

Annex 4 B

Cost-Benefit Analysis of Environmental Protection

Socio-Economic and Environmental Health Benefits of Interventions

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ACKNOWLEDGEMENTS

The analysis in this report is based on the estimated national cost of environmental degradation in Strukova (2007). The report relies extensively on data from various ministerial departments, institutions, and institutes in Honduras. The analysis also relies on Honduran and international research studies.

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I. INTRODUCTION

The objective of this report is to provide estimates of benefits and costs of water-sanitation-hygiene improvements and indoor air pollution control from solid fuels.

Strukova (2007) presents estimates of the cost of environmental damage for a set of environmental categories. These damage costs are equivalent to the benefits that society would enjoy if environmental quality was improved to a condition with no environmental risks to health, no negative impacts on productive assets from environmental degradation, and no damages to health, infrastructure and housing from natural disasters. The estimates of damage costs presented in Strukova (2007) can therefore be used as a point of departure to evaluate the benefits of interventions to improve environmental quality and reduce environmental damage. From a socio-economic point of view, the welfare of society will improve if those interventions are implemented that provide larger benefits than the cost of the interventions.

A whole range of potential interventions could conceptually be evaluated in terms of their benefits and costs to society. Data and resource limitations do however constrain the level of detail and the number of interventions that can practically be evaluated in a relatively short period of time. Interventions evaluated in this report are therefore confined to a relatively small number of interventions, and are aggregated to a level that reflects the limited data, time, and resources availability for the study. It is however hoped that the interventions evaluated in this report by and large are consistent with interventions that are generally believed to be the most effective in improving environmental conditions. The report can also be utilized for further assessment of the effectiveness, and benefits and costs of interventions at local levels in the areas of inadequate water supply, sanitation and hygiene and indoor air pollution that produce the major relative health damage associated with environmental factors in Honduras.

Environmental cost-benefit analysis (CBA), the primary focus of this report, is extensively used in environmental policy in for instance the United States. It has also been undertaken in developing countries, but most often for a particular environmental issue. In contrast, this report provides an opportunity to compare benefits and costs of interventions that span several environmental issues or categories. It should however be recognized that the estimated benefits and costs represent orders of magnitude and gross

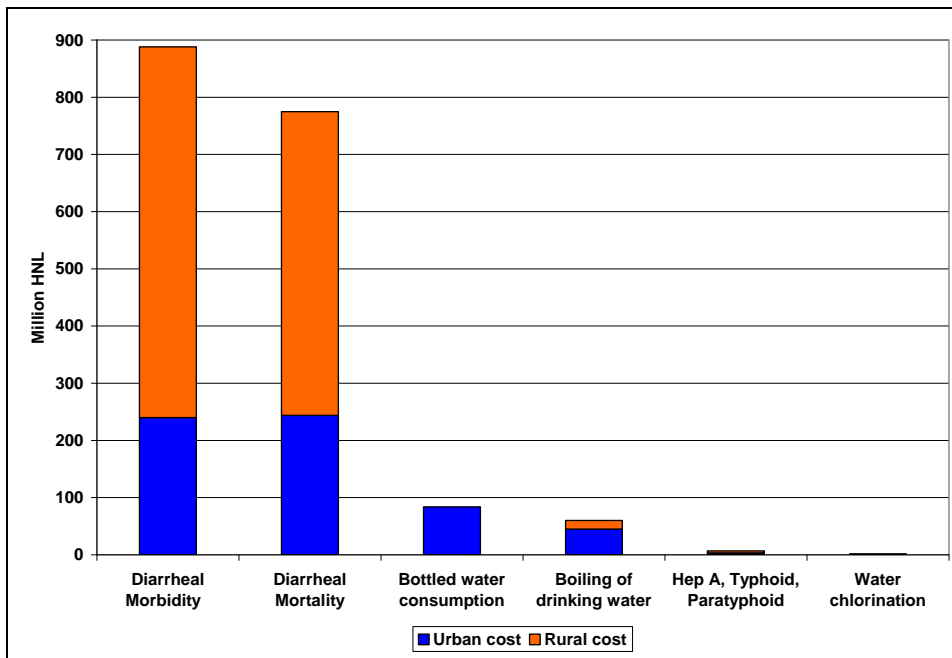
averages at the national level. They should therefore be subject to sensitivity analysis, and can undoubtedly be improved by a more extensive data collection and in-depth analysis.

II. WATER, SANITATION AND HYGIENE

Damage Cost

The estimated annual cost associated with inadequate water supply, sanitation and hygiene ranges from 1418-2238 million L per year, with a mean of 1828 Million L – equivalent to about 1 percent of GDP in 2006. These costs include those relating to mortality in children, morbidity in children and adults, and avertive expenditures (bottled water consumption, water chlorination, and water boiling) (see Figure 2.1). The estimated costs of under-5 child diarrheal mortality are about half of the costs of morbidity in children and adults. Child mortality is valued using the human capital approach (HCA).¹ Urban costs account for 34 percent, while rural costs represent 66 percent of the total costs associated with inadequate water supply, sanitation and hygiene. Details of these estimates are provided in Strukova (2007).

Figure 2.1: Annual Costs by Category (Million L.)



Source: Strukova, 2007

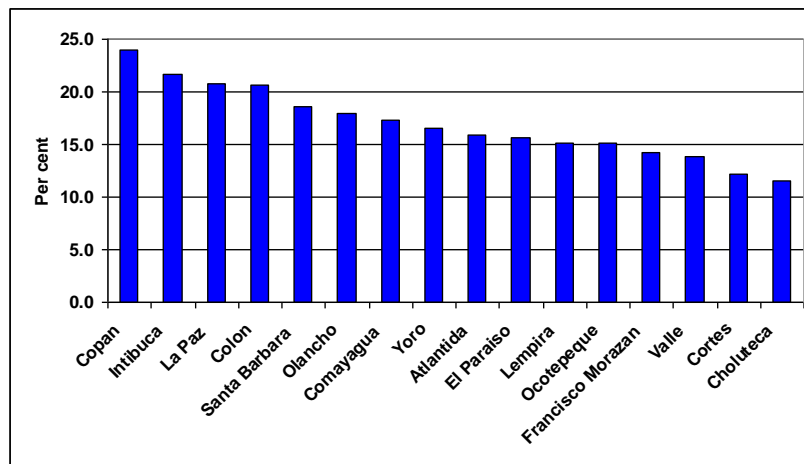
¹ See Strukova, 2007 for details.

Diarrheal Morbidity and Mortality in Honduras

As can be seen from Figure 2.1, diarrheal morbidity dominates the cost of health impacts from inadequate water supply, sanitation and hygiene. This is followed by diarrheal child mortality. Hepatitis A, typhoid and paratyphoid represents only a minor fraction of total health costs.

Figure 2.2 presents diarrheal prevalence in children from the ENDESA 2005-2006 survey in various departments in Honduras. Even across whole departments and sub-regions the prevalence rate varies substantially. It was almost or more than twice as high in Copan and Intibucá than in Cortes and Choluteca.

Table 2.2: Diarrheal Prevalence Rates in Children

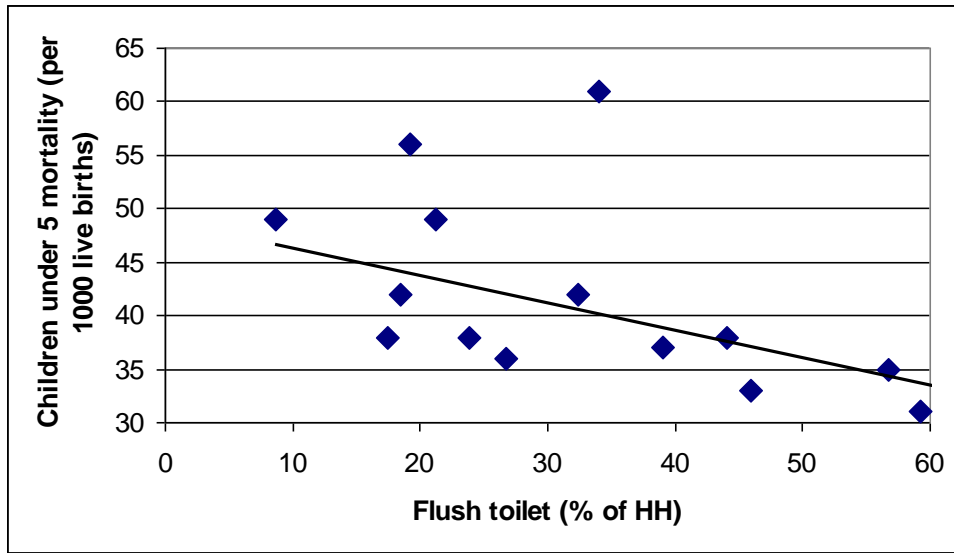


Source: ENDESA 2005-2006.

Figure 2.4-2.5 present child mortality rates in relation to water sanitation network coverage rates and literacy rates by department.² Child mortality is clearly lower in departments with higher sanitation network coverage and high literacy rates.

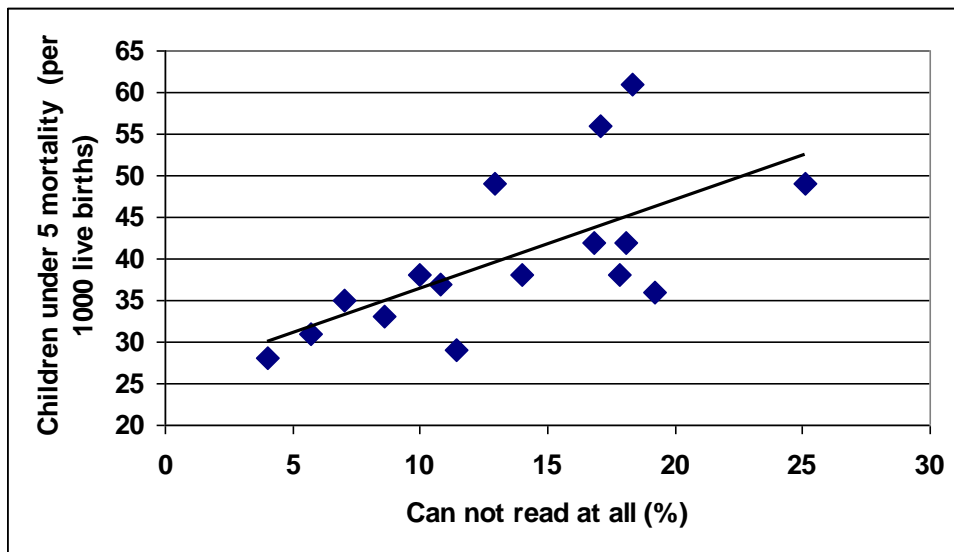
² Each dot in the chart is a department.

