Health in the green economy

Co-benefits to health of climate change mitigation

HOUSEHOLD ENERGY SECTOR IN DEVELOPING COUNTRIES

Executive Summary

Key messages

Health co-benefits

- **Significant gains for both health and climate can be attained by providing access to clean cookstoves and fuels for the 2.7 billion people still dependent on the use of rudimentary, traditional biomass and coal stoves.** The use of cleaner household energy technologies to reduce climate change represents a major opportunity that is not been adequately explored. More systematic assessment of benefits is needed by the Intergovernmental Panel on Climate Change (IPCC) – along with greater consideration within climate, energy and health sectors of investment opportunities.
- **Traditional biomass and coal stoves used by almost half of the world's population** cause about 2 million deaths annually, including over 1 million deaths from chronic obstructive pulmonary disease and almost another million deaths from pneumonia in children under the age of 5.
- **These deaths are largely avoidable with cleaner and more energy-efficient stoves.** Scenario modelling, for instance, estimates that 11% of all chronic lung disease burden in Latin America and Sub-Saharan African among adults over 30 could be averted in less than a decade by the introduction of more advanced biomass or biogas stoves, in pace with UN targets for universal energy access.
- **Close to 17% of all pneumonia deaths among sub-Saharan African and Latin American children under 5 could be avoided by 2020** if more advanced biomass or clean fuel stoves were introduced at a pace compatible with the UN target for universal energy access, according to findings from scenario modeling.[a]
- **Lung cancer deaths of about 36,000 people every year are also due to** indoor air pollution from coal stoves, and these, too, are also largely avoidable with cleaner stoves.
- **More than one-third of the annual deaths from chronic lung disease worldwide and nearly 3% of lung cancer deaths** are due to indoor air pollution from biomass and coal stoves, and most of this burden is borne by poor women in developing countries. Action on this issue could thus have a huge impact on women's health, and particularly on the health of the poor.
- **Recent evidence suggests that exposure to indoor air pollution is also associated with other types of non-communicable diseases** such as heart disease, stroke, cataract, and other cancers, and also suggests that smoke from biomass stoves may also cause lung cancer.
- **Air pollutants from these stoves also have a strong impact on climate change.** Introduction of clean cookstoves will help reduce that impact, at the same time benefiting health.

About Health in the Green Economy

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

WHO's *Health in the Green Economy* series, to be published in 2011, is reviewing the evidence about expected health impacts of greenhouse gas mitigation strategies in light of mitigation options for key economic sectors, considered in the *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007* (IPCC).

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

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[a] Target as set by the United Nations Secretary General's Advisory Group on Energy and Climate and Climate Change (AGECC) for achieving "universal access to modern energy services by the year 2030. In the case of Latin America and Africa, keeping pace with this target would mean introducing about 13.1 million advanced biomass or biogas stoves, or other clean technologies, e.g. LPG. every year between 2010 and the end of 2019.

World Health Organization

The climate footprint of household energy in developing countries

Nearly 18% of global CO_2 emissions are attributed to energy and fuel use by the residential sector (International Energy Agency, 2008), including grid-electricity and household coal, oil, gas, LPG, etc. for cooking and heating. However, IEA estimates do not consider CO_2 emissions from household biomass fuel combustion, which is a primary household fuel source in developing countries and may or may not be harvested sustainably.

In addition to CO_2, the poor combustion of traditional biomass and coal stoves also releases very high levels of other pollutants, as "products of incomplete combustion". These include methane, a recognized greenhouse gas, as well a number of other pollutants like carbon monoxide and black carbon particles – not regulated by any climate change convention. Many scientists now believe that, on balance these products of incomplete combustion also are likely to contribute to global warming, although this remains a topic of some debate. Climate impacts of biomass stoves are even larger when biomass is harvested non-renewably.

