Valuing Integrated Public Health Interventions: Combined Household-level Clean Energy, Sanitation, and Hygiene in Sub-Saharan Africa

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Abstract
Placing poor households at the center of energy, sanitation, and hygiene interventions offers opportunities to effectively address multiple development priorities simultaneously using integrated approaches. Understanding and quantifying the health benefits of integrated household energy-sanitation-hygiene interventions is a key ingredient in the decision making process. Using a test case of a latrine-connected biogas digester accompanied by hygiene education, this study estimates the economic value of health benefits associated with access to clean energy, sanitation and hygiene practices in Sub-Saharan Africa, including an analysis of households with and without access to safe drinking water. To value intervention-associated disease burden, we combine the Disability Adjusted Life Years (DALYs), published by the World Health Organization, with per capita estimates of GNI and agricultural GDP. The results of the analysis suggest that the economic value of combined annual household-level health benefits, conservatively estimated, amount to roughly $80-$126 per year depending on assumptions.

Introduction
In Sub-Saharan Africa, the majority of poor households lack basic cooking facilities, access to safe drinking water and even the most rudimentary latrine. As a result, poor families breathe polluted air from indoor cooking, drink contaminated water from lack of access to adequate sanitation, and often fail to practice basic hygiene, leading to more than 3.2 million deaths each year on a global basis[1]. Indoor air pollution alone led to 392,000 deaths in Africa in 2000 (WHO 2006c). Household-level interventions can prevent disease and death because they are "effective, inexpensive, and rapidly deployable" (WHO, 2006a). Understanding the health benefits associated with household-level investments in clean energy, sanitation, safe drinking water and hygiene promotion in Sub-Saharan Africa is a critical ingredient in the policy and investment decision making process. Rational, information-based decision making requires a basis for comparison among alternative investments. A core problem facing decision makers is a lack of information about the economic value of health benefits associated with a household level clean energy-sanitation-hygiene program in Sub-Saharan Africa.

The objective of this study is to measure the economic value of health benefits from an integrated perspective, with a focus on household-level clean energy, sanitation, hygiene, and water quality interventions in Sub-Saharan Africa. The two primary economic benefits associated with interventions that affect health outcomes will be measured, namely health-related productivity and income effects and illness-related health expenditures. Estimating the economic value of health benefits involves four key steps:

1) Defining the intervention: identify intervention parameters

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[1] 1.5 million resulting from indoor air pollution and 1.7 million due to diarrhea.

2) Establishing the health impacts: link exposure to health outcomes based on epidemiological studies.
3) Quantifying the health impacts: aggregate health outcomes and determine the proportion due to attributable causes, such as indoor air pollution.
4) Valuing health impacts: place economic values on productivity losses and health care costs.

These four steps are discussed in further detail below, along with analysis of results from several test scenarios, followed by conclusions and their implications for integrated health intervention investments.

Defining the Intervention

In our test scenarios, the "intervention" involves reducing exposure to indoor air pollution and fecal-oral pathogens by changing from solid fuels to cleaner-burning methane, providing access to sanitary latrines and improving hygiene behaviors. The basic intervention includes provision of a household-level biogas digester with an attached sanitary latrine, coupled with hygiene education, resulting in clean burning fuel for cooking and lighting, improved sanitation and enhanced hygiene behavior.

Several intervention scenarios are modeled (Table 1). Under all three scenarios households switch from burning polluting solid fuels to cleaner-burning methane produced from a biogas digester with a sanitary latrine attached[2]. Hygiene promotion includes two possible levels of behavior change – the first results in moderate behavior change (Scenario 1) and the second more significant behavior changes (Scenarios 2 and 3), especially increased hand washing. Under Scenarios 1 and 2 households are assumed to already have access to enough water to meet basic household needs, including the biogas digester[3]. For Scenario 3, it is assumed that households have access to safe drinking water from an *improved* source and a sufficient quantity to meet basic household needs.