Figure 2.4: Child Mortality in Relation to Sanitation Network Coverage by Department



Source: Based on data from ENDESA 2005-2006.

Figure 2.5: Child Mortality in Relation to Illiteracy Rates by Department



Source: Based on data from ENDESA 2005-2006.

Effectiveness of Improved Water, Sanitation and Hygiene

In a seminal review of international studies, Esrey et al (1991) reported mean estimates of reductions in diarrheal illness around the world from improvements in water supply, sanitation and household hygiene practices. Since then, Curtis and Cairncross

(2003) presented results from a meta-analysis of studies that have investigated reductions in diarrheal illness from hand washing. In 2004, Fewtrell and Colford provided a systematic review and meta-analysis of water, sanitation and hygiene interventions on diarrheal illness.

The main results of Fewtrell and Colford (2004) are presented in Table 2.1 for developing countries. The relative risk ratio (RR) is in relation to a non-intervention situation. The percentage reduction in diarrheal illness from intervention is therefore $1.0 - RR$. The relative risk ratio for hand-washing intervention in Table 2.1 is very similar to the results from the meta-analysis by Curtis and Cairncross (2003).

The single most effective hygiene intervention is hand-washing after defecation, before preparing meals, and before eating. This intervention is therefore reported in Table 2.1. Improved sanitation refers to facilities for safe and hygienic removal of excreta, such as flush toilets, pour-flush latrines, ventilated improved pit latrines (VIP), and simple pit latrines. Unimproved sanitation is open pit latrines, public latrines, service or bucket latrines, and the absence of any facilities. Improved water supply refers to house connection, standpipes, boreholes, protected wells or springs, and collected rain water. Unimproved water supply includes unprotected wells or springs, open surface water and rivers, and water provided by vendor or tanker trucks. In terms of water quality improvement, the studies reviewed by Fewtrell and Colford that have assessed reduction in diarrheal illness from source water treatment are not very conclusive. The pooled study results suggest a mean reduction in diarrheal incidence of 10 percent, but with no statistical significance. In contrast, point-of-use drinking water treatment (i.e., household drinking water treatment) seems very effective in reducing diarrheal illness. Point-of-use treatment refers to non-chemical (e.g. boiling of water) and chemical treatment (e.g. chlorination) and seems to be most effective in rural areas.

Table 2.1: Summary of Meta-Analysis by Fewtrell and Colford (2004)

Intervention	Relative Risk (RR)	Confidence Interval (95%)
Improved Hygiene (hand-washing)	0.556	0.334-0.925
Improved Sanitation	0.678	0.529-0.868
Improved Water Supply	0.749	0.618-0.907
Water Quality Improvement (source treatment)	0.891	0.418-1.899

Water Quality Improvement (point-of-use treatment; rural)	0.534	0.392-0.727
Water Quality Improvement (point-of-use treatment; urban)	0.771	0.725-0.819
Water Quality Improvement (point-of-use chemical treatment)	0.605	0.443-0.828
Water Quality Improvement (point-of-use non-chemical treatment)	0.534	0.379-0.752

Note: Summarized from Table 22 in Fewtrell and Colford (2004).

To evaluate the benefits and costs of the interventions in Table 6.1 it is important to distinguish between interventions that involve changes in household behavior and interventions that involve infrastructure or hardware improvements. Interventions that involve changes in household behavior are improved hygiene and water treatment at point-of-use. While public authorities can promote these behaviors, actual changes in behavior is beyond their control. It is therefore important to explicitly account for this behavioral component in a benefit-cost analysis. As regards infrastructure or hardware (water supply and sanitation facilities), improvements are predominantly functions of provision and are likely to be utilized by households if design and service delivery reflect demand and provide convenience. Uncertainties regarding behavioral change in relation to water supply and sanitation tend therefore to be less important in a benefit-cost analysis than for hygiene improvement and point-of-use treatment of drinking water.

A Benefit-Cost Analysis Framework

Pruss et al (2002) provide a framework for estimating the burden of disease from water, sanitation and hygiene. This is presented in Table 2.2. Pruss et al applied this framework to estimate the global burden of diarrheal disease, but it can also conveniently be applied to estimate the benefits and costs of improved water supply and sanitation.

According to the Global Burden of Disease 2002 (WHO), diarrheal incidence (cases per person per year) in most developing regions of the world is 3-5 times higher than in North America and high-income countries in Europe, and as much as 6 times higher in Sub-Saharan Africa. These figures are relatively consistent with Table 2.2, suggesting that most developing countries are somewhere in the range of Scenario 4 to Scenario 6. These figures represent averages, and it should be made clear that there are larger variations within each developing country with some parts of the population being closer to Scenario II.

Table 2.2: Selected Exposure Scenarios

Scenario/ Situation	Description	Pathogen Load	Relative Risk (RR)
VI	NO IMPROVED WATER SUPPLY AND NO BASIC SANITATION in a country that is not extensively covered by those services, and where water supply is not routinely controlled	Very High	11.0
Vb	IMPROVED WATER SUPPLY and no basic sanitation in a country that is not extensively covered by those services, and where water supply is not routinely controlled	Very High	8.7
Va	BASIC SANITATION but no improved water supply in a country that is not extensively covered by those services, and where water supply is not routinely controlled	High	6.9
IV	IMPROVED WATER SUPPLY AND BASIC SANITATION in a country that is not extensively covered by those services, and where water supply is not routinely controlled	High	6.9
IIIc	IV and improved access to drinking water (generally piped to household)	High	-
IIIb	IV and improved personal hygiene	High	4.5
IIIa	IV and drinking water disinfected at point of use	High	3.8
II	Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically found in developed countries	Medium to Low	2.5
I	Ideal situation, corresponding to the absence of transmission of diarrheal disease through water, sanitation, and hygiene	Low	1.0

Based on Pruss et al 2002.

Pruss et al derived the relative risks of diarrheal illness from the international literature (Table 2.3).

Table 2.3: Reductions in Diarrheal Illness used by Pruss et al

Scenario Progression		Reduction in Diarrheal Illness	Source
From VI to Vb	Providing improved water supply	20.8%	Esrey (1996)
From VI to Va	Providing basic sanitation facilities	37.5%	Esrey (1996)
From VI to IV	Providing improved water supply and basic sanitation facilities	37.5%	Esrey (1996)
From IV to IIIb	Improved personal hygiene	35%	Huttly et al (1997)
From IV to IIIa	Disinfection of drinking water at point-of-use	45%	Quick et al (1999)
From IV to II	Regulated water supply and full sanitation coverage, with partial treatment of sewage	65%	Combined results from Huttly et al (1997) and Quick et al (1999)
From II to I	Absence of transmission of diarrheal disease through water, sanitation and hygiene	60%	Using results from Mead et al (1999)

Benefit-Cost Analysis of Water and Sanitation Improvements

The framework by Pruss et al (2002) is applied in this report to estimate the benefits and costs of interventions to reduce diarrheal illness and diarrheal mortality in Honduras. The relative risks in Table 2.2, or reductions in diarrheal illness in Table 2.3, are modified to reflect the more recent findings of relative risks in the meta-analysis study by Fewtrell and Colford (2004), and the meta-analysis study of hand washing by Curtis and Cairncross (2003).

The first modification to the framework presented by Pruss et al is to distinguish between households that disinfect their drinking water at point-of-use and those households that do not disinfect their drinking water. This distinction is made for each of the scenarios from III to VI. The second modification is to distinguish between households with piped water supply that is treated at source (water treatment plant) and those with piped water that is not treated at source. Scenario III_d is therefore added in Table 2.4.

To allow for a comparison to Table 2.2 the relative risk for scenario VI without point-of-use disinfection is also 11.0 in Table 2.4. The relative risks in V_b and V_a is derived by multiplying the relative risk in VI by the relevant relative risk ratios in Table 6.1. As in Pruss et al, there is no difference between V_a and IV. The difference between IV and III_d is a relative risk ratio of 0.9, reported in Fewtrell and Colford (2004) for household water supply connection. And the difference between III_d and III_c is the relative risk ratio of 0.891 presented in Table 2.1.

The difference between with and without point-of-use disinfection for scenarios VI to III_d is a relative risk ratio of 0.53. This corresponds to the relative risk ratio for rural water supply in Table 6.1. This ratio may be considered more appropriate to apply than the urban relative risk ratio because Scenarios IV-VI is typically found in rural areas and water quality in scenarios III_d to VI is on average likely to involve higher disease risk than urban treated piped water supply. The relative risk for III_c and III_d is assumed to be the same if drinking water is disinfected at point-of-use.

Scenario II is not included in Table 2.4. Scenario II is the situation typically found in developed countries (see Table 2.2). To provide this level of service (including partial sewage treatment) to the entire urban and rural population in developing countries

is likely to be very costly. The benefit-cost analysis in this report therefore focuses on improved water supply and basic sanitation to those segments of the population without these services.

Table 2.4: Exposure Scenario Application to Honduras

Scenario/ Situation	Description	WITHOUT Point-of Use Disinfection	WITH Point-of-Use Disinfection
		RR	RR
VI	No Improved Water Supply and No Basic Sanitation	11.0	5.8
Vb	Improved Water Supply and No Basic Sanitation	8.2	4.4
Va	Basic Sanitation but No Improved Water Supply	7.5	4.0
IV	Improved Water Supply and Basic Sanitation	7.5	4.0
IIIId	IV and Water Supply Piped to Household (no source treatment)	6.7	3.6
IIIc	IV and Water Supply Piped to Household (source treatment)	5.9	3.6

Modified from Pruss et al 2002. Note: RR is relative risk of diarrheal disease.