- **It is estimated that emissions of climate change pollutants could be reduced by about 0.4-0.9 billion tonnes of CO2-eq[b] between 2010 and 2020 as a result of the** dissemination and adoption of new, very-low emission biomass stoves or other clean fuel technologies (especially renewable fuels such as biogas) to households in sub-Saharan Africa and Latin America at the same universal energy access rate. This translates into distribution of about 9 million stoves annually in 2010-2020.
- **The health risks of coal use and kerosene use for cooking, heating and lighting also require closer examination** as these fuels are associated with the release of much higher levels of health damaging and climate change emissions than, for instance, LPG or natural gas, or in the case of lighting, small PV solar-powered panels and lanterns.

"Win-win" strategies for health and mitigation

- **There is increasing synergy between cost-effective stove and fuel technologies and health gain potential.** New stove technologies and cleaner liquid and gaseous fuels that substantially reduce carbon emissions (e.g. CO_2, methane and black carbon) also reduce exposures to the most health-damaging air pollutants (e.g. particulate matter) by as much as 90%[c].[12–15] Field studies are needed to better assess uptake of these technologies and health impacts on multiple diseases.
- **New and relatively inexpensive biomass stoves using fans and/or secondary combustion (gasification)** have shown reductions of up to 40% in fuel consumption, and up to 90% in indoor air emissions in laboratory evaluations.[1,12,14] Field-based studies are needed to confirm that similar reductions can be obtained in households.

SCOPE AND METHODS

This analysis reviews the potential health impacts of mitigation strategies and technologies for the household energy sector in developing countries, as highlighted in IPCC's *Working Group III – Fourth Assessment Report.* Additional reference is made to other relevant policy documents. These include the summary report of the United Nations Secretary General's Advisory Group on Energy and Climate Change (AGECC)[26] and the recently published International Energy Agency's *World Energy Outlook 2010*[1] chapter on energy poverty. Both of these reports include recommendations and specific targets for household energy in the context of climate change and sustainable development. They also examine the impacts and investment required for alternative scenarios for providing universal access to clean, modern household energy.

Mitigation options are assessed in terms of health benefits and risks, using two approaches and drawing on an extensive review of laboratory and field testing. The first approach is a schematic summary of overall health and mitigation benefits for a range of available fuel and technology combinations, including consideration of costs and any potential limitations or tradeoffs. This is followed by scenario-based estimates of avoided deaths and mitigation potential resulting from adoption of the most promising low-emission household energy interventions when applied to populations in sub-Saharan Africa (excluding two countries with low solid fuel use) and continental Latin American countries.

Supportive policies and decision-making tools discussed in this review include the use of health impact assessments (HIA) to estimate potential health gains from improved technologies, and financial instruments such as carbon finance, which is an important way to help poor communities access cleaner fuels and technologies.

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[b] CO_2 or other climate active pollutants. Published but not official 100-year global warming potentials (GWP) for carbon monoxide, non-methane volatile organic carbons and official UNFCCC GWPs for methane and nitrous oxide were used to calculate the range of emissions reductions from the intervention. Net reductions in CO_2 are not accounted for in these estimates as biomass harvesting was assumed to be 100% renewable. The methodology to estimate emissions in CO_2-eq saved per stove day was developed for a paper in the Lancet series on the health co-benefits of climate change mitigation, a series co-sponsored by the Wellcome Trust (coordinating funder); Department of Health, National Institute for Health Research; the Royal College of Physicians; the Academy of Medical Sciences; the Economic and Social Research Council; the US National Institute of Environmental Health Sciences; and WHO.[7]

[c] The typical range of $PM_{2.5}$ personal exposure from traditional fuel use in developing countries is 200 to 500 µg/m^3.Therefore reductions of kitchen concentrations by 90% or more would bring exposure at or near the WHO Air Quality Guidelines Interim Target-1 of an annual mean concentration of 35 µg/m^3, a level at which is thought to substantially reduce disease risk from air pollution[27].

