interventions range from industry and transport efficiency standards to encourage a shift to cleaner fuels for vehicles and reduced emissions from nearby industrial processes. Urban investments in bus rapid transit, tram and active transport routes both reduce harmful pollutants, and encourage increased rates of physical activity. Combined with smart urban planning strategies, mixed land-use, and the preservation and creation of green spaces, policymaker can dramatically improve cardiac and respiratory health.

Whereas seven years ago, urban pollution was not a key issue in the global climate mitigation agenda today it is, and its importance appears to be growing. IPCC's AR5 report concludes that the social co-benefits associated with air quality improvements would produce cost-savings of a similar order to the initial costs of the associated mitigation interventions (making any such policy, effectively cost-neutral).

3.2 Urban transport systems

It has already been established that the transport sector is responsible for a large component of global GHG emissions and the release of other climate pollutants. The sector also has important links to health and wellbeing in an urban setting. These include the release of localised air pollutants (the health implications are summarised in Table 5, below); road traffic accidents; noise pollution with important cardiovascular and mental health implications; and the potential for a lack of physical activity. Many of these impacts are best observed in cities, and it is often in the rapidly emerging urban centres found in low and middle income countries, that they are most damaging and worrying. Indeed, the WHO estimates that urban air pollution (much of which arises from transport) and traffic injuries are responsible for some 2.6 million deaths annually in low and middle income countries.

Urban transport policies designed with both local public health and climate change in mind result in a new set of priorities than either would alone, and hold the potential for powerful synergies and substantial cost-savings. These can be conceptualised in to three interdependent groups: improved land use and urban planning; enabling healthy transport modes; and encouraging the use of more efficient vehicles and fuels. A combination of policies centred on encouraging mixed land use and active transport are particularly important, and have the potential to yield greater and more immediate health benefits.

Improving urban design entails a shift towards mixed land use (which brings together residential and commercial areas), the construction of cycleways and footpaths, and improved street connectivity. These policies often require intervention at the community and street level, and are targeted at reducing road safety, reducing air pollution, and increasing the proportion of journeys which are cycled or walked. Importantly, these urban re-designs must be coupled with the adoption of cleaner fuels and a shift towards public transport. Without this, they run the risk of resulting in increased exposure to harmful air pollutants. For example, whilst a shift to diesel fuels may result in net GHG emissions reductions, it is closely associated with worsening health impacts through increased $PM_{2.5}$ and PM_{10} emissions. Whilst there are risks and benefits to any form of transport, in cities which are designed to encourage active transport, the current evidence suggests that the greatest net health benefits are found in walking and cycling, followed by public transport and then private motorised transport.

There are also important health equity considerations and gains to be made from well-designed urban transport policies. Transport plays a vital role in providing access to a variety of services such as schools, jobs, healthcare, and commercial areas. The elderly, women, disabled people, and the urban poor disproportionately lack access to private vehicles and so face certain barriers in properly engaging with these services. Improved proximity planning, public transport infrastructure, and interventions to enable independent mobility and active transport provide the greatest benefits for these otherwise vulnerable populations in terms of reduced health impacts and improved access to city services.

3.3 Urban design and the "Heat island effect"

The sprawling expanses of concrete and high-rise buildings characteristic of many cities, as well as the absence of green spaces, tends to concentrate radiant solar heat absorption, so that temperatures in the city centre may be 3-5 degrees Celsius higher than in surrounding rural areas. Known as the urban heat island (UHI) effect, this can be a particularly important public health risk, greatly exacerbated by the dual trends of climate change and rapid unplanned urbanisation. UHI has a number of important health implications. These include increased heat stress (causing respiratory distress and heat stroke, syncope, and exhaustion) and cardio-pulmonary disease from an increase in local air pollution. This in turn has the mal-adaptive effect of increasing energy consumption in urban buildings – indeed, it is estimated that every 1 degree increase in urban temperatures results in a 2-4% increase in electricity use, primarily from air conditioning in high income settings. By direct implication, socially disadvantaged populations which are unable to gain access to such cooling experience the worst of these health effects,