Table 1. Definition of intervention scenarios modeled

Intervention	Scenario 1	Scenario 2	Scenario 3
Energy	Cleaner fuel through biogas digester	Cleaner fuel through biogas digester	Cleaner fuel through biogas digester
Sanitation	Improved latrine basic	Improved latrine basic	Improved latrine basic
Hygiene	Hygiene promotion I—moderate behavior change	Hygiene promotion II—significant behavior change	Hygiene promotion II—significant behavior change
Water	Access to water	Access to water	Access to *safe* water

[2] Unimproved sanitation facilities include: Flush or pour-flush to elsewhere (flushed to street, yard, open sewer or ditch, or other location), pit latrine without slab or open pit; hanging toilet or hanging latrine; or no facilities or bush or field. Improved sanitation facilities include: flush or pour-flush to piped sewer system, septic tank or pit latrine, or ventilated improved pit latrine, pit latrine with slab, or composting toilet.

[3] Households must have access to water for biogas digesters, therefore it is assumed that sufficient quantity of water is already available. For health benefits, the quality of water is also important.

Establishing Health Impacts

There is compelling evidence linking indoor air pollution and poor hygiene and sanitation to negative health impacts (see Table 2). Burning solid fuels leads to very high levels of indoor air pollution, inhaled smoke contains a complex cocktail of hundreds of health-damaging pollutants[4] (WHO, 2006a). Women and children, who spend the most time exposed to indoor air pollution, are at greatest risk. Epidemiological studies have established associations with several specific health impacts of indoor air pollution[5]. The evidence base is most conclusive for acute lower respiratory infections (ALRI), especially among children under age five, and chronic obstructive pulmonary diseases (COPD) for women over age 30. Due to the strength of evidence and magnitude of disease burden, ALRI and COPD are focused on in this study. Epidemiological studies have also established links between exposure to indoor air pollution and lung cancer, asthma, cataracts, and tuberculosis. While these additional diseases are not included in our current economic analysis of health impacts, their economic impacts may be quantified at a later date if future studies reach consensus on the percentage of each disease attributable to indoor air pollution.

Since the 1950s, epidemiological studies have established a solid evidence base that demonstrates the positive health outcomes associated with access to improved water and sanitation facilities, especially when coupled with hygiene promotion. These studies have also shown that lack of access to safe drinking water and adequate sanitation significantly increases exposure to pathogens through a variety of pathways[6]. The focus of the current study is on water-born and water-washed diseases, which at the household level are the diseases most closely associated with poor water supply, sanitation and hygiene practices (Hutton and Haller, 2004). The disease burden from water-borne and water-washed diseases consists mainly of infectious diarrhea[7]; children, particularly those under the age of five, are most vulnerable. As with indoor air pollution, there are several diseases associated with poor hygiene and sanitation, but these diseases lack epidemiological quantifications of the percentages directly attributable to hygiene and sanitation. Thus, only diarrheal disease is included in our economic analysis, and our conclusions regarding impacts of hygiene, sanitation, and water quality should be considered conservative.

[4] Primarily small respirable particles and carbon monoxide, but also nitrogen oxides, benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and many other health-damaging chemical substances (WHO, 2006). Where coal is used, additional contaminants such as sulfur, arsenic and fluorine may also be present. Typical 24-hour exposure to particulate matter indoor air pollution associated with burning solid fuels is 1000+ μ/m^3. (US EPA 24-hour standard for ambient air is 65 μ/m^3). Typical exposure for women and children, who spend large amounts of time in indoor kitchens, is equivalent to smoking 2 packs of cigarettes per day.

[5] For example, inhaling indoor air pollution (1) doubles the risk of pneumonia and other acute infections of the lower respiratory tract among child under the age of 5 years, and; (2) triples the incidence of chronic obstructive pulmonary disease (e.g. chronic bronchitis or emphysema) among women exposed to indoor smoke than those who cook with gas, electricity or cleaner fuels.

[6] Five basic routes of infections: (1) water-borne diseases (typhoid, cholera); (2) water-washed diseases (trachoma); (3) water-based diseases (schistosomiasis); (4) water-related vector-borne diseases (malaria, filariasis and dengue); and (5) water-dispersed infections (legionellosis). Hutton and Haller, 2004.