- **Biogas stoves fueled by anaerobic digesters of animal, human and crop waste have been shown in laboratory studies to reduce health-damaging air pollution by up to 90% with a very low climate impact, and are being used widely in China and South-East Asia for household cooking and lighting.**[16,17] If the digester is also linked to a latrine, the resulting improvement in sanitation could help prevent worm infestation, diarrhoeal disease and malnutrition.[18,19]
- **Liquefied petroleum gas (LPG) reduces health-damaging indoor air pollution exposures by more than 90% in comparison to open fires or traditional stoves.**[14,20] LPG is a fossil fuel whose combustion has a low climate impact in comparison to traditional biomass and coal at point of use. This does not, however, consider environmental impacts related to production and transport or logistics and equity impacts of accessing fuel sources, particularly in rural areas.[20]
- **While kerosene is described as a clean cooking fuel on par with LPG in terms of its potential to replace biomass in IPCC assessment,** the health impacts of kerosene cookstoves may be more severe than LPG cookstoves, as kerosene leads to higher indoor air pollution than most other liquid and gaseous fuels as well as an increased risk of burns, fires and poisonings.[13,20]
- **Small, solar-powered light emitting diode (LED) lighting can reduce risks of burns and exposure to air pollution when it replaces kerosene lamps.** As IPCC notes: "While kerosene lamps provide only 1% of global lighting, they are responsible for 20% of lighting-related CO_2 emission and consume 3% of the world's oil supply, while a compact fluorescent light (CFL) or LED light is 1000 times more efficient." In India, household and community-level photovoltaic systems are already being widely used to power domestic lights. Photovoltaic (PV) electricity also offers potential for expanded use and development of other low-power direct current (DC) devices, including for communications and refrigeration.
- **Cooking technologies that also heat water, for example the WAter DIsinfection Stove (WADIS)**, can reduce exposure to both air pollution and water-borne disease. This also improves quality of life by providing warm water for bathing and laundry and by reducing time spent collecting fuel that would be needed for these activities.[21]
- **Health and mitigation impacts of space heating, as well as cookstoves, need more thorough assessment to identify "packages" of technologies most suited to different climatic environments, e.g. regions where space heating is required.** For example, a highly efficient wood-burning stove used for space heating may be cleaner than an unvented kerosene space heater. Failure to consider space heating needs may result in households adopting clean cooking solutions but supplementing these with traditional stoves and fuels for adequate thermal comfort. The net emissions and health impacts of heating and cooking systems thus need assessment in an integrated manner.

BACKGROUND AND RATIONALE

The residential sector is a substantial source of greenhouse emissions and other climate-damaging pollutants, with direct CO_2 emissions accounting for nearly one fifth of global CO_2 emissions in 2008.[10] The net contribution to climate change is considerably greater when other greenhouse gases (i.e. methane) and short-lived pollutants (i.e. black carbon) are accounted for, as it is the non-CO_2 pollutants from the incomplete combustion of household fuels that have the most immediate effects on climate and damaging effects on health.

IPCC assessment notes that the residential and commercial building sector has the highest immediate mitigation potential to reduce climate change pollutants. In comparison with other sectors, larger absolute reductions in CO_2-equivalent emissions of climate change pollutants addressed in the Kyoto protocol[c] are possible by the year 2030 – at a cost of less than US$ 100 per ton of CO_2-equivalent. This arises from opportunities to markedly reduce energy consumption in buildings, to switch to low-carbon and renewable fuels and to control emissions of climate change pollutants other than CO_2 (e.g. methane).

Particularly in developing countries, household solid fuel use also results in a substantial disease burden[5]. Close to three billion people obtain their household energy for cooking and heating from solid fuels (wood, coal, charcoal, dung and crop wastes) burned in open fires and traditional stoves.[1,2] This combination of inefficient stove design and solid fuel use leads to very incomplete combustion and high levels of air pollution emissions (indoor and outdoor) that are severely damaging to both health and climate.