To estimate the health benefits of water and sanitation interventions it is necessary to provide an estimate of the Honduran population shares in each of the scenarios. Three sources of data from Honduras are used for this purpose, i.e., the ENDESA 2005-2006 household survey with data on the water and sanitation situation in urban and rural areas, as well as household drinking water disinfection data, and data from Honduras water supply authorities on piped water network and water treatment plants (Análisis Sectorial De Agua Potable Y Saneamiento De Honduras. 2003).

The water supply and sanitation situation according to the ENDESA 2005-2006 is presented in Table 2.5. As discussed in relation to Table 2.2, unimproved or no basic sanitation mainly refers to households with no sanitation facilities or open pit latrines. Similarly, no improved water supply refers mainly to surface water, tanker trucks, and unprotected well or spring water.

Table 2.5: Water Supply and Sanitation in Honduras (% of Households)

Water Service by	% Households	Urban	Rural
Pipe inside HH	33.4	51.2	14.9
Pipe outside HH in lot	46.2	40.8	51.9

Public fountain	4	2	6.1
Pub/priv well	0.7	0.9	0.5
Purchase/ tanker	1.6	2.6	0.5
River, watershed	11.2	0.8	21.9
Other	2.9	1.7	4.2
Sanitation Service by			
Toilet w/sew connect	31.3	58.9	2.5
Toilet w/septic tank	14.1	14.0	14.3
Hydraulic latrine	19.2	31.6	7.3
Other latrine	18.3	15.6	21.1
No sanitation	17.1	4.2	30.5

Source: ENDESA, 2005-2006

In order to use the data in Table 2.5 to estimate the population shares in each of the scenarios in Table 2.4, a set of allocation “rules” were applied. These “rules” are presented in Table 2.6. Data from Honduras local sources were used to provide an estimate of the urban population share with piped water supply that is not treated. According to them in urban areas in 2006, only 75% of the drinking water was disinfected. In rural areas, it was estimated in 2004 that only one-third of the systems provided continual service and less than 14% of the systems delivered disinfected water³.

Table 2.6: Scenario Allocation Rules

Scenario/ Situation	Allocation rule
VI	The lesser of the population share without improved water supply and without basic sanitation.
Vb	The difference between population share without basic sanitation and without improved water, if difference is > 0.
Va	The difference between population share without improved water supply and without basic sanitation, if difference is > 0
IV	The lesser of the population share with improved water supply and basic sanitation minus the population share with piped water.
III d	Population share with piped water supply.
III c	

Table 2.7: Rural Water Supply and Sanitation in Honduras (% of Rural Population)

Scenario/ Situation	Description	Share of rural population

³ Water Supply and Sanitation in Honduras.

http://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Honduras#_note-1

VI	No Improved Water Supply and No Basic Sanitation	33%
Vb	Improved Water Supply and No Basic Sanitation	17%
Va	Basic Sanitation but No Improved Water Supply	0%
IV	Improved Water Supply and Basic Sanitation	35%
IIIId	IV and Water Supply Piped to Household (no source treatment)	15%
IIIc	IV and Water Supply Piped to Household (source treatment)	

Table 2.8: Urban Water Supply and Sanitation in Honduras (% of Urban Population)

Scenario/ Situation	Description	Share of urban population
VI	No Improved Water Supply and No Basic Sanitation	8%
Vb	Improved Water Supply and No Basic Sanitation	12%
Va	Basic Sanitation but No Improved Water Supply	0%
IV	Improved Water Supply and Basic Sanitation	29%
IIIId	IV and Water Supply Piped to Household (no source treatment)	51%
IIIc	IV and Water Supply Piped to Household (source treatment)	

Table 2.9 presents data about drinking water treatment in households.

Table 2.9: Water Treatment at the Point of Use in Honduras (% of Households)

Type of water treatment	% Households	Urban	Rural
Boiling	20.9	19.1	22.8
Chlorination	22	20.9	23.2

Source: ENDESA, 2005-2006

The source does not provide the share of households using disinfection in relation to their type of water supply and sanitation. The data on disinfection is therefore applied uniformly to each of the scenarios.

Strukova (2007) presents the estimated number of diarrheal illness cases in Honduras based on the ENDESA, 2005-2006 (Table 2.10). The total number of annual cases was estimated at close to 15.5 million, or close to 1.2 cases per person.

Table 2.10: Estimated Annual Cases of Diarrheal Illness in Honduras in 2005

	National	Urban	Rural
2-week diarrheal prevalence (children < 5yrs)	21.7%	13.3%	17.2%
2-week diarrheal prevalence (population > 5yrs)	3.7%	2.3%	2.9%
Annual diarrheal cases in children u-5 (000)	4189	1107	1889
Annual diarrheal cases in population >5 (000)	4968	1531	1974
Total annual diarrheal cases	9157	2637	3863
Diarrheal cases per person (all population)	1.24	0.73	1.02

Source: Strukova, 2007.

Estimated cases of diarrheal illness per person per year in rural areas in Honduras is estimated for Scenarios IIIc to VI from the relative risks in Table 2.4, the scenario population distribution in Table 2.7, and the average diarrheal cases per person in Table 2.10. Table 2.11 indicates that cases per person is on average 0.46 in households with piped water supply and basic sanitation that practice disinfection of drinking water, and 1.41 per year in households that do not have improved water supply, no basic sanitation and that do not practice drinking water disinfection.

Table 2.11: Estimated Annual Cases of Diarrheal Illness per Person in Rural Honduras

Scenario/ Situation	Description	WITHOUT Point-of Use Disinfection	WITH Point-of-Use Disinfection
VI	No Improved Water Supply and No Basic Sanitation	1.41	0.75
Vb	Improved Water Supply and No Basic Sanitation	1.05	0.56
Va	Basic Sanitation but No Improved Water Supply	0.95	0.51
IV	Improved Water Supply and Basic Sanitation	0.95	0.51
IIIId	IV and Water Supply Piped to Household (no source treatment)	0.86	0.46
IIIc	IV and Water Supply Piped to Household (source treatment)	0.77	0.46

Providing piped water supply to all rural households is likely to be very expensive. A realistic objective might be to at least provide improved water supply (protected well or borehole) and sanitation facilities (improved pit latrine or pour-flush latrines). The aim of the infrastructure interventions is to improve water supply and sanitation, largely in rural areas. Two programs are investigated: one that provides 1.9

million people with improved sanitation, and one that provides 1.3 million people with an improved water supply

Local data indicate that annualized per capita costs amount to 75 Ls for improved sanitation and 132 Ls for improved water supply. This is based on a 10 percent annual discount rate, annual 5% O&M and 5% promotion/water source protection cost, and 6 USD in annual sewage cost.⁴ The benefits are derived from a range of studies and are calculated separately for different categories of individuals in rural Honduras'. Population receiving improved water supply and sanitation is calculated from Table 2.9. Diarrheal cases averted are calculated from Table 2.4. Deaths averted is calculated based on an estimated case fatality rate of 0.4 per 1000 cases in children under-5, based on data presented in Strukova, 2007. The key assumptions in deriving the benefits relate to the costs of morbidity and mortality and to the value of time saved. The morbidity costs, based on the costs of treatment and value of lost time, are 170 Ls. per case of diarrhea. The mortality costs are calculated based on the 'Human Capital Approach' (HCA) as presented in Strukova, 2007. However, there are strong reasons to believe that the HCA approach underestimates the value of a lost life; hence, the figures reported here should be taken as lower bounds. Finally, the programs generate savings in time, which is an important ingredient in the calculations. It is based on data for households more than a 15-minute walk from a water source (approximately 35,000 households are in this category). Time saved is valued at 75 percent of the average rural wage (180 Ls./day, or 22 Ls/hour).

Table 2.12: Benefits of Reductions in Diarrheal Morbidity and Mortality in Rural Honduras

	Improved Sanitation Facilities	Improved Water Supply
Population (million) Receiving Improved Sanitation*	1.9	
Population (million) Receiving Improved Water Supply**		1.3
Percent reduction in diarrheal illness per person (from Fewtrell & Colford 2004)	32%	25%
Diarrheal Cases (million) Averted per Year	0.6	0.4
Deaths in Children Averted per Year	120	80
Annual Health Benefits of Improved Services (Million Ls)	190	130
Annual Value of Time Savings from Improved Services (Million Ls)	650	105

⁴ Per capita investment costs represent average costs in South America (WHO/Unicef 2000). O&M is operations and maintenance.

Annualized Cost of Service Provision (Million Ls)	145	165
Benefit-Cost Ratio (Health Benefits Only)	1.3	0.8
Marginal cost (million Ls. per 1 % of WSSH health cost reduction)	14	23
Benefit-Cost Ratio (Health Benefits and Time Savings)	5.5	1.4

The data reveal that programs to improve sanitation in rural areas have a benefit-to-cost ratio greater than 1.0 when the time savings of improved water are excluded. However, the ratio increases to over 5.0 when time savings are taken into account. For water supply program benefit cost ration is greater than 1 only if time benefits are included. For water supply/sanitation programs in urban areas the costs are higher and the benefits lower due to lower diarrheal mortality among children under five and lower diarrheal prevalence. Thus benefit-cost ratio is above 1 only for sanitation program when time saving is included.

Marginal cost⁵ would exceed marginal benefits⁶ (health damage reduction) only for sanitation programs in rural areas.

Benefit-Cost Analysis of Hygiene Improvements

The single most effective hygiene intervention is in many studies found to be hand-washing after defecation, before preparing meals, and before eating. Curtis and Cairncross (2003) provide a meta-analysis of close to 20 hand-washing studies and report a mean reduction in diarrheal illness of about 47 percent. Fewtrell and Colford (2004), in their meta-analysis, report a mean reduction in diarrheal illness of about 45 percent from hand-washing interventions (Table 2.1). About two-third of the studies reviewed in the two meta-analysis studies assessed the effect of hand-washing on diarrheal illness in children under the age of 5 years. The meta-analyses do not report the effect of hand-washing on diarrheal illness in children under-5 versus older children and adults. A pooled analysis of the studies reviewed in the two meta-analyses was therefore undertaken in this report, but found no statistically significant difference in diarrheal reduction in children and adults. A reduction in diarrheal illness of 45 percent is therefore applied in the benefit-cost analysis in this report for all age groups.