However, there are a number of well-defined and understood interventions which can help to reduce the presence of a heat island. These include city designs which encourage openness for cooling winds, the use of reflective materials designed to absorb less solar radiation, the creation of urban green spaces and urban woods, which shade, cool and filter the air, as well as and urban fountains, ponds and, where feasible lake, insofar as water moderates temperature change. Through the strategic development of green rooftops and “arterial parks”, such as tree-lined walkways and bicycle lanes, cleverly-designed cities can achieve both compact design and urban greening. Along with moderating temperatures, green spaces filter particulates and other air pollutants, act as are “sinks” for CO2. Arterial parks can offer routes for active transport, as well as leisure activities, supporting reduced risks of cardiovascular disease, Type 2 diabetes, and obesity-related illness, as well as stimulating children’s physical and social development. There is growing evidence that access to green spaces also has mental health benefits,

3.4 City-level governance

A major challenge regularly identified by those investigating the design of sustainable, healthy cities, is their complex and deeply interdependent nature. The IPCC provides an overview discussion of the drivers of urban emissions, outlining four factors: economic geography and income; socio-demographic factors; technology; infrastructure and urban form. They refer to their adaptive nature which – in absence of cross-sectoral, city wide mitigation policies – leads to a tendency to maintain a constant (or growing) level of emissions. Governance mechanisms to interact with, and efficiently manage complex adaptive systems have long eluded the policy community, whose methods traditionally rest on linear conceptualisations of the policy process. This is particularly problematic, given that regions and countries with rapidly developing urban areas (those most in need of techniques for designing sustainable and healthy urban centres) are also often those with relatively weak institutional capacity, limited governance and technical expertise, and insufficient capital necessary to overcome the initial investment costs. Combined, these present the largest barriers to the development of sustainable cities and urban areas, and present a significant policy dilemma for the global community.

Compounding these governance challenges at the municipal level, is the fact that essential services such as food, water, electricity, and other resources required for a city to function are often sourced externally. This adds additional political complexity to managing the emissions and health co-benefits of a given city. However, there are some notable successes such as a ban in Krakow, Poland, on the use of coal and biomass for household heating, or a recent announcement from Beijing’s provincial government of a series of transport, energy supply, and industry policies designed to drastically reduce local air pollution.

To drive progress forward, a series of health and climate indicators are required at the city level, both to help monitor and compare reductions between cities, and to identify successful policy interventions which benefit health. At this level, some potential indicators worth monitoring might include exposure to urban air pollution (and related morbidity and mortality), the use of healthy and sustainable transport solutions, and access to low-carbon healthy housing with access to modern energy services for heating and cooking. There is hence a need for responsive processes of urban planning, implementation, and evaluation which are held accountable for improving these indicators and simultaneously decreasing any revealed health inequity.

4. Climate-smart health systems

Global demographic trends towards an ageing population coupled with an increasing incidence and prevalence of chronic diseases such as type 2 diabetes, cardiovascular disease and respiratory illness are threatening to overwhelm the capacity of healthcare systems around the world. As overall demand for complex health care services that increasingly rely on diagnostic and treatment options that are heavily technology dependent increases, particularly in low and middle income countries, an urgent need for cost-saving policies is apparent.

In the health system, many of the mitigation measures implemented to reduce the carbon-footprint have this exact effect, often simultaneously reducing costs whilst enhancing the quality of patient care.

Available data on the size of the carbon footprint of a health system is limited. However, some estimates from the UK and US suggest that in these country contexts GHG emissions from the health sector can comprise as much as 3-8% of total national emissions. Very few data exist on GHG emissions from health systems in low and middle income countries, pointing to the need for further research in this area. However, anecdotal evidence suggests that emissions in low income countries are substantially lower, with many health systems having the opposite problem of lacking access to reliable energy.

Within the health system, energy consumption and GHG emissions come from a number of sources, including from buildings and health care facility infrastructure, health system related transport, and procurement of services, food, medical devices, medicines and health commodities. Given the central role of health professionals and the health system in protecting and promoting the wellbeing of the public, there is a compelling argument for the health sector to lead by example in implementing mitigation measures in order to avoid contributing to the devastating health impacts of climate change. Not only that, but there is also a major opportunity for the health sector to harness climate mitigation finance to support critical health facility infrastructure improvements, particularly for clean and more reliable energy and power systems, as well as healthier and more climate resilient buildings. Finally, this is one area where the health sector has almost complete authority to take rapid action.