[7] Infectious diarrhea includes cholera, salmonellosis, shigellosis, amoebiasis, and other (protozoal or viral) intestinal infections.

Table 2. Health impacts associated with indoor air pollution exposure and lack of sanitation, and evidence base

Health Outcome	Evidence Base[(a)]
Sanitation Impacts	
Diarrheal disease*	Strong
Protein-energy malnutrition	Strong
Intestinal nematode infections	Strong
Trachoma	Strong
Indoor Air Pollution Impacts	
Acute lower respiratory infection (ALRI)*	Strong
Chronic obstructive pulmonary disease(COPD)*	Strong (women >30 yrs), Moderate I (men (>30 yrs)
Asthma	Moderate II (> 5 yrs)
Lung cancer**	Strong (women >30 yrs), Moderate I (men (>30 yrs)
Tuberculosis	Moderate II
Cataracts	Moderate II adults >15 yrs

Sources: WHO, 2006a. UNESCO-WWAP, 2006.
* indicates most significant health impacts, and a disease quantified in our economic analysis
**specific to coal use
a) *Strong* indicates a well-established and compelling evidence for all age/sex groups. *Moderate I* indicates strong evidence for specific age/sex groups. *Moderate II* indicates limited evidence.

Quantifying Health Impacts

Understanding and evaluating the impacts of ALRI, COPD and infectious diarrhea on poor households is an important ingredient in the decision making process. In general, evaluating health impacts to make rational decisions on public health interventions has been difficult because of the lack of a tool to compare and aggregate the range of health outcomes, especially fatal versus disabling diseases. In addition, it has been difficult to attribute a cause to health outcomes. For example, many of the health outcomes related to lack of sanitation, safe water and indoor air pollution may have other root causes. For example, acute respiratory infection could be related to smoking or auto pollution and diarrheal disease could be due to improperly cooked meat.

The landmark Global Burden of Disease and Injury series (Murray and Lopez, 1996), a result of eight years of painstaking research, was the first internally consistent global epidemiological data set on disease burden (Pruss and Havelaar, 2001). Initially, the study focused on assessing the public health significance of different diseases, available interventions to reduce disease risks and their cost effectiveness. An important outcome of this initial work was the creation of a new summary measure for analyzing diverse disease outcomes known as the DALY (or Disability Adjusted Life Year), a summary measure of population health and an important indicator for assessing disease burden. Since 1996, the DALY has been continually refined and updated to include estimates for disease burden by both disability and death. It has also been used increasingly to assess public health priorities, particularly in developing countries.

The DALY is a common measurement unit that allows comparison between different health outcomes and quantification of non-fatal outcomes. The DALY allows integration of the health burden of different health effects from one agent (such as air pollution) or comparing the effects of different agents (air pollution from indoor cooking verses auto pollution) (Pruss and Havelaar, 2001). For each disease, the DALY is the discounted sum of years lost due to premature mortality or years lost due to disability for incident cases of ill-health. In economic valuation terms, DALYs represent time that is lost as a result of illness or death that could have been used for productive and income generating activities, education and leisure. For those diseases with the most significant disease burden, DALYs are decomposed to identify the proportion of DALY's attributable to specific agents and interventions (such as sanitation). These estimates can be utilized to identify the most effective public health intervention strategies.

Table 3 shows the estimated DALYs for health outcomes related to indoor air pollution and lack of access to safe drinking, poor sanitation and hygiene[8]. As described above, DALYs include both death (mortality) and disability (morbidity). These are the DALYs that could be prevented through effective clean household energy, sanitation and hygiene programs. The DALYs shown in Table 3 are associated with the intervention scenarios described in Table 1[9]. For example, for diarrheal diseases, three different levels of DALYs are shown which correspond to the three intervention scenarios. These include DALYs that could be prevented through (1) clean energy, improved sanitation and moderate hygiene behavior change (Scenario 1), (2) clean energy, improved sanitation and significant hygiene behavior change (Scenario 2), and (3) clean energy, improved sanitation, significant hygiene behavior change and safe drinking water (Scenario 3).