⁵ Approximated by average cost per one percent of WSSH cost reduction

⁶ Value of one percent of WSSH cost reduction, estimated at about 18 million Ls.

A benefit-cost analysis of hygiene improvement (hand-washing programs) involves an assessment of several key parameters and outcomes. These are listed in Table 2.13. The costs of improved hand washing practices are two-fold. First, a program to encourage behavioral change (improved hand-washing) has a cost that should be fully captured. This includes the cost of program preparation and implementation. Second, improved hand-washing practices have a private cost that includes cost of increased water and soap consumption. The most uncertain and critical parameter is the effectiveness of the hand-washing program in terms of changing household and individual behavior, and the lasting effect of changed behavior (sustainability). This is likely dependent on a several dimensions and will vary from country to country. It will also depend on the design, duration and overall magnitude of the hand-washing program. The expected benefit of the program can be estimated from the diarrheal illness risk reductions reported in Curtis and Cairncross (2003) and Fewtrell and Colford (2004), and the monetized benefits (or costs avoided per case of diarrheal illness reduction) presented in Strukova, 2007 for Honduras.

Table 2.13: Key Parameters and Outcomes in a Benefit-Cost Analysis of Hand-Washing

Key Parameters:	Outcomes:
Program Cost	Overall cost of hand-washing program
Program Effectiveness	Behavioral change in target population (% of population that improves or start regular hand-washing)
Program Sustainability	The lasting effect of the program
Private Cost	Costs of hand-washing in the group with behavioral change (increased water and soap expenditures)
Program Benefits	Percent reduction in diarrheal illness from hand-washing in group with behavioral change Monetized benefits of reduced diarrheal illness

A review of three hand-washing programs that provide program costs and behavioral change is presented in Table 2.14. The program in Guatemala was national in scope and targeted households with children under 5 years of age (Saade et al 2001). The program in Thailand focused on all households in a set of rural villages and involved a

different level of program intervention in two sub-sets of the villages (Pinford and Horan 1996). The program in Burkino Faso involved one city and targeted household with children under 3 years of age (Borghi et al 2002). As seen in the table, the percentage of the target population that changed behavior (i.e., started regular hand-washing or improved hand-washing practices) range from 10 to 18 percent, and cost per target household range from US \$0.36 to US \$5.03. While the studies are too few to draw a definite conclusion, the results do suggest that program cost per unit of behavioral change (per percentage point increase in population with behavioral change) may increase substantially if the objective is behavioral change in a large share of the target population. This issue may therefore have major impact on the overall cost of hygiene programs that aims to achieve substantial reductions in the overall number of cases of diarrheal illness in a country.

Program cost per target household with behavioral change is the most relevant unit cost in Table 2.14 for a benefit-cost analysis. This cost can then be compared to the reduction (and thereby benefits) in diarrheal illness in the target population with behavioral change.

Table 2.14: A Review of Costs and Effectiveness of Hand-Washing Programs

	Guatemala	Thailand		Burkino Faso
Target area	National	25 rural villages		One City
Intervention Level		"Low"	"High"	
Target Population	HH w/children under-5	All HHs	All HHs	HH w/children under-3
Number of Target Household	1570000	10000	6550	38600
Duration of Program Implementation	1 year	3-4 months	3-4 months	3 years
Behavioral change (% of target population)	10%	11%	16%	18%
Program Cost (US \$)	561400	5960	7715	194000
Program Cost per Target Household (US \$)	0.36	0.60	1.18	5.03
Program Cost per Target Household with Behavioral Change (US \$)	3.58	5.42	7.36	27.92

Source: Derived from Saade et al (2001), Pinford and Horan (1996), and Borghi et al (2002).

A benefit and cost analysis of rural and urban hand-washing program is presented in Table 2.15-16. Three scenarios are provided for diarrheal reduction in children under the age of 5 years.

The “low” to “high” scenarios for children represent: (a) a program effectiveness of 10-20 percent in terms of the percent of households (or primary caretaker of children) that start regular hand-washing or improve hand-washing practices for the protection of child health; and (b) a program cost ranging from US \$0.4-5.0 per targeted household or primary caretaker (US \$ 4.0-25.0 per household or primary caretaker with behavior change). This range of program effectiveness and costs are based on the figures in Table 6.15. The “high” scenario corresponds to the experience in one city in Burkino Faso. It is however possible that a national program will benefit from economies of scale and therefore achieve a 20 percent effectiveness at lower unit cost than US \$5.0 per primary caretaker of children under-5. It is therefore possible that the “high” scenario represent a higher bound of program cost. The diarrheal illness baseline data, and cost of illness per case of diarrhea and diarrheal mortality in Table 2.15-16 are from Strukova, 2007. Avoided cost of illness is the program benefit per case of reduced or averted diarrheal morbidity and mortality. Mortality is valued by the human capital approach as in the section on water and sanitation improvement in this report. The percent reduction in diarrheal illness (45 percent) in children with caretakers that start regular hand-washing or improve hand-washing practices is from Curtis and Cairncross (2003) and Fewtrell and Colford (2004), as presented in Table 2.1. Regarding the private cost of hand-washing, the quantity of increased water and soap consumption reflects the assessment of experts in Honduras. Rural and urban price of water is communicated by experts from Honduras, and the cost of soap is based on a spot survey of soap retail prices in Honduras.

The estimated reduction in annual cases of diarrheal illness ranges from 0.15-0.3 million in children under-5. With morbidity and mortality costs estimated in Strukova, 2007 the total program benefit range from 65-135 Million Ls. Total program cost range from less than 30 to 130 Million Ls.

Table 2.15: Benefits and Costs of a Rural Hand-Washing Program

	Rural Households with Children Under 5 Years		
	"Low"	"Medium"	"High"
Program Effectiveness			
Program Target (million households)*	0.7	0.7	0.7
Program Response (% of households with Behavioral Change)	10%	15%	20%
Percent reduction in diarrheal illness per child (Fewtrell and Colford 2004)	45%	45%	45%
Program Cost			

Total Program cost (Million Ls)	4	12	50
Private Costs			
Cost of water and hygiene products per year (Million Ls)	12	18	24
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	85	128	170
Deaths in children averted per year	35	50	70
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	2.5	2.0	1.1
MEDIUM: If Behavioral change lasts 2 years**	2.9	2.5	1.6
HIGH: If Behavioral change lasts 3 years**	3.0	2.7	1.9
Marginal cost for medium scenario (million Ls. per 1 % of WSSH health cost reduction)		11	

* There are about 0.5 million rural children under the age of five years in Honduras. It is assumed there is one child under 5 in each household (thus the program target is 0.7 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under 5. ** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

Table 2.16: Benefits and Costs of a Urban Hand-Washing Program

	Urban Households with Children Under 5 Years		
	"Low"	"Medium"	"High"
Program Effectiveness			
Program Target (million households)*	0.4	0.4	0.4
Program Response (% of households with Behavioral Change)	10%	15%	20%
Percent reduction in diarrheal illness per child (Fewtrell and Colford 2004)	45%	45%	45%
Program Cost			
Total Program cost (Million Ls)	3	10	40
Private Costs			
Cost of water and hygiene products per year (Million Ls)	10	15	20
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	50	75	100
Deaths in children averted per year	20	25	35
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	1.9	1.5	0.9
MEDIUM: If Behavioral change lasts 2 years**	2.1	1.9	1.2
HIGH: If Behavioral change lasts 3 years**	2.2	2.0	1.5
Marginal cost for medium scenario (million Ls. per 1 % of WSSH health cost reduction)		15	

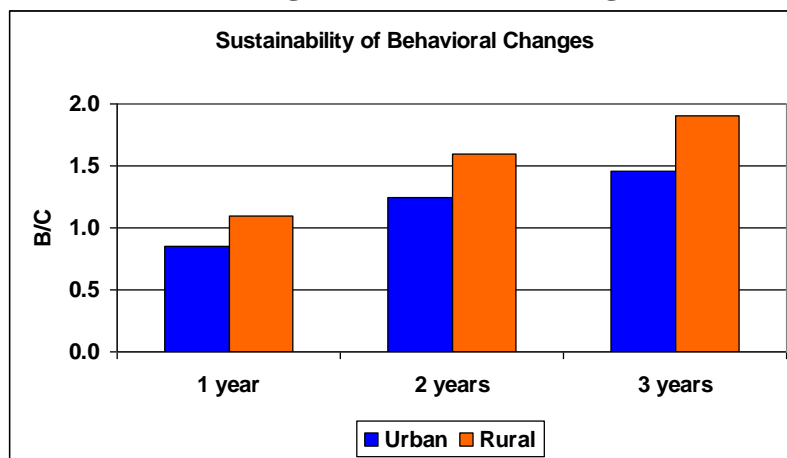
* There are about 0.4 million urban children under the age of five years in Honduras. It is assumed there is one child under 5 in each household (thus the program target is 0.4 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under 5. ** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

The total estimated benefits and costs result in a benefit-cost ratio that range from 2 in the "low" scenario to about 1 in the "high" scenario. Not only children under-5 can benefit from a hand-washing program. The population over 5 years of age can also benefit. However, this programs were found to have lower than one benefit cost ratio. This low ratio, even at zero incremental program cost, is due to the fact that diarrheal

incidence is on average substantially lower in this population group than in children under-5.

One very important aspect of the benefit-cost analysis presented above should be noted. It is implicitly assumed that the benefit of the program is only realized for one year, or that behavioral change (hand-washing) only lasts one year. While it is difficult to assess the sustainability of behavioral change, benefits for only one year is clearly a very conservative assumption. If benefits are sustained for 2 years, the estimated benefit-cost ratios would increase. Note that the benefit-cost ratio does not change for the population over 5 years of age. This is because of the assumption that behavioral change takes place at no incremental program cost. Figure 2.6 presents benefit-cost ratios for children for this target for a program with sustainability of behavioral change lasting from 1 to 3 years.