4.1 Access to clean energy and renewable energy production

Hospitals and large health care facilities are among the largest consumers of energy among public institutional and commercial buildings. Also, hospitals and clinics delivering any emergency services universally require backup sources of energy for peak period and emergencies. These unique features make health facilities particularly poised to take advantage of climate mitigation strategies and new technologies, both to save significant energy costs as well as to create energy systems that are more reliable day-to-day, and more resilient and operational in emergencies.

In low-income countries, energy access and day-to-day energy reliability are major concerns for health facilities struggling to deliver basic services. A recent WHO assessment found, for instance, that in 11 sub-Saharan African countries, about 26% of facilities, on average, had no energy at all, and only 33% of hospitals had what could be called "reliable electricity provision" as defined by no outages of more than two hours in the past week.

Energy savings and energy innovations that put health care facilities on a low-carbon energy trajectory not only reduce long-term operating costs, but also promote greater accessibility and affordability of energy for critical health services. This, in turn, supports a key health sector goal – universal health coverage.

Low carbon strategies being used to improve access to energy in small, off-grid health facilities include: solar thermal energy for hot water heating, solar refrigeration for lights, communications and vaccine refrigeration.

Larger hospitals in developed and developing countries are also increasingly taking advantage of renewable energy to power whole-building systems. Examples include the new 300-bed Mirebalais Hospital in Haiti, powered primarily by solar energy from 1,800 rooftop panels. Hydroelectric systems are a source of clean, onsite energy for hospitals in Uganda, Rwanda and the Democratic Republic of Congo. Combined heat and power generation are also becoming a common energy solution for facilities with large energy demands. Such systems are typically powered by natural gas or oil, or advanced biomass combustion, although they may integrated with other renewable technologies, such as solar or wind, with battery storage.

In larger clinics, hybrid diesel and PV solar power systems with battery storage can reduce fuel costs, improve reliability – while reducing particulate pollution (including black carbon) as well as long-lived CO_2 emissions from diesel generators, sometimes on an order of 75% (Table 7). In the case study of a real-life Nigerian clinic considered here, the hybrid alternative also was projected to save nearly US$ 300 000 in operating costs over 20 years, mostly fuel costs.[5]

Table 7. Potential climate and pollution savings from hybrid PV/solar - case study

Pollutant	**Emissions**		**Hybrid system savings**
	Existing system: diesel + battery storage	**PV/diesel hybrid system + battery**	
	(Kg/Yr)	(Kg/Yr)	(Kg/Yr)
Carbon dioxide (CO_2)	8533	1848	**6685**
Carbon monoxide (CO)	21.1	4.56	**16.54**
Unburned hydrocarbons	2.33	0.505	**1.825**
Particulate matter (PM)	1.59	0.344	**1.246**
Sulfur dioxide	17.1	3.71	**13.39**
Nitrogen oxides	188	40.7	**147.3**

Source: Adapted from: Ani & Emetu, 2013, for World Bank & WHO, *Access to modern energy services for health facilities in resource-constrained settings* (WHO, 2014)

Health facilities as "anchors" for community energy development

In light of their high and constant need for energy and backup system requirements, health facilities could potentially play a wider role as electricity suppliers in community mini-grid systems, given appropriate policy and financial incentives.

In North America, Europe and other developed countries, carbon incentives, environmental tax breaks and "feed-in" tariffs are stimulating hospitals to invest in "greener" energy production. When such incentives are available, a hospital may become an "energy anchor" for a clean energy investment. Or, a hospital may invest in its own energy system – selling off excess power in off-peak periods to the grid through "feed-in tariffs" designed to promote energy efficiencies.

[5] Note: Facility simulation of a real life facility in Nigeria, considering geographical location and solar radiation, as well as detailed analysis of existing energy load requirements of available equipment, for a peak load power requirement of 3.4 kW and total requirement of19kWh/daily.