Table 3. Annual preventable DALYs in Sub-Saharan Africa through clean indoor energy, improved sanitation, hygiene, and water quality

Health Outcomes	Scenario 1	DALY Scenario 2 ('000)	Scenario 3
Diarrheal diseases	13,761	15,934	21,246
ALRI	12,608	12,608	12,608
COPD	267	267	267
Total	**26,637**	**28,810**	**34,121**

The estimated number of DALYs in Table 3 shows the significant impact on infectious diarrhea and ALRI in Sub-Saharan Africa, especially children under age five who comprise most deaths from both diseases (See Appendix Table A.1 for a breakdown of DALYs by age). For example, each year the equivalent of 12.6 million years of productive time is lost in Sub-Saharan Africa to

[8] Estimating DALYs attributable to specific agents, or different agents, is a very complex and time intensive process. Because of the public health importance in developing countries of indoor air pollution and lack of access to safe water, improved sanitation and poor hygiene, estimates of DALYs attributable these agents have been estimated. The percentage of total DALYs for ALRI and COPD due to indoor air pollution from burning solid fuels is 35% and 11%, respectively (WHO, 2006a, b). The percentage of total DALYs due to infectious diarrhea for the 3 scenarios modeled are (1) improved sanitation and moderate hygiene behavior change (57%, Cairncross and Valdmanis (2005) based on Esrey et al., 1991), (2) improved sanitation and significant hygiene behavior change (66%, Cairncross and Valdmanis(2005), and (3) access to safe drinking water, improve sanitation and significant hygiene behavior change (88%; Cairncross and X, and WHO, 2004).
[9] More detailed data on mortality and DALYs by age are shown in Appendix table A.1.

indoor air pollution related ALRI. This translates into roughly 6 days per person each year lost to indoor air pollution. Similarly, diarrhea from poor sanitation and hygiene results in an annual loss of over 13.7 million years of productive time (WHO, 2006).
DALYs also provide a basis to evaluate the cost-effectiveness of alternative investments in public health. Although cost estimates are not available, it is interesting to note that sanitation and better hygiene combined yield greater reductions in diarrhea-related DALYs than access to safe drinking water alone. While access to safe drinking water is of paramount importance, these results underscore the importance of sanitation and hygiene promotion in improving the health and livelihoods of the poor.

Valuing Health Impacts
There are two categories of economic benefits associated with interventions that affect health outcomes: health-related income and productivity effects and expenditures related to disease treatment.

Health-related income and productivity effects. Improved health and fewer illness days means more time available for productive activities. Economic valuation of the social benefits of health related interventions should include the opportunity costs of time lost to illness (Drummond *et al.* 1997, WHO, 2006b). This study utilizes the human capital approach to valuing illness-free days, which uses labor market prices to value changes in health status[10]. Three key questions related to valuation are: (1) What value to assign to a day of productive time? (2) How should this value vary based on age, employment status and nature of work? (3) What about children's time?

In this study, productive time is valued using the 2004 gross national income (GNI) ($US) per capital for Sub-Saharan of $606 ($1.66/day). Both GNI and GDP are commonly used for valuation of time with GNI being a slightly more conservative measure[11]. In this study, we opted for GNI following Hutton and Haller (2004) and Hutton and Rehfuess (2006) in their economic valuation of health benefits. In addition, we also estimate the value of productive time using agricultural gross domestic product (GDP) for Sub-Saharan Africa of $186 ($.51/day) per *rural* capita[12] as an ultra conservative estimate for the value of time in poor rural areas. Given the regional nature of this study and limitations of available data across countries, we chose not to value time differently based employment status and nature of work. However, we do value time differently based on age.