**Figure 2.6: Estimated Benefit-Cost Ratios
(20% Program Effectiveness Target)**



It is important to note that some authors link hand washing and ARI prevention (Cairncross, 2003). Although there is a lack of meta studies in this area, some evidence is already collected. Some suggest that about 20 percent of ARI could be reduced if hand washing program is implemented. If one takes this into account then benefit from hygiene improvement may be increased at least 30 percent. It would make it by far the most efficient intervention. To be on a conservative side we did not include this additional benefit waiting for additional scientific evidence.

Benefit-Cost Analysis of Drinking Water Disinfection

The data from ENDESA 2005-2006 (Table 2.9) presented data on the share of households in Honduras that disinfect drinking water. The source does not provide the share of households using disinfection in relation to their type of water supply and sanitation. The data on disinfection is therefore applied uniformly to each of the scenarios.

According to the survey, the most common method of disinfection is boiling water and is therefore the method considered in the benefit-cost analysis. The benefit-cost analysis is presented in Tables 2.17-20. Fewtrell and Colford (2004) report from their meta-analysis that disinfection of drinking water at point-of-use on average reduces diarrheal illness by 47 percent in rural areas and 23 percent in urban areas. These baseline data are presented in Table 6.18-19.

In order to estimate the reduction in the number of cases of diarrheal illness, it is necessary to estimate the diarrheal incidence in the population share that does not practice point-of-use disinfection of drinking water. This is given by the following equation:

$$P_s d + (1 - P_s) d(1 - r) = d_A \quad (1)$$

where P_s is the population share not practicing disinfection; d is diarrheal incidence in P_s ; r is reduction in diarrheal incidence from disinfection; and d_A is the national average diarrheal incidence. This equation provides an estimated diarrheal incidence of 1.3 in the rural population not practicing disinfection, compared to a rural average of 1.0 from Strukova, 2007, in urban areas an estimated diarrheal incidence is 0.8 for population not practicing disinfection, compared to the urban average of 0.7 from Strukova, 2007.

There are no estimates of program costs to promote drinking water disinfection at point-of-use. The same costs as for hand-washing programs (and for the same three scenarios of effectiveness ranging from 10-20 percent) have therefore been applied in Tables 2.17-20. The program cost, instead of per primary caretaker of children, is now per household with the assumption that one person in the household is primarily responsible for boiling of drinking water. The private cost of boiling drinking water is estimated at 80 Ls. per year for urban households using commercial fuels and about 40 Ls. for rural households using fuelwood that is collected by the household members.

Collection time is estimated at 75 percent of the average rural wage (180 Ls./day, or 22 Ls/hour). The cost of water chlorination is estimated at about 4 Ls. per household based on an average drinking water consumption of 0.75 liters per person per day. The disinfection program benefits are estimated the same way as for hand-washing program.

In rural areas the disinfection programs are estimated to avert 250-500 thousand cases of diarrhea and 50-100 deaths in children per year (Table 2.17, 2.19). The benefit-cost ratio for the central estimate in water boiling program is 4.5, corresponding to a 15 percent program response rate with drinking water disinfection sustained for two years. Even for the “high” program cost, and with improved hand washing only sustained for one year, the benefit-cost ratio is 3.2. Benefit cost ratios are lower, but well above one in urban areas. In urban areas the disinfection programs are estimated to avert 80-170 thousand cases of diarrhea and 10-25 deaths in children per year (Table 2.18, 2.20). Drinking water chlorination programs both in rural and urban areas have high benefit cost ratio since private program cost are low.

Table 2.17: Benefits and Costs of a Rural Drinking Water Boiling Program

	"Low"	"Medium"	"High"
Program Effectiveness			
Target population – rural population not practicing disinfection (millions)	2	2	2
Target Households (millions)	0.37	0.37	0.37
Program Response (% of households with Behavioral Change)	10%	15%	20%
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	47%	47%	47%
Program Cost			
Total Program cost (Million Ls)	3	8	35
Private Costs			
Cost of boiling drinking per year (Million Ls)*	6	9	12
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	125	190	250
Deaths in children averted per year	25	35	50
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	4.6	3.5	1.7
MEDIUM: If Behavioral change lasts 2 years**	5.4	4.5	2.6
HIGH: If Behavioral change lasts 3 years**	5.7	5.0	3.2

* Estimated based on efficiency of LPG and wood stoves, cost of LPG, fuel wood collection time of 30 min per day and 10% of fuel wood is used for water boiling, and per person water consumption of 0.75 liter per day.

** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

Table 2.18: Benefits and Costs of an Urban Drinking Water Boiling Program

	"Low"	"Medium"	"High"
Target Households – urban population not practicing disinfection (millions)	0.5	0.5	0.5
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	23%	23%	23%
Cases of diarrheal illness averted per year (thousands)	40	65	85

Deaths in children averted per year	<10	<15	<20
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	1.7	1.2	0.5
MEDIUM: If Behavioral change lasts 2 years*	2.2	1.7	0.8
HIGH: If Behavioral change lasts 3 years*	2.5	2.0	1.1

* Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

Table 2.19: Benefits and Costs of a Rural Drinking Water Chlorination Program at the point of Use

	"Low"	"Medium"	"High"
Program Effectiveness			
Target Households (millions)	0.37	0.37	0.37
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	47%	47%	47%
Cases of diarrheal illness averted per year (thousands)	125	190	250
Deaths in children averted per year	25	35	50
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	13.4	6.9	2.3
MEDIUM: If Behavioral change lasts 2 years**	24.3	12.8	4.3
HIGH: If Behavioral change lasts 3 years**	33.4	18.0	6.1

** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

Table 2.20: Benefits and Costs of an Urban Drinking Water Chlorination Program at the point of Use

	"Low"	"Medium"	"High"
Target Households – urban population not practicing disinfection (millions)	0.5	0.5	0.5
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	23%	23%	23%
Cases of diarrheal illness averted per year (thousands)	40	65	85
Deaths in children averted per year	<10	<15	<20
Benefit-Cost Ratios			
LOW: If Behavioral change lasts 1 year	3.4	1.8	0.6
MEDIUM: If Behavioral change lasts 2 years*	6.3	3.3	1.1
HIGH: If Behavioral change lasts 3 years*	8.7	4.6	1.5

* Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

As in the case of the hand-washing program, one very important aspect of the analysis should be noted. It is implicitly assumed that the benefit of the disinfection program is only realized for one year, or that behavioral change (boiling of drinking water) only lasts one year. While it is difficult to assess the sustainability of behavioral change, benefits for only one year is clearly a very conservative assumption. If benefits are sustained for 3 years, the estimated benefit-cost ratios would increase in the same way as for hygiene programs.

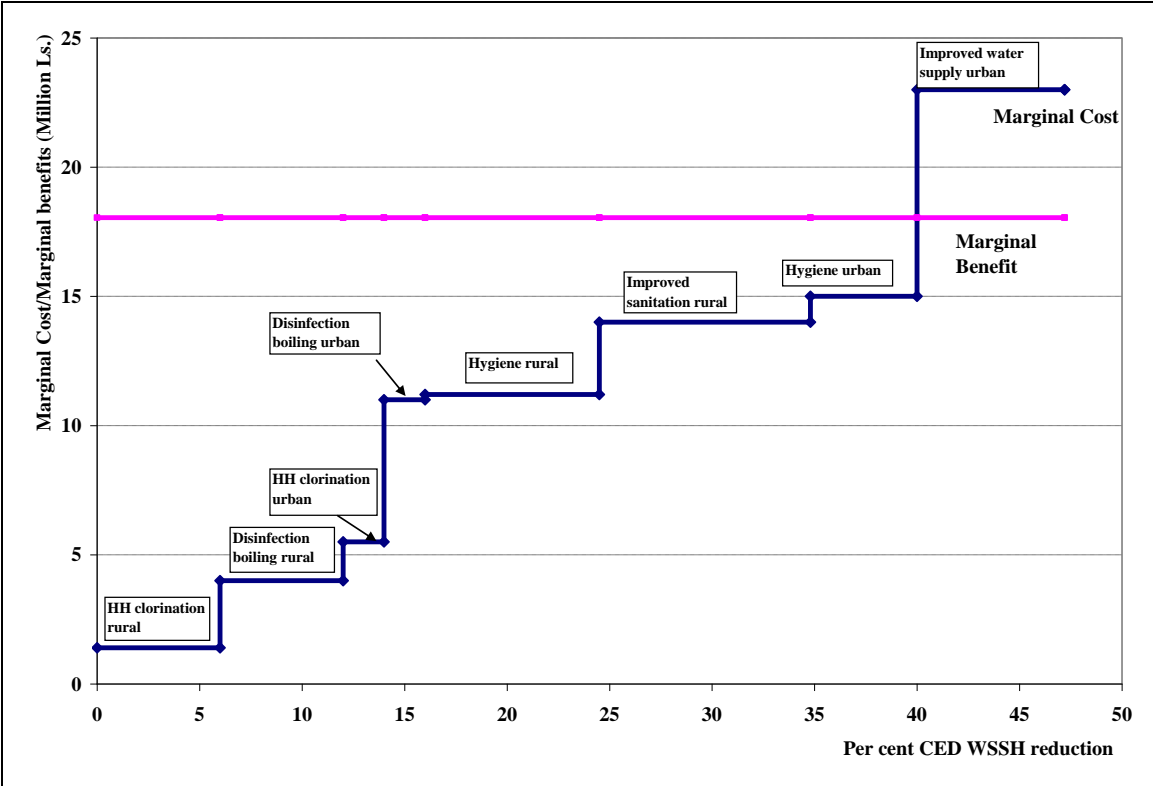
The different interventions discussed above can be summarized in terms of their contribution to reduced environmental damages and the costs per one percent of health damages reduction (marginal cost). This is done in Figure 2.7. It shows the percent of reduction of environmental damage on the horizontal axis and the marginal cost as

explained above on the vertical axis. The graph then plots the relative values of these two pieces of information for a number of interventions. The disinfection and hygiene programs are estimated to have the largest potential health benefits, but only if at least 20 percent of the population responds favorably to the program and improves hand-washing practices. Hygiene improvement and disinfection of drinking water at point-of-use have a substantial potential to reduce diarrheal illness and mortality, as indicated in Table 2.3. The challenge however is to develop and deliver programs that induces sustained behavioral response at a large scale, while containing program costs at an affordable level.