In Africa and the Caribbean, some of the large new investments in hospital hydroelectric and solar energy have also included such arrangements with communities or utilities. Off-grid, certain small health clinics have created micro-enterprises, whereby a small portion of excess power generated by a solar investment is sold for cell phone charging to members of the community – and earnings support maintenance of the solar system and spare parts.

However, there remains an urgent need to expand and adapt financial and business models for clean energy provision to the special conditions of low and middle income economies – and health system policymakers need to be sensitized to the special advantages that may be obtained from transitioning facilities to cleaner and greener modes of energy production. Many regulatory barriers also need to be overcome to make clean energy technologies more accessible to large hospitals of the developing world.

Promoting such health sector partnerships with communities can represent an important health sector contribution to the global 'Sustainable Energy for All' (SE4ALL) – goals of expanding universal energy access – as well as achievement of global targets in the area of women and children's health. The creation of a recent SE4All *High Impact Opportunity* initiative focusing on the nexus between clean energy provision and women's health, illustrates that there is both recognition and appetite for widespread adoption of these types of integrated approaches.

4.2 Green health-care buildings

Much of the work of IPCC's Working Group III on buildings is directly applicable to the health facility infrastructure, and key principles are covered in the *Buildings* section of this report. In addition, however, health-sector specific reports have estimated that retrofits and design of new climate-smart facilities can generate long-term energy savings of 30- 50% or more. Strategies include appropriate siting and use of passive cooling and heating through landscaping, daylight siting and building orientation, as well as natural and mixed-mode ventilations strategies. Natural and mixed-ventilation systems in well-designed buildings can also reduce risks of airborne disease transmission, by through better air circulation, as measured by hourly air exchanges. Rediscovery of its benefits has led to increased design of health facilities in high income settings with naturally ventilated areas or wards. Siting a health campus near public and active transport facilities is another design-based strategy that can keep the facility's carbon footprint low, while improving access for health care workers, patients and visitors.

4.3 Procurement and consumables management

Health facilities procure and manage a wide range of health consumables, chemicals and food. The term 'procurement' makes reference to all of these, as well as other inputs which go in to running a hospital or clinic, such as medicines, medical devices, business products, and auxiliary services.

In high-income countries, procurement is increasingly regarded as a key source of GHGs, whose mitigation can yield health system savings. For example in the UK National Health Service(NHS), it is estimated that procurement accounts for some 65% of the total carbon footprint of the health system, beginning with production, transport and disposal of products, a proportion of which are never used and thus wasted. Strategies to reduce the carbon impact of procurement activities can include sourcing products from local providers with environmental considerations built in to their supply-chains, and more efficient management of products to ensure lower rates of expired or un-used equipment and food. Increased access to local fresh foods in healthcare settings can also protect against lifestyle related disease. More efficient and sustainable procurement of pharmaceuticals and health care commodities such as cleaning agents and medical supplies (e.g. gloves) can not only reduce GHG emissions, it can also reduce occupational hazards and illnesses, ranging from reproductive disorders to occupational dermatitis (e.g. from rubber gloves) and asthma (e.g. from chronic inhalation of cleaning agents).

4.4 Health-care waste management

Part of the GHG emissions released by procured goods and services comes from the waste management processes used to dispose of them. Interventions to reduce waste volumes include the separation of hazardous health care waste from general waste that can be recycled; composting of kitchen waste or other general biodegradables; and careful disinfection and reuse of certain – but not all – medical instruments in the case of infectious and hazardous health care wastes. For infectious health care waste, advanced disposal techniques, including autoclaving or treatment with chemical or biological processes, and under appropriate conditions incineration, is usually required. Some of these measures are more successful at reducing the environmental impact of waste than its carbon footprint – for example waste autoclaving decreases exposure to carcinogenic and neurotoxic dioxins and furans which are emitted as a by-product of health care waste incineration in the simple, single combustion chamber incinerators commonly used in low and middle income settings. However autoclaving is also a heavy consumer of electricity – which requires energy to produce. Managing health-care waste remains challenging, then, in terms of balancing climate, health and environmental objectives.