In this study, we differentiate between two age groups: children and adults. Children ages 5-15 should be in school and illness-related absences are valued following Hutton and Haller (2006) and others. Children under the age of five are usually cared for by an adult when they are sick making the adult less productive. Similar global-level studies in the area of water, sanitation and energy interventions suggest valuing child's illness time at one-half the adult value (Hutton and

[10] The other two approaches for valuing illness free days, including the revealed preference approach and contingent valuation approach are described in relation to energy and health in WHO's cost-benefit guidelines on valuing changes in energy and health (see Hutton and Rehfuess, 2006)
[11] For example, 2004 per capita estimates for Sub-Saharan Africa for GDP and GNI were $729 and $606, respectively.
[12] Agricultural GDP per *rural* capita for this study was valued as the Ag GDP divided by the rural population.

Haller, 2004; Hutton and Rehfeuss, 2006). At the time of this study, disaggregated DALYs based on disability and deaths for children under the age of five attributable to indoor air pollution and lack of sanitation were not readily available.

Aggregated DALYs can present a challenge in valuation studies in such situations because DALYs for deaths include the discounted value of entire estimated lifetime of a child, should s/he live into adulthood. In short, early years and later years, which are not very economically productive, are heavily discounted. If deaths comprise the majority of DALYs for children under the age of 5, as is the case for infectious diarrhea and ALRI, estimates of the value of DALYs at one-half adult rates will significantly underestimate the total value. However, if disability-related DALYs comprise the majority, then discounting by one-half should lead to a reasonable estimate. Given that deaths comprise a substantial share of DALYs for the 0-4 age group, estimates based on one-half of their value (such as in Case B below) would lead to significant underestimations. We therefore include both valuation methods for comparison purposes.

Expenditures on disease treatment. Health expenditures due to infectious diarrhea, ALRI, and COPD include 2 categories of costs: health care system costs (costs for outpatient consultation and inpatient admissions) and patient (costs for drugs, materials and procedures and transportation costs to seek care). Health system and patient costs were estimated using Sub-Saharan Africa regional estimates contained in WHO global health studies related to water and sanitation and indoor air pollution (Hutton and Haller, 2004; Hutton and Rehfeuss, 2006). Due to the paucity of data, aggregate regional estimates for health expenditures for WHO sub-regions in Sub-Saharan Africa were used to derive per capita estimates (see Table 4).

Table 4. Per Capita Annual Direct Health Expenditure for Sub-Saharan Africa

Type of cost	Diarrhea	ALRI & COPD	Total
health care system	$1.70	$0.13	$1.83
patient	$0.11	$0.02	$0.12
total	$1.81	$0.15	$1.95

Sources: Estimated using aggregate annual regional health care system and treatment costs for WHO sub-regions in Sub-Saharan Africa divided by population (Hutton and Haller, 2004; Hutton and Rehfeuss, 2006)

Results

Table 5 shows the annual economic value of health-related income and productivity effects in Sub-Saharan Africa associated with access to clean energy, adequate sanitation, and improved hygiene behaviour based on GNI of $606/year. Values are estimated for 3 intervention scenarios and under two different assumptions for the valuing of DALYs for the 0-4 age group. In Case A, the DALYs for children under the age of 5 years are valued at that of adults, yielding household annual productivity losses ranging from $115-$148, depending on the level of hygiene behaviour change and access to safe water. In Case B, the DALYs for children under the age of 5 years are valued at one-half the rate of adults, resulting in household annual losses ranging from $67-$85 depending on the scenario. Because DALYs for children under the age of 5 are predominately due to deaths, Case B underestimates the value of productivity losses. As such, it can be considered a lower bound estimate. “Ultra” lower bound estimates, which attach an annual value of the agricultural GDP in Sub-Saharan Africa of $186/year for Cases A and B, range from $32-$72/year (see Appendix Table A.2). Based on these results, a reasonable estimate of annual household productivity losses due to lack of access to clean energy, sanitation and improved hygiene is $70-$115 *per year*.

Table 6 shows the estimated annual total household-level economic health benefits in Sub-Saharan Africa due to clean energy, sanitation, water, and hygiene practices. The economic value of total health benefits under Cases A and B range from $126-$158 to $78-$95 per household, respectively. Based on these results, a reasonable estimate of total annual economic benefits attributable to access to clean energy, sanitation and improved hygiene is $80-$126 per household *each year*.