Such indoor air pollution is a major risk factor for childhood pneumonia, chronic obstructive pulmonary disease and also lung cancer where coal is used.[6] Recent evidence has also shown associations with an increased risk of adverse pregnancy outcomes,[22] cardiovascular disease,[7,23] cataracts and tuberculosis, as well as other cancers.[24] In low-income countries, indoor smoke was responsible for an estimated 4.0% of the overall disease burden in 2004, making it the most important cause of death and illness after childhood underweight, unsafe sex, lack of safe water and sanitation and suboptimal breastfeeding.[5]

Women and children are most directly exposed to indoor air pollution, as well as being more at risk for burns and scalding, and vulnerable to attack and injury during fuel collection.[24, 25]

New technologies for more efficient household fuel use in developing regions hold some of the greatest potential co-benefits for both health and climate in the household energy sector because they greatly reduce emissions. These interventions offer other co-benefits to health, gender equity and sustainable development for billions of people.

The WHO review brings together initial evidence of such co-benefits to identify strategies and measures worthy of further systematic exploration.

SUMMARY OF INITIAL FINDINGS

The IPCC has identified important opportunities for climate change mitigation in the residential building and energy sectors. However, mitigation options for household energy in developing countries require more systematic assessment, including review of potential health co-benefits.

This review highlights the climate-changing role of short-lived pollutants that result from inefficient use of solid fuels in developing countries. The serious health impacts that arise from these emissions, estimated at almost two million premature deaths for the year 2004, underlines the global opportunity to achieve very large health gains through mitigation measures.

Regarding household energy use in developing countries, the IPCC proposed a range of improved stove technologies and cleaner fuels to reduce climate changing emissions. While most of these will deliver climate and health benefits, the overriding message of this review is that some of those having the largest impact on mitigation may also deliver the largest health gains.

For example, biogas and advanced biomass stoves using secondary combustion can potentially deliver very large combined health and climate benefits. Fossil fuels such as LPG also can deliver significant health gains with lower climate impact than traditional solid fuel use, due to LPG's more complete combustion. Electricity is the cleanest household fuel at point of use, but that does not consider pollution and climate impacts from power generation. Also, grid extension of electricity sufficient for cooking and heating poses logistical and financial challenges in many rural areas.

In the case of lighting and low-wattage appliances, renewable home and community-based electrical systems, such as solar photovoltaic (PV) or hydro-electric, may replace kerosene lamps, and provide immediate and sustainable benefits to health and development at low cost and with minimal climate impact.

Overall, more specificity is needed for better assessment of the health co-benefits and tradeoffs for a range of existing and emerging technologies. Rural biogas and improved biomass technologies need more systematic evaluation in light of fast-growing energy demands and the logistical and environmental barriers to conventional grid expansion. The health impacts of kerosene use may be greater than, and should be distinguished from, those arising from other liquid or gaseous fossil fuels such as LPG. The continuing widespread use of coal as a household fuel in some regions, especially China, suggests that further consideration of its health impacts and mitigation opportunities is needed.

Consideration of local needs, opportunities and costs is needed to make solutions relevant to developing countries, and to mount pragmatic investment and infrastructure programmes.

Some of the world's poorest people stand to gain the most in terms of health and development from clean household energy. However, substantial investment is required if the universal energy access goals proposed by AGECC are to be met. Innovation also is needed to facilitate access by those most disadvantaged.

The large climate change mitigation potential of household energy improvements offers opportunities for substantial use of carbon finance mechanisms. Such investments could be much enhanced if the Clean Development Mechanism of the United Nations Framework Convention on Climate Change was reformed to consider mitigation of short-lived climate change pollutants, and to account for health co-benefits.