4.5 Healthy and low-carbon models of care: telemedicine and e-health

One component of the problem facing modern healthcare systems is their relative inefficiency. Health clinics in cities and rural areas often stand empty after sunset – representing unused or wasted infrastructure resources – including energy. At the same time, health systems struggle to provide adequate access to care to people in underserved rural regions in low and resource constrained settings. And systems in both poor and affluent countries struggle with complex care issues, and the management of chronic diseases. Too often, technologically-complex and expensive interventions occur very late in the disease process due to under-investment in preventive public health and primary care measures, and a perceived lack of ability to engage with behavioural and lifestyle-related determinants of health. This, too, increases the "carbon intensity" of services delivered.

To address these challenges, new "telemedicine" and "e-health" strategies are breaking the old paradigms, with documented success in both developed and developing countries. These strategies allow patients to obtain consultations for minor conditions, and obtain treatments for chronic conditions, without leaving their homes. Such networks can also allow health workers in a remote area to consult with better trained nurses or doctors elsewhere on appropriate treatment of urgent conditions or on the management of health issues for which specialised expertise is lacking.

Access to essential health services such as reproductive health also works to improve women's and children's health, enhance gender equity, and through culturally appropriate family planning measures, can help to reduce population growth, energy consumption, and emissions.

The development of innovative models of care may then become one of the overarching strategies for reducing the health system's GHG emissions. This requires a modern understanding about the nature of healthcare which encourages a strong shift towards preventative health and as appropriate a shift towards more community-centred facilities and services.

Insofar as traditional health care facilities are expected to remain the anchor for health care activities worldwide, transport-related policies also need deeper consideration. New hospitals, in particular, which require large swathes of available space, may be sited far away from city centres and thus difficult to access for poor patients and those without cars – as well as for health care workers. In addition, this drives up their carbon footprint. Strategies to reduce these emissions by linking planning and siting of health care facilities with smarter transport policies as described in section 2.3 can increase healthcare accessibility (particularly for those without private vehicles) and improving employee wellbeing through decreased traffic risks and obesity-related disease.

5. Economic Considerations and existing Governance Mechanisms

In addition to the technical mitigation measures, their health benefits, and the specific policy contexts mentioned above, there is also a need to briefly discuss the cost considerations associated with such interventions. Perhaps the most important implication of these reduced health costs (other than that gained from the intrinsic value of human wellbeing) are the resultant cost-savings found from reduced healthcare costs. When coupled with improved economic productivity (from lower absenteeism and higher work productivity) and social capital gains from the health benefits, these gains can be discounted against the initial cost of the intervention.

Costing these co-benefits has traditionally been a difficult task, given their sensitivity to local assumptions and other methodological complexities. The cost benefits associated with policies which reduce household and outdoor air pollution are one exception to this, with the IPCC's AR5 supporting the idea that for a number of air quality related policies, the cost-savings from the social co-benefits would offset the cost of the policy itself. In other cases, such as transport policy, quantitative methods for estimating health impacts from pollution emissions and injury risks created by different transport systems are well defined. However, these tools have not yet been mainstreamed into decision-support tools currently used to inform finance and Investment policy decisions in the transport sector.

Improved integration of knowledge about health impacts into broader framework of cost-benefit analysis of mitigation measures is required in order for rational policymaking. Conducting both a health impact assessment (HIA) and corresponding cost-benefit analysis (CBA) on new mitigation policies is one way of ensuring that these health gains and their corresponding cost savings are maximised.

IPCC/WGIII's Fifth Assessment Report suggests that global aggregate costs of mitigation measures required to track along low-end emissions trajectories up until 2100 would result in no more than a 2% decrease in global GDP by 2100 once independent trends in economic growth are accounted for. Of particular interest, the report does not consider any of the potential benefits mentioned above or those from averted damages and reduced costs of adaptation.

The technical mitigation responses to climate change have progressed rapidly in recent years, approaching a point where many of the solutions necessary to mitigate climate change in a way that promotes public health are now readily available. However, equally important, is their successful deployment, which is in part determined by the political context and governance frameworks within which these interventions must function.