Table 5. Economic value of health-related productivity gains in Sub-Saharan Africa due to integrated clean energy, sanitation, hygiene, and water quality interventions (2004) using GNI

	per capita			per household*		
Health Outcomes	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Case A						
Diarrheal diseases	$11.50	$13.32	$17.75	$59.68	$69.11	$92.14
ALRI	$10.54	$10.54	$10.54	$54.68	$54.68	$54.68
COPD	$0.22	$0.22	$0.22	$1.16	$1.16	$1.16
Total	**$22.26**	**$24.07**	**$28.51**	**$115.52**	**$124.95**	**$147.98**
Case B						
Diarrheal diseases	$6.05	$7.00	$9.34	$31.40	$36.35	$48.47
ALRI	$6.73	$6.73	$6.73	$34.91	$34.91	$34.91
COPD	$0.22	$0.22	$0.22	$1.14	$1.14	$1.14
total	**$13.00**	**$13.95**	**$16.29**	**$67.45**	**$72.41**	**$84.53**

*Average household size in SSA is 5.19 according to UN Population Statistics

Table 6. Household-level* health-related economic benefits in Sub-Saharan Africa due to integrated clean energy, sanitation, hygiene, and water quality interventions (2004) using GNI

	Scenario 1	Scenario 2	Scenario 3
Case A			
value of productivity	$115.52	$124.95	$147.98
health expenditures	$10.15	$10.15	$10.15
total	**$125.67**	**$135.09**	**$158.13**
Case B			
value of productivity	$67.45	$72.41	$84.53
health expenditures	$10.15	$10.15	$10.15
total	**$77.60**	**$82.56**	**$94.67**

*Average household size in SSA is 5.19 according to UN Population Statistics

Conclusions and Implications

The results of this analysis suggest that there are significant health benefits associated with integrated investments in clean energy, sanitation, safe drinking water and hygiene promotion in Sub-Saharan Africa. With an estimated 91 million *additional* inhabitants in Sub-Saharan Africa without access to proper sanitation by 2015 (WHO & UNICEF, 2006), and no current trend signaling a substantial decrease in solid fuel combustion, our reported DALY values (based on 2002 WHO data) will likely increase in absence of significant intervention. In addition to improving the health status of millions of women, men and children, investments in clean energy, sanitation and hygiene promotion will yield substantial economic benefits, conservatively estimated between $80-$126 per year for each household impacted by integrated intervention. Estimated household-level economic benefits may increase further with the confirmation of initial studies linking indoor air pollution, hygiene and sanitation to other diseases (Table 2), but these diseases are not included in our current analysis to maintain conservative estimates.

Since our reported health benefits accrue annually, any cost-benefit analyses undertaken with respect to a proposed intervention needs to consider the payback from health benefits in relation to initial capital and operating costs of the investment. Therefore, a large initial investment (relative to annual household benefits) may be justified, as long as the intervention is expected to last for a reasonable duration. Another major implication from the study is that substantial subsidies for health-related interventions are justified, since the majority of the economic gain from improved health will be realized from increased productivity and (to a lesser extent) decreased public health care expenditures, rather than direct consumer cost savings. In households where productivity gains are immediately generated in working-age adults, such as adults previously affected by ALRI or caring for sick children, microfinance may also represent an attractive option. However, since most DALYs and associated health-related economic benefits come from children under five, the bulk of economic productivity gains will likely take years to materialize. This lends further justification to subsidize health interventions that generate real public welfare benefits, but will not be initiated through private capital and market forces alone.

Selected References

Cairncross, S. and V. Valdmanis, 2005. "Water Supply, Sanitation, and Hygiene Promotion," in *Disease Priorities in Developing Countries*. World Bank

Drummond, M. and B. Obrien, G. Stoddard, and G. Torrance, 1997. M*ethods for the economic evaluation of health care programs. (*2nd ed.), Oxford Press.