Reduction in emissions from selected fuel/stove combinations

(Compared to open fire or traditional cookstove at point of use)

IPCC strategy to reduce cooking energy needs	Technology evaluated	Reduction in health-damaging pollutants	Reductions in climate change pollutants	Potential for renewability of fuel supply	Comments
Improved biomass stoves	Advanced biomass stoves using forced ventilation with or without secondary combustion (gasification) i.e. fan-assisted biomass stoves, forced draft gasifier	High	High	High	Emissions have been tested in laboratory settings, but field testing has been limited. Stoves are being used mainly in China and India. Fuel processing is required (e.g. pellets or small cuttings), which may increase fuel cost. Stoves fitted with fans require low-wattage electric power, and batteries permit stove use even with intermittent electricity supply. Some newer models generate power independently from heat (thermo-electric generation). Suitable largely for cooking, rather than space heating.
	Intermediate stove technologies using improved combustion chambers i.e. rocket stoves, natural draft gasifier	Moderate	Moderate	High	Emissions have been tested in both laboratory and field settings. Performance varies widely between models, settings and accessories. Fuel must be cut smaller, but processed fuels are not usually required. Those stoves with well-maintained chimneys will further reduce indoor smoke exposures. Also can provide some space heating, although well-insulated models emit less radiant heat.
	Simple improved stoves, typically enclosed and with some improvement to combustion	Low (moderate, with well-functioning chimney)	Low	High	Emissions have been tested in laboratory and field settings. Performance varies greatly depending on design and condition, with some stoves delivering little or no reduction in emissions and exposure, while others can halve indoor exposure where chimneys are fitted and the stove is kept in good condition. Processed fuels not required. Can be expected to provide some space heating.
Improved access to clean cooking fuels, both liquid and gaseous	Biogas	High	High	High	Emissions have been tested in laboratory settings. Used widely in Nepal and China. Convenient; one digester can meet an average family's cooking needs for most months of the year. However, digesters require a water supply and a waste supply from at least two livestock – although human and crop waste can contribute. Initial cost of digester is high. Unlikely to be suitable where substantial space heating is needed due to volume of gas required. Methane leakage may compromise some climate benefits. Relatively long lifespan compared to most stoves.
	Liquefied petroleum gas (LPG)	High	High	None	Convenient, clean and relatively safe, but moderately expensive (stove, gas storage bottle and fuel) with rising prices expected. LPG stove technology is relatively durable and long-lasting. LPG supply in rural areas is often limited and adds to costs. Unlikely to be suitable for space heating in low-income households due to costs required for large volumes of fuel.
	Kerosene	Moderate	Moderate (high with efficient pressurized combustion)	None	Historically regarded as a relatively 'clean' fuel. However, emerging evidence has linked kerosene use with a number of respiratory diseases, including tuberculosis. Emissions are highly dependent on fuel content (e.g. sulphur) and purity, on the combustion/lighting device, and whether the device is pressurized. There are also significant health risks from poisoning and burns. Relatively inexpensive as a fuel, although linked to oil prices.

The reductions in both climate emissions and health-damaging pollutants achieved by any particular type of intervention will vary for the different fuel/stove groups illustrated, according to the precise technology, condition, quality of fuel and many other factors, but these reductions can be broadly defined. These definitions are typical averages based on an extensive review of laboratory and field test evidence, using per cent reduction in emissions of CO_2-equivalents, particulate matter (PM) and carbon monoxide (CO). High emissions reductions are defined as ≥ 90%, moderate as ≥ 30% and < 90% (usually substantially less than 90%) and low as <30%.