The United Nations Framework Convention on Climate Change is a central forum for inter-governmental negotiations on climate change, and contains a number of potential entry-points for public health. For example, through leveraging of a requirement (coupled with the provision of adequate resources and expertise) that countries conduct an HIA on new policies to be implemented under the Convention. Legal grounding for this recommendation exists in article 4.1(f) of the Convention, where member states commit to "employ appropriate methods, for example impact assessments… with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, to projects or measures undertaken by them to mitigate or adapt to climate change".

Other policy processes are beginning to focus as well on sub-national governance, such as in provincial and mayoral contexts. City and other sub-national governments are uniquely positioned to influence individual and community behaviours, and engage with national policy discussions directly and by acting as best-case examples. There are, however, also difficulties experienced at this level, in that many of the most important macro decisions relating to mitigation – such as a national energy strategy, the establishment of a formal price on carbon, or a country's international negotiating stance – are well outside of the policy domain of a city government. Here, well-established bodies such as the Climate Leadership Group (the C40) and Local Governments for Sustainability (ICLEI) which (through their members) work to drive and implement tangible mitigation measures on the ground regardless of what's happening at the ongoing national and international negotiation processes.

Another key consideration is the need to ensure that policy measures also influence behavioural changes conductive to more sustainable living. For example, global and national trade and agricultural policies can shift certain incentives away from red meat production and over-consumption in affluent countries, to more fresh foods production, reducing both climate change emissions as well as health risks from colorectal cancer, heart disease and obesity related illness. However, individual consumers also have to be persuaded that healthier diets are a worthy lifestyle change.

6. Conclusion

This briefing has provided an overview of health effects of climate change mitigation policies, placing emphasis on the potential reductions in burden of disease, improvements in health equity, and corresponding cost-savings. Available evidence clearly shows that long-term cost of global mitigation efforts needed to stabilise global warming at an acceptable level is relatively small over the long-term when compared to the cost-savings from the health benefits of these policies. In addition the health benefits that will result from such measures are often realised in the short-term, and thus further offsetting initial costs of investment

A key issue that emerges in this briefing as well as in other more in-depth analysis of climate mitigation policies and health is the finding that while there are clear and significant disease prevention opportunities provided by climate mitigation measures being implemented in different sectors, including the health sector, related opportunities for health (and for health systems strengthening) are not widely recognized. Also not well recognized by either climate or health actors are linkages between these health (and health systems) co-benefit opportunities and wider global health priorities such as universal coverage or the attainment of maternal and child health related millennium development goals.

Global concern and interest in curbing further climate change is at an all-time high. This is therefore a critical moment for the health sector to harness primary prevention opportunities afforded by smarter investments in key sectors such as energy, transport, urban planning, and even health systems.

For the health sector, a clear and compelling case can now be made to leverage climate mitigation finance to pay for the initial capital investment needed to introduce low carbon technologies (especially energy related) in health care facilities (both large and small). For larger facilities, savings generated as a result of reductions in operational costs could be used to enhance quality, accessibility, and safety of other essential health services. In a time where health care costs continue to rise, and global demand for complex preventive and curative health care services continues to increase, particularly in low and middle income countries, enhancing operational and functional efficiency of health care facilities is essential. For smaller facilities, climate finance could be used to support investment in low-carbon energy technologies (e.g. renewables) needed to overcome energy poverty issues in remote and under-serviced areas. Lack of access to essential material and child health services (many of which are electricity dependent) is a well-documented barrier to the achievement of MDGs.

What is now urgently needed is for the health sector to position itself to better advocate and leverage the above described opportunities for health and development.

Following is an overview of the key roles that the health sector can play in moving this agenda forward:

1. **Provision of authoritative an evidence-based advice about health risks and benefits associated with different climate mitigation policies and about best buy policy options for climate and health.** This in turn will require that the overall evidence base about health co-benefits associated with different sector policies and interventions is expanded, including through operational and empirical research. It will also require more systematic analysis of the effectiveness (in health terms) of measures and interventions taken. New tools and guidance (e.g. to support burden of disease estimates, economic evaluation, and GHG estimation) will also need to be developed to support the above.
2. **Provision of health leadership in relevant multi-sectoral and multi-stakeholder decision making processes related to climate mitigation**, including with relevant sector actors, as well as with other key stakeholders such as civil society, and the private sector.
3. **Establishment and strengthening of core public health functions and capacities to**:
    a. analyse and communicate health co-benefit opportunities associated with different climate mitigation policies for instance using tools and decision-support instruments such as health impact assessment (HIA);
    b. monitor, evaluate, and report on the results (in health-terms) of those policies;
    c. advocate and engage on climate mitigation and health issues with key sector actors and stakeholders;
    d. evaluate/assess health risks and benefits associated with new technologies promoted as part of a transition to a low-carbon economy.
4. **Ensure that climate mitigation measures are incorporated into relevant national health systems policies and plans** where the health sector has primary control and responsibility over GHG emissions sources (i.e. associated with health care activities). This might cover for example: health care waste management, procurement policies, and health care facility infrastructure performance standards (where energy, siting and other facility related issues could be addressed).
5. **Raise public awareness** about opportunities for climate and health afforded by the above types of measures so as to build support and create demand for broader uptake and implementation of climate and health promoting mitigation measures.

This draft discussion document has been designed to provide an overview of the technical knowledge on the co-benefits of climate change mitigation, so as to allow a common starting point for discussion at the WHO conference on Health and Climate. The purpose of subsequent discussion at the conference is to deliberate and agree on a framework for advancing the health sector's engagement in climate change and sustainable development, and for harnessing associated benefits for health and health systems.

Selected References

- Adair-Rohani, H et al. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability. *Global Health: Science and Practice,* 1(2), pp. 249–261.
- African Renewable Energy Access Program (2010). *Photovoltaics for community service facilities: guidance for sustainability.* Washington, DC: The World Bank. Available at: http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1266613906108/PV_Toolkit_FINAL_12-14-10.pdf [Accessed 4 July 2014].
- Ani, VA & Emetu, AN (2013). Simulation and optimization of photovoltaic diesel hybrid power generation systems for health service facilities in rural environments*. Electronic Journal of Energy and Environment*, 30 April. Available at: http://repositoriodigital.uct.cl:8080/xmlui/handle/123456789/1465 [Accessed 11 June 2014]
- Ani, VA (2014). Energy optimization map for off-grid health clinics in Nigeria. *International Journal of Renewable Energy Research,* 4(1). Available at: http://www.ijrer.org/index.php/ijrer/article/view/1071 [Accessed 20 June 2014].
- Atkinson J et al. (2009). *Natural ventilation for infection control in health-care settings.* Geneva: World Health Organization. Available at: http://www.ncbi.nlm.nih.gov/books/NBK143284/
- [Accessed 04 July 2014].
- Audsley EM et al., *How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope to reduce them by 2050.* 2009: Food Climate Research Network (FCRN) and World Wildlife Federation/United Kingdom (WWF/UK).
- Berners-Lee M, Hoolohan C, Cammack H, and C. Hewitt C (2012). *The relative greenhouse gas impacts of realistic dietary choices.* Energy policy. **43**: p. 184-190.
- Carbon Trust (2013). Introducing combined heat and power. Available at: http://www.carbontrust.com/media/19529/ctv044_introducing_combined_heat_and_power.pdf [Accessed 20 January 2014].
- Carlsson-Kanyama, A. and A. Gonzalez, *Potential contributions of food consumption patterns to climate change.* American Journal of Clinical Nutrition, 2009. **89**(5): p. 1704S-1709S.
- Chester M, Pincetl S, Elizabeth Z, Eisenstein W, and Matute J (2013). Infrastructure and automobile shifts: positioning transit to reduce life-cycle environmental impacts for urban sustainability goals. *Environmental Research Letters, 2013*. 8(1): p. 015041.
- Chester, M. Environmental Life-cycle Assessment of Passenger Transportation. [cited 2014 22 August]; Available at: http://www.transportationlca.org/
- Dora C et al. (2014). Indicators linking health and sustainability in the post-2015 development agenda, *The Lancet*. doi:10.1016/S0140-6736(14)60605-X. Available at: http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2814%2960605-X/abstract
- FAO (2011). *Biodiversity for food and agriculture. Contributing to food security and sustainability in a changing world*. 2011. Avaialble at: http://www.fao.org/fileadmin/templates/biodiversity_paia/PAR-FAO-book_lr.pdf
- Foresight (2011). *The future of food and farming. Final project report*. London, The Government Office for Science, United Kingdom of Great Britain and Northern Ireland.
- Global Green and Health Hospitals Network (2011). *A Comprehensive Environmental Health Agenda for Hospitals and Health Systems around the World*. Health Care Without Harm. Available at: http://greenhospitals.net/wp-content/uploads/2011/10/Global-Green-and-Healthy-Hospitals-Agenda.pdf
- GIZ and WHO (2011). *Urban transport and health: a sourcebook for policy-makers in developing countries.* Eschborn, Germany. Available at: http://www.who.int/hia/green_economy/giz_transport.pdf
- Haines et al. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *The Lancet.* 374:9797 pp- 2104-2114. http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(09)61759-1/abstract
- Health and Environment Alliance (2013). *The unpaid health bill: how coal power plants make us sick*. Avaialble at: http://www.env-health.org/resources/projects/unpaid-health-bill/