Hutton, G. and L. Haller, 2004. "Evaluation of the costs and benefits of water and sanitation improvements at the global level," WHO.

Hutton, G. and E. Rehfuess, 2006. "Guidelines for conducting cost-benefit analysis of household energy interventions," WHO.

Murray, C. and A. Lopez, 1996. *The Global Burden of Disease and Injury Series. Volumes I-II.* Harvard School of Public Health, World Bank and World Health Organization.

Pruss, A. and A. Havelaar, 2001."The Global Application of disease study and applications in water, sanitation and hygiene," in WHO *Water Quality Guidelines* (eds. Fewtrell and Bartram), London: IWA Publishing.

Pruss, A, and D. Kay, L. Fewtrell, J. Bartram, 2002. "Estimating the Burden of Disease from Water, Sanitation, and Hygiene at a Global Level." *Environmental Health Perspectives.* v.110, no.5, May 2002. http://www.who.int/quantifying_ehimpacts/global/en/ArticleEHP052002.pdf.

Rehfuess, E. and S. Mehta, A, Pruss-Ustun, 2006. "Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals." *Environmental Health Perspectives. v*.114, no.3, March 2006.

World Bank, 2006. *Development Indicators database.* April 2006. http://devdata.worldbank.org/external/CPProfile.asp?PTYPE=CP&CCODE=SSA.

WHO, 2006a. "Fuel for Life: Household Energy and Health." www.who.int/indoorair/publications/fuelforlife.pdf.

WHO. 2006b. "Revised Global Burden of Disease (GBD) 2002 Estimates." http://www.who.int/healthinfo/bodgbd2002revised/en/index.html.

WHO, 2006c. "Estimates of burden of disease caused by the environment and occupational risks: Indoor Air Pollution." http://www.who.int/quantifying_ehimpacts/global/globalair/en/index.html.

WHO & UNICEF. 2006. "Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade." http://www.who.int/entity/water_sanitation_health/monitoring/jmpfinal.pdf

World Bank. 2006. *Disease Control Priorities in Developing Countries.* http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=dcp2.table.5965.

Appendices

Table A.1 Annual DALYs attributable to indoor air pollution and lack of sanitation, water and hygiene in Sub-Saharan Africa (2004)

	Total Mortality	DALY Total	0-4 yrs	5-14 yrs	15+ yrs
Scenario I			('000)		
Diarrheal diseases	419	13,761	13,044	212	505
Lower respiratory infections	392	12,608	9,117	1,886	1,605
Chronic obstructive pulmonary disease	13	267	7	2	259
total	825	26,637	22,168	2,101	2,369
Scenario II					
Diarrheal diseases	485	15,934	15,104	246	584
Lower respiratory infections	392	12,608	9,117	1,886	1,605
Chronic obstructive pulmonary disease	13	267	7	2	259
	891	28,810	24,227	2,134	2,448
Scenario III					
Diarrheal diseases	647	21,246	20,139	328	779
Lower respiratory infections	392	12,608	9,117	1,886	1,605
Chronic obstructive pulmonary disease	13	267	7	2	259
	1,053	34,121	29,262	2,216	2,643

Table A.2 Economic value of avoided lost productivity due Sub-Saharan Africa due to clean energy, sanitation, water, and hygiene practices (2004) using Ag GDP

	per capita			per household*		
Health Outcomes	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Case A						
Diarrheal diseases	$5.50	$6.37	$8.49	$28.55	$33.05	$44.07
ALRI	$5.04	$5.04	$5.04	$26.15	$26.15	$26.15
COPD	$0.11	$0.11	$0.11	$0.55	$0.55	$0.55
total	$10.65	$11.51	$13.64	$55.25	$59.76	$70.78
Case B						
Diarrheal diseases	$2.89	$3.35	$4.47	$15.02	$17.39	$23.18
ALRI	$3.22	$3.22	$3.22	$16.70	$16.70	$16.70
COPD	$0.11	$0.11	$0.11	$0.55	$0.55	$0.55
total	$6.22	$6.67	$7.79	$32.26	$34.63	$40.43