For improved water supply in rural areas benefits exceed costs with time saving benefits taken into account. Safe water supply in rural areas is estimated to have higher marginal costs than benefits. Finally, the benefits of hand washing among adults and safe water supply and sanitation programs in urban areas, are not presented at the graph above. These interventions were estimated to have significantly higher costs than benefits and corresponding benefit cost ration lower than one. All interventions that have marginal costs lower than marginal benefits could reduce total WSSH health cost for about 40 percent. The benefit-cost ratios for hand washing and drinking water disinfection are based on behavioral change being sustained for two years. The ratios would be higher (lower) if, as a result of promotion programs, households sustain improved behavior for longer (shorter) than two years. This figure does not consider the possible interaction effects between different interventions (i.e., how the impacts of a first intervention affect those of a second intervention), because data constraints preclude a sound analysis of such effects.

From the analysis presented here, it is clear that most measures to improve the water supply and sanitation facilities in rural areas yield benefits in excess of costs under most assumptions. The programs are also justified because the benefits are concentrated primarily among the poor. These measures include drinking water disinfection, hand washing, improved rural water supply and safe rural sanitation. The highest priority should be given to the drinking water disinfection and hand washing programs

Figure 2.7: Ranking of Interventions to Reduce WSSH Cost in Honduras

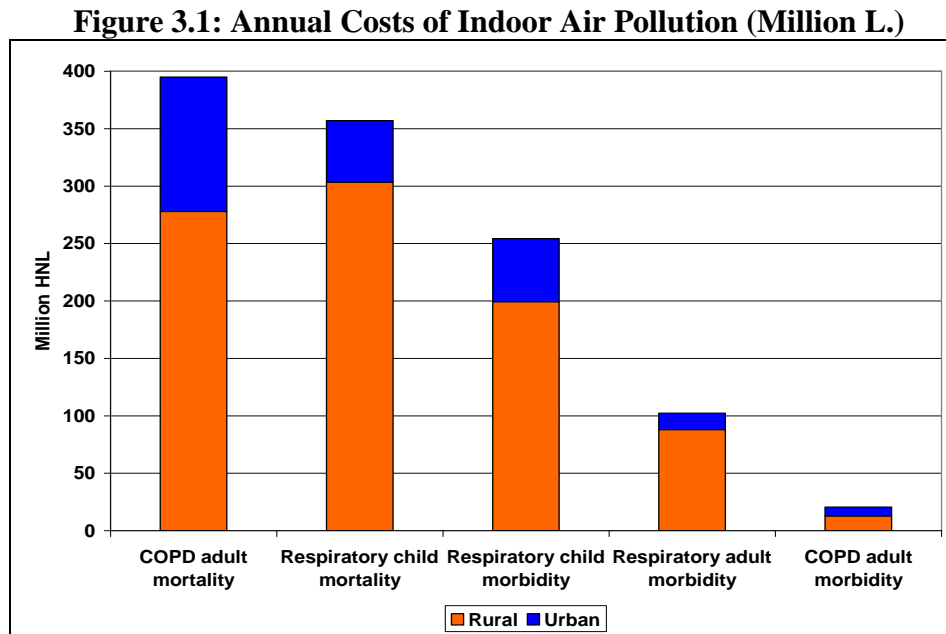


III. INDOOR AIR POLLUTION

This section presents the damage cost of indoor air pollution and provides estimates of the benefits and costs of interventions to reduce this damage cost. The damage cost is from the health effects of smoke from solid fuels used in the household environment, as presented by Strukova (2007).

Damage Cost

The mean estimated annual cost of health impacts from indoor air pollution associated with the use of traditional fuels (mainly fuel wood) is 1.1 billion Ls, or 0.64 percent of GDP. These costs are predominantly originated in the rural areas (about 80 percent of total indoor air pollution costs). As presented in Figure 3.1, chronic obstructive pulmonary disease (COPD) mortality in adult females is 35 percent of the cost, and respiratory child mortality in children represents 32 percent. Acute respiratory illness (ARI) in children represents 23 percent of cost, COPD and ARI morbidity in adult females represent 11 percent of cost.



Details of these estimates are provided in Strukova (2007).

Acute Respiratory Illness in Honduras

Table 3.1 presents acute respiratory illness (ARI) prevalence in children as reported by the ENDESA 2005-2006⁷. The prevalence rate varies substantially across whole departments, with a range from 8 percent to as high as 16.8 percent.

Table 3.1: Acute Respiratory Illness (ARI) Prevalence Rates in Children

	ARI Prevalence in Children under-5 (per cent, 2-weeks prior to survey)
Atlantida	14.2
Colon	16.1
Comayagua	11.2
Copan	15.1
Cortes	8.0
Choluteca	11.9
El Paraiso	14.4
Francisco Morazan	9.8
Intibuca	13.4
La Paz	10.9
Lempira	8.9
Ocotepeque	16.8
Olancho	11.1
Santa Barbara	13.6
Valle	11.6
Yoro	12.8
All Honduras	11.4

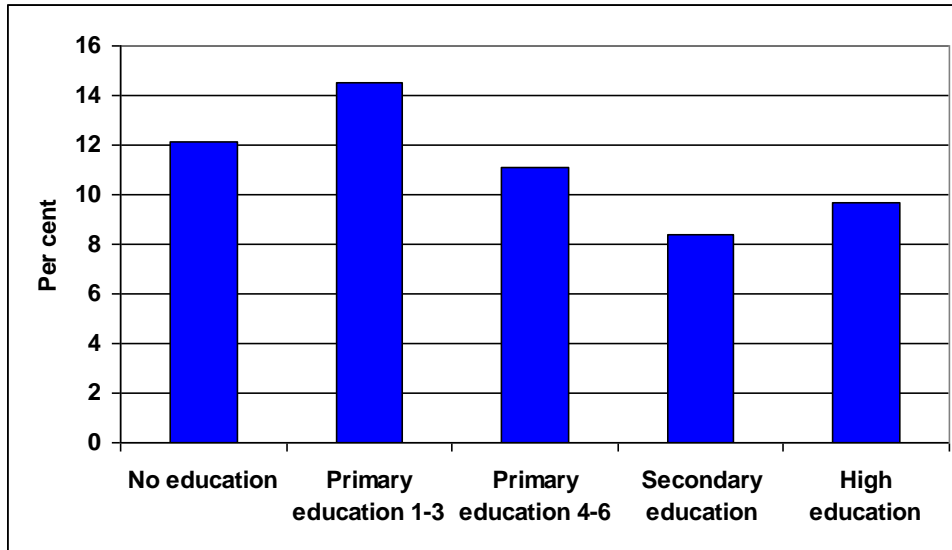
Source: ENDESA 2005-2006.

Figure 3.2 presents ARI prevalence in children under the age of five years in Honduras by the mother's level of education. The ARI prevalence rate does not vary much, although it is somewhat higher in children with mothers who have no education or primary education. However, the percentage of ARI cases that receives medical attention is more than three times higher for children with mothers that have university education compared to children with mothers that have no education (Table 3.2). As lack of treatment increases the risk of ARI mortality, the figures in Table 3.2 may indicate that the burden of ARI, in terms of morbidity and mortality, is higher among lower socio-

⁷ The ENDESA 2005-2006 is a household survey that was carried out in thousands of households in Honduras.

economic groups. These groups are also more likely to use solid fuels for cooking, increasing the risk of ARI morbidity and mortality in children.

Figure 3.2: ARI Prevalence in Children by Mother’s Education Level



Source: ENDESA 2005-2006. ARI prevalence refers to percent of children under the age of 5 years with ARI in the preceding 2 weeks of the household survey date.

Table 3.2: Child Health, ARI Treatment, and Maternal Education

	ARI prevalence rate in Children	Percent of ARI cases treated at health facilities	Child mortality rate (per 1000 births)
No education	12.1	45.4	55
Primary education 1-3	14.5	44.6	44
Primary education 4-6	11.1	58.0	37
Secondary education	8.4	71.2	19
High education	9.7	n/a	21

Source: Data are from ENDESA 2005-2006 for children under the age of 5 years. Diarrheal prevalence rate is for 2 weeks prior to survey date.

Health Effects of Indoor Air Pollution

It is well documented from studies around the world that indoor air pollution from solid fuels used for cooking and heating in the indoor environment has substantial respiratory health effects. Women and young children appear to bear the largest effects

because they tend to spend more time indoors and/or closer to the cooking areas. However, studies have also found health effects in men.

Smith et al (2004) and Desai et al (2004) report results of health effects from biomass smoke (fuel wood, etc.) and coal smoke based on a meta-analysis of available studies. The results are presented in Table 3.3. The relative risks (RRs) represent the risk of health effect or illness relative to the use of clean fuels such as LPG. The RR for households using LPG is therefore 1.0.

The strongest evidence of health effects is for acute lower respiratory illness (ALRI) in children under 5 years, COPD in adult females, and lung cancer in adult females from coal smoke. Smith et al and Desai et al do not report a relative risk ratio (RR) for acute respiratory illness in age groups above 5 years of age. This is because most of the studies have concentrated on children under 5 years. However, Ezzati and Kammen (2002) from a study in Kenya find that the RR for the age group 5-49 years is quite similar to the RR for children under-5 at various levels of pollution levels.