SELECTED REFERENCES

1. Energy poverty: How to make modern energy access universal? In: *World Energy Outlook 2010 for the UN General Assembly on the Millennium Development Goals.* Paris, Organisation for Economic Co-operation and Development & International Energy Agency, 2010.
2. Legros G et al. *The Energy Access Situation in Developing Countries.* New York, United Nations Development Programme & World Health Organization, 2009.
3. Smith KR et al. Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants. *Lancet,* 2009, 374(*9707*):2091–103.
4. Smith KR, Haigler E. Co-benefits of climate mitigation and health protection in energy systems: scoping methods. *Annual Review of Public Health,* 2008, 29:11–25.
5. *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva, World Health Organization, 2009.
6. Smith KR, Mehta S, Mäusezahl-Feuz M. Indoor air pollution from household use of solid fuels. In: Ezzati M et al., eds. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attribution to Selected Major Risk Factors*. Geneva, World Health Organization, 2004:1435–93.
7. Wilkinson P et al. Public health benefits of strategies to reduce greenhouse-gas emissions: household energy. *Lancet,* 2009, 374(*9705*):1917–29.
8. Levine M et al. Residential and commercial buildings. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge & New York, Cambridge University Press, 2007:387–446.
9. Sims REH et al. Energy supply. In: Metz B et al., eds. *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge & New York, Cambridge University Press, 2007:251–322.
10. *CO_2 Emissions from Fuel Combustion: Highlights*. Paris, Organisation for Economic Co-operation and Development & International Energy Agency, 2010:130.
11. Unger N et al. Attribution of climate forcing to economic sectors. *Proceedings of the National Academy of Sciences of the United States of America,* 2010, 107(*8*):3382–7.
12. Venkataraman C et al. The Indian National Initiative for Advanced Biomass Cookstoves: The benefits of clean combustion. *Energy for Sustainable Development,* 2010, 14(*2*):63–72.
13. Bond T, Venkataraman C, Masera O. Global atmospheric impacts of residential fuels. *Energy for Sustainable Development,* 2004, 8(*3*):20–32.
14. MacCarty N, Still D, Ogle D. Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance. *Energy for Sustainable Development* 2010;14(*3*):161–71.
15. Smith KR et al. *Greenhouse gases from small-scale combustion devices in developing countries, phase IIa: household stoves in India*. Washington, United States Environmental Protection Agency, 2000.
16. Yu L et al. Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. *Renewable Energy,* 2008, 33(*9*):2027–35.
17. Smith K et al. Greenhouse gases from small-scale combustion in developing countries: an analysis for India. *Annual Review of Energy and the Environment,* 2000, 25:741–63.
18. Remais J, Chen L, Seto E. Leveraging rural energy investment for parasitic disease control: schistosome ova inactivation and energy co-benefits of anaerobic digesters in rural China. *PLoS One,* 2009, 4(*3*):e4856.
19. Acharya J, Bajgain MS, Subedi PS. Scaling up biogas in Nepal: What else is needed? *Boiling Point,* 2005:50.
20. Smith KR, Rogers J, Cowlin S. *Household Fuels and Ill-Health in Developing Countries: What improvements can be brought by LP gas?* Paris, World LP Gas Association, 2005.
21. Christen A, Navarro CM, Mäusezahl D. Safe drinking water and clean air: An experimental study evaluating the concept of combining household water treatment and indoor air improvement using the Water Disinfection Stove (WADIS). *International Journal of Hygiene and Environmental Health* 2009, 212(*5*):5628.
22. Pope DP et al. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic Reviews,* 2010, 32(*1*):70–81.
23. Pope CA, Burnett RT, Krewski D et al. Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke: shape of the exposure-response relationship. *Circulation* 2009;120(*11*):941–8.
24. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization,* 2000, 78(*9*):1078–92.
25. Rehfuess E. *Fuel for Life: household energy and health.* Geneva, World Health Organization, 2006:42.
26. *Energy for a Sustainable Future: Summary Report and Recommendations*. New York, United Nations Secretary-General's Advisory Committee Group on Energy and Climate Change, 2010.
27. World Health Organization. WHO air quality guidelines -- global update 2005. Copenhagen: World Health Organization, 2006.

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Cooking on a biogas stove, Kim Thanh District, Vietnam.
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