- International Energy Agency (2011). *Energy for all: Financing access, for the poor – special early excerpt of the World Energy Outlook 2011*. Paris: International Energy Agency. Available at: http://www.iea.org/papers/2011/weo2011_energy_for_all.pdf
- IPCC (2014): *Climate Change 2014: Mitigation of Climate Change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Edenhofer, OR et al, eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at: http://mitigation2014.org.
- IPCC (2014): Summary for Policymakers. In: *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Edenhofer, OR, et al, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at: http://mitigation2014.org.
- IPCC (2007): *Climate Change 2007: Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Metz B, et al, eds). Available at: http://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html$
- Kovats S, Depledge M, Haines A, Fleming LE, Wilkinson P, Shonkoff SB, and Scovronick N (2014). The health implications of fracking. *The Lancet*. **383**(9919): p. 757-758.
- Pan A, Sun Q, Bernstein AM et al (2012). Red meat consumption and mortality: results from 2 prospective cohort studies. *Arch Intern Med* ; 172: 555–63.
- Pan A, Sun Q, Bernstein AM, Manson JE, Willett WC, Hu FB (2013). Changes in red meat consumption and subsequent risk of type 2 diabetes mellitus: three cohorts of US men and women. *JAMA Intern Med*; 173: 1328–35.
- Norat T, Lukanova A, Ferrari P, Riboli E (2002). Meat consumptionand colorectal cancer risk: dose-response meta-analysis of epidemiological studies. *Int J Cancer*; 98: 241–56.
- Sathaye J et al (2011). Renewable Energy in the Context of Sustainable Development, in IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, (Edenhofer O, et al, editors). Cambridge University Press: Cambridge.
- NHS-England (2012). *Sustainability in the NHS. Health check 2012*. London, NHS-England. Available at: http://www.sduhealth.org.uk/documents/publications/Sustainability_in_the_NHS_Health_Check_2012_On-Screen_Version.pdf
- Wallén A, Brandt N, Wennersten R (2004). Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy*. 7(6): p. 525-535.
- WHO Regional Office for Europe (forthcoming). *The Health Implications of the IPCC's 5th Assessment Report*.
- WHO (2014). *Air Pollution Statistics*. Available at: http://www.who.int/topics/air_pollution/en/
- WHO and World Bank (2014). *Access to modern energy services for health facilities in resource-constrained settings. A review of status, significance, challenges and measurement*. Geneva, World Health Organization.
- WHO (2013). *Health in the green economy – health co-benefits of climate change mitigation*. *Housing, Household Energy, Transport, Health-care facilities, Occupational health* (series). Available at: http://www.who.int/hia/green_economy/en/.
- WHO (2003). *Diet, nutrition and the prevention of chronic diseases.* Report of a joint WHO/FAO expert consultation on Diet Nutrition and the Prevention of Chronic Diseases, Geneva, 28 January–1 February 2002. Geneva, World Health Organization, Department of Nutrition for Health and Development.
- WHO and Health Care Without Harm (2008). *Healthy Hospitals, Healthy Planet, Healthy People*. Available at: http://www.who.int/globalchange/publications/climatefootprint_report.pdf?ua=1