Table 3.3: Relative Risks for Strong and Moderate Health Outcomes

Evidence	Health Outcome	Group	RR	CI
Strong	ALRI	Children <5 yrs	2.3	1.9-2.7
	COPD	Women >30 yrs	3.2	2.3-4.8
	Lung Cancer (from coal smoke)	Women > 30 yrs	1.9	1.1-3.5
Moderate-I	COPD	Men > 30 yrs	1.8	1.0-3.2
	Lung Cancer (from coal smoke)	Men > 30 yrs	1.5	1.0-2.5
Moderate-II	Lung Cancer (from biomass smoke)	Women > 30 yrs	1.5	1.0-2.1
	Asthma	Children 5-14 yrs	1.6	1.0-2.5
	Asthma	All > 15 yrs	1.2	1.0-1.5
	Cataracts	All > 15 yrs	1.3	1.0-1.7
	Tuberculosis	All > 15 yrs	1.5	1.0-2.4

Source: Desai et al (2004). Notations: RR= relative risk. CI= confidence interval. ALRI=acute lower respiratory infection. COPD=chronic obstructive pulmonary disease.

A Benefit-Cost Analysis Framework

A benefit-cost analysis of interventions to reduce indoor air pollution from solid fuels represents a challenge for many reasons. The relative risks reported in Table 3.3 represent averages from many studies, and do not necessarily reflect the pollution exposure situation in households using solid fuels in Honduras. Moreover, the pollution

load from solid fuels is not homogeneous across households. Some household use unimproved stoves or open fire while others use improved stoves with chimneys, and some households use a combination of solid fuels and clean fuels such as LPG. A benefit-cost analysis framework should therefore be flexible enough to accommodate these differences and allow for a sensitivity analysis of parameters that will influence the benefits and costs of interventions to reduce pollution loads and/or exposure.

For the purposes of this report, five scenarios were selected that represent five stylized situations commonly found in most developing countries (Table 3.4). These stylized situations reasonably well represent the pollution loads from solid fuel use. Actual pollution exposure, however, can vary substantially in each scenario, and depend on additional factors such as household ventilation practices, housing characteristics, and household behavior. As data on these factors are not readily available at a national level, a sensitivity analysis of relative risk will need to be undertaken in order to assess the likely influence of these factors on the benefit-cost ratios of interventions.

Table 3.4: Fuels, Stove Technology and Pollution Scenarios

Stylized Situation	Stylized Description	Relative Risk
I. Unimproved Wood Stoves or Open Fire	Low energy efficiency. No chimney or ventilation device. Very high indoor pollution load.	Very High
II. Improved Wood Stoves	Relatively low energy efficiency. Chimney (or other ventilation device) taking much of the smoke outdoors. Still relatively high indoor pollution load if stove/chimney is not well maintained.	High
III. Unimproved Wood Stoves and LPG (or other clean fuel)	Pollution load reduced in proportion to the use of LPG (relative to situation I.).	Medium
IV. Improved Wood Stoves and LPG (or other clean fuel)	Pollution load reduced in proportion to the use of LPG (relative to situation II.).	Medium to Low
V. LPG or other clean fuel	Absence of smoke from solid fuels.	Low

Note: The framework in this table is very similar to the exposure scenario framework presented in Pruss et al (2002), which was applied in the water-sanitation-hygiene section of this report.

The next step is to assign population shares and relative risks to each of the stylized situations in Table 3.4. According to the ENDESA 2005-2006, about 86 percent of the

rural population in Honduras relies on fuel wood (85.5%), and charcoal (0.2%) as their main fuel for cooking. In the urban areas, about 20 percent of the population relies on these fuels. There is a total annual fuel wood consumption of 5 million cubic meters (Cruz & Centro 2001) A total of nearly 0.8 million households use fuel wood and charcoal as their primary energy for cooking, with an average annual household consumption of 3.01 tons. Similarly, very little information is available in Honduras to assign relative risks to each of the stylized situations in Table 3.4. While some information is available from the international literature, the situation specific evidence is less firm than for water and sanitation. It is therefore necessary to apply a base case of relative risks to each of the stylized situations and perform a sensitivity analysis.

The base case for population shares and relative risks is presented in Table 3.5. It is almost exclusively the rural population in Honduras that uses solid fuels as their main cooking fuel. Rural and urban population shares are therefore applied in Table 3.5. As already mentioned, the ENDESA data do not provide the population shares for situations I-IV. So the relative shares applied are from international experience (Ahmed et al 2005).

Table 3.5: Base Case Estimation of Scenario Specific Relative Risks in Honduras

Stylized Situations	Rural			Urban		
	Population Share	RR for ARI	RR for COPD in Women	Population Share	RR for ARI	RR for COPD in Women
I. Unimproved Wood Stoves or Open Fire	43%	2.8	4.1	7%	2.8	4.1
II. Improved Wood Stoves	43%	1.9	2.6	7%	1.9	2.6
III. Unimproved Stoves and LPG (or other clean fuel)	5%	1.9	2.5	5%	1.9	2.5
IV. Improved Stoves and LPG (or other clean fuel)	5%	1.5	1.8	5%	1.5	1.8
V. LPG or other clean fuel	4%	1.0	1.0	76%	1.0	1.0
Weighed average risk of I to IV		2.2	3.1		1.3	1.4

An important factor is the reduction in “excess” risk from using improved stoves instead of unimproved stoves. While there is limited guidance from the international literature, there are several studies from around the world that presents measurements of particulate exposure from solid fuel use, particularly from cooking. Some results from

Latin-America are presented in Table 3.6. The 24-hour average concentration levels from open fire or traditional stoves are many times higher than urban air quality standards in most countries. The improved stoves, such as the *plancha*, produce PM 2.5 or PM 3.5 levels that are often only 20 percent of concentration levels from an open fire, and are even found to be less than 10 percent of that of an open fire in a study in Guatemala by McCracken and Smith (1998). According to the figures in Table 3.6 the reduction in PM 2.5 seems to even larger than reductions in PM 10. While the indoor concentration levels of PM can be substantially reduced by using improved stoves, it is not clear that the health benefits are proportional. The concentration levels of PM, even with an improved stove, are still substantially higher than found in most outdoor urban environments.

Table 3.6: Particulate (PM) Concentrations from Cooking Stoves

	Open fire/ Traditional Stove	Improved Stove	LPG	
24-hour PM 3.5	1930	330	-	Guatemala. Albalak et al (2001).
24-hour PM 10	1210	520	140	Referenced in Albalak et al (2001), adapted from Naeher et al (2000).
24 hour PM 2.5	520	88	45	
24-hour PM 2.5	868	152	-	
PM 10	600-1000	300	50	Mexico. Saatkamp et al (2000)

Table 3.7 provides the results of a study by Ezzati and Kammen (2002) which presents odds ratios for ARI in relation to PM 10 indoor concentrations levels. A halving of PM 10 levels from 1000-2000 to 500-1000 ug/m³ can correspond with the concentration levels associated with the use of an unimproved stove vs an improved stove. This reduction in concentration level is associated with a reduction in the odds ratio of about 50 percent for children under-5 and 25 percent for the age group 5-49 years. The risk reduction of 50 percent has therefore been applied in the base case in Table 3.5 for ARI to establish the relative order of magnitude of the RR in situation I and II.

Table 3.7: Odds Ratios for ARI

PM 10 (ug/m ³)	Children under 5 years	Age group 5-49 years
<200	1.0	1.0
200-500	2.42	3.01
500-1000	2.15	2.77
1000-2000	4.30	3.79
2000-3500	4.72	-
2000-4000	-	4.49

>3500	6.73	-
4000-7000	-	5.40
>7000	-	7.93

Source: Ezzati and Kammen (2002).

As regards chronic respiratory illness, Albalak et al (1999) find a 60 percent reduced risk of chronic bronchitis from outdoor cooking with solid fuels compared to indoor cooking with the same fuels in a study from Bolivia. It should be noted however that outdoor cooking is not free from fine particulate exposure. Studies have found that those engaged in outdoor cooking activities are exposed to elevated levels of pollution. Dennis et al (1996) in a study from Bogota find that individuals who did not use solid fuels in the household had an almost 75 percent lower prevalence rate of (chronic) obstructive airways disease than those who had lived in households with solid fuel use. Similar results were found in study from Mexico for chronic bronchitis, with an even larger difference in prevalence in individuals with longer life-exposure to solid fuel pollution (Perez-Padilla et al 1996). In Table 3.5, a 50 percent “excess” risk reduction in COPD is applied for the switching from open fire/traditional stove to an improved stove with chimney.

Using the parameter values discussed above, the estimated RRs are presented in Table 3.5. Only COPD in women and ARI are included. While there is moderate evidence for an increased risk of COPD in men, this is not included in this report. For ARI, however, both children under 5 years and women over 15 years are included although ARI in adult women is not included in the meta-analysis results presented in Smith et al (2004) and Desai et al (2004). However, the study by Ezzati and Kammen (2002) provide some evidence of similar ARI risk ratios for children under-5 and the age group 5-49. A sensitivity analysis is performed for ARI in women 15+ in the benefit-cost ratio estimations later in this section.

The population shares and the relative risk ratios in Table 3.5 allow a base case estimation of the health benefits of interventions such as improved stoves and switching to clean fuels (Table 3.4). In order to estimate benefit-cost ratios, however, the costs of interventions need to be estimated. In addition to costs of improved stoves and LPG stoves (or stoves for other clean fuels), this involves an assessment of household energy consumption for cooking in order to estimate the recurrent cost of LPG requirements or

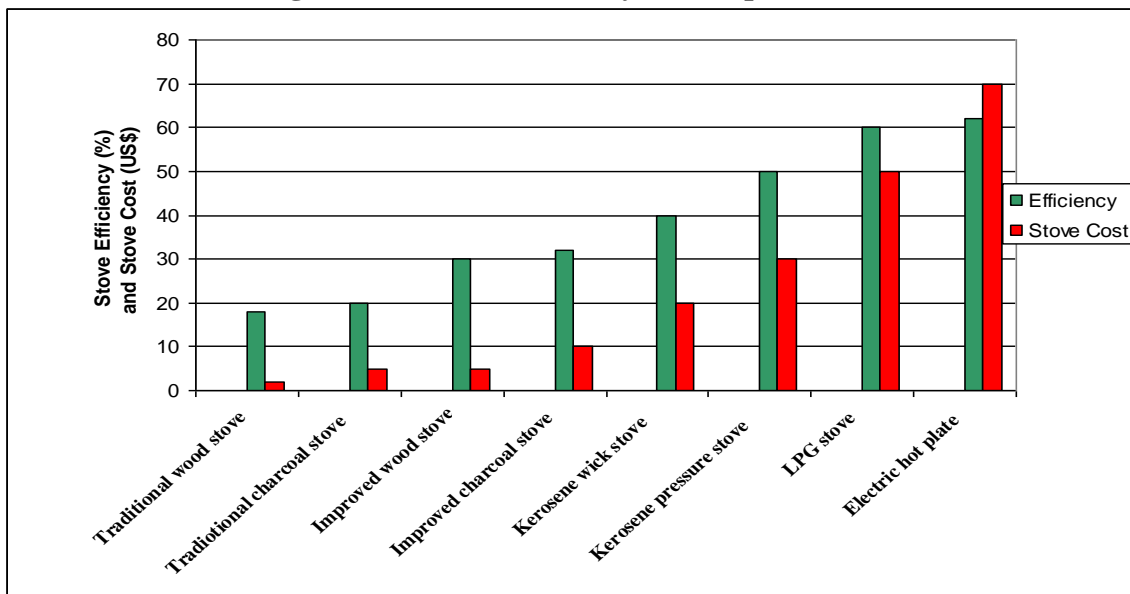
other clean fuels. Also, time savings from less fuel wood collection may be an important benefit for many households of switching to improved stoves or clean fuels. Fuel wood consumption must therefore be estimated for the various stylized situations or scenarios in Table 3.4. A first step in estimating the costs of interventions is therefore to consider stove efficiencies.

Stove Efficiency

Figure 3.3 presents an energy efficiency ladder for stoves, and their typical costs, that is often cited in the research literature on fuel use and indoor air pollution (e.g. Baranzini and Goldemberg 1996; Luo and Hulscher 1999; and Saatkamp et al 2000). The stove efficiency ladder provides a generic perspective on potential energy savings from improved wood and charcoal stoves and kerosene, LPG, and electric stoves in comparison to traditional stoves. According to Figure 3.3 improved wood and charcoal stoves are about 50 percent more efficient than traditional stoves, and LPG and electric stoves are 2 times more efficient than the improved wood and charcoal stoves.

A study of stove efficiency in Colombia was conducted by the National University of Colombia, Department of Physics. The results of the study was provided by UPME for the purposes of this report, and presented in Figure 3.4. The study estimated the stove efficiency for three different sizes of pots/kettles. The efficiency for electric plates was around 80 percent for all three pot sizes. LPG and natural gas stoves had an efficiency of 45-55 percent for the two smallest pot sizes. The efficiency for the largest pot size was more than 75 percent. For a “wood firebox”, an improved wood stove, the efficiency was less than 10 percent for the two smallest pots, but about 30 percent for the largest pot. The efficiency of “fuel wood”, or traditional open stove, was less than 5 percent for the smaller pots, and 20 percent of the largest pot.

Figure 3.3: Stove Efficiency and Capital Costs

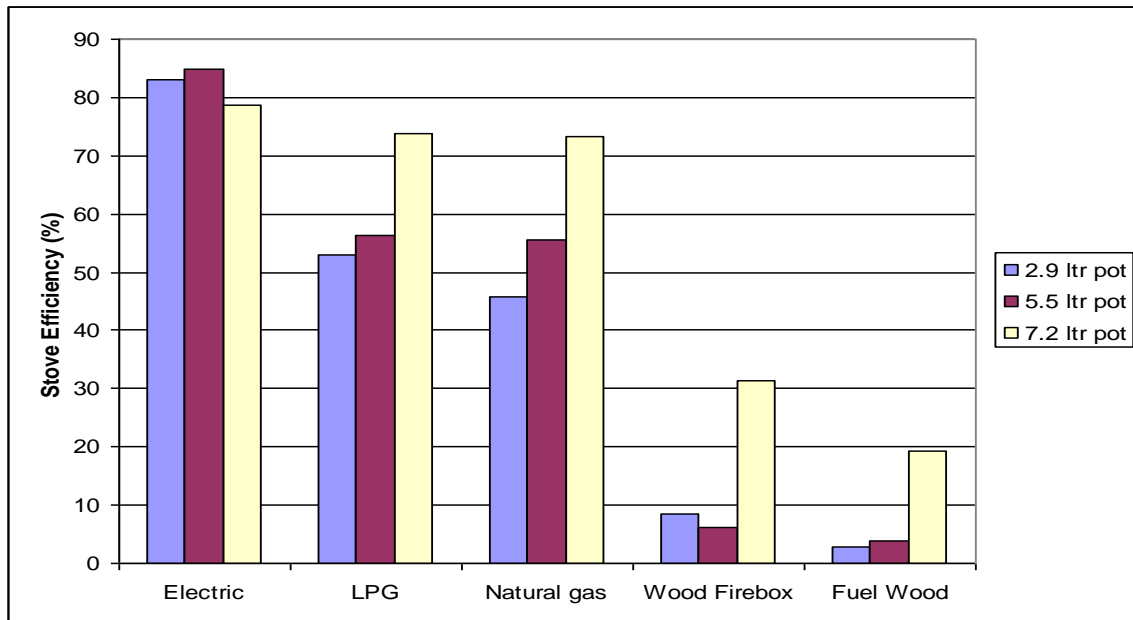


For the most part, the results from this Colombian study are consistent with the generic efficiency ladder in Figure 3.3. A notable difference is the wood stove efficiencies for the two smallest pot sizes. However, a study of the *plancha* woodstove in Guatemala found an efficiency of around 10 percent, and very similar to the efficiency of using open fire. A modified version of the *plancha* had an efficiency of around 12 percent (Boy et al 2000). McCracken and Smith (1998) find an efficiency of 13-14 percent for the *plancha* and open fire. Saatkamp et al (2000) presents estimates of stove efficiencies in Jaracuaro, Mexico, and find that the efficiency of the *loreña* woodstove is not much different than traditional open stoves.

Trees, Water, & People (TWP), the Honduran Association for Development (AHDESA), and the Aprovecho Research Center are undertaking the “Micro-Enterprise Stove Project” to introduce safer and more environmentally friendly cook stoves for the people of Honduras. The team came together after Hurricane Mitch devastated Honduras in 1998 to adapt the Rocket stove technology to cooking conditions in Honduras. Working along with local Honduran women, Aprovecho stove technicians came up with the Justa stove design in 1999. Justa stoves save an average of 50-70% on firewood compared to traditional stoves. The Justa also removes about 90 percent of toxic smoke from the kitchen (Conway et al, 2006). In 2004, with a grant from the United States

Environmental Protection Agency (USEPA), and with technical assistance from Aprovecho, TWP and AHDESA began developing commercial models based on the existing Rocket and EcoStove designs. Efficiency of the Justa stoves introduced through this project in Honduras was not estimated, but for the purpose of the study was considered in the same range as in Colombia.

Figure 3.4: Stove Efficiency from a Study in Colombia



Source: Study conducted by the National University of Colombia, Department of Physics. The results of the study were provided by UPME.

The *justa* woodstoves have been adopted by many communities in Latin-America. While these stoves are often not very efficient, they are equipped with a chimney that removes the smoke from the indoor environment and therefore have important health and quality of life benefits. Several versions and off-springs of these stoves have also been developed in order to improve stove efficiency. (Conway et al, 2006).

Fuel Wood Consumption

Among households that use fuel wood, there are typically three types of situations. Some households use open fire/traditional woodstoves. Others use improved woodstoves. And finally, some households use fuel wood in combination with LPG or other type of cleaner fuel. Based on data from UPME, it is estimated that the average

household that uses fuel wood has a consumption of 3.01 tons per year. However, household consumption, for any given household size, will tend to vary depending on efficiency of woodstove and whether or not the household also uses other types of fuels for cooking.

Fuel wood consumption was estimated for different scenarios using corresponding share of population with each stove type and stove efficiency from Figure 3.4. The estimates are presented in Table 3.8. These estimates are based on the assumption that the groups of households have, on average, the same demand for cooking energy.

Table 3.8: Estimated Annual Household Consumption of Fuel Wood

<u>Technology:</u>	Fuel wood consumption (tons)
Unimproved stoves	3.8
Improved stoves	2.6
Unimproved stoves and LPG stoves	1.9
Improved stoves and LPG stoves	1.3

It is important to assess the realism of the fuel wood consumption in these four cases. Saatkamp et al (2000) estimates fuel wood consumption in Jaracuaro, Mexico, in the range of 0.5-1.0 kg per meal per person for the *lorena* stove and open fire. For two meals a day, and an average household size of 5, this implies an annual fuel wood consumption of 1.8-3.6 tons per year. For three meals a day, the annual consumption would be 2.7-5.4 tons per year. This is in the range of the estimated fuel wood consumption in Table 3.8.

Cost of Interventions

Estimated annual recurrent cost of switching from fuel wood to commercial energy, or from a combination of fuel wood and LPG to LPG only, is presented in Table 3.9. At current prices (in 2006) of energies in Honduras, LPG and electricity are found to be very close price options. Using electricity to replace fuel wood is found to be a little less expensive than LPG, but it is difficult to ensure adequate access to electricity in rural areas. The cost is the same for households using unimproved and improved woodstoves

(with 10 and 15 percent efficiency). This is because of the assumption that they have the same effective energy demand. LPG therefore seems to be the most viable option.

It should be noted that the estimated costs in Table 3.9 are likely to represent underestimates of the costs of providing commercial energy to distant rural areas. Currently only about 7 percent of rural households in Honduras are already using LPG and other commercial energies according the ENDESA 2005-2006. Thus supplying these fuels to other rural households may not be substantially more expensive than to those households already using commercial fuels.

Table 3.9: Annual Recurrent Cost of Complete Fuel Substitution

	Annual Cost Per Household (000 Ls)	
	LPG	Electricity
	25 lb bottles	Urban only
Unimproved stoves	3.2	3.1
Improved stoves	3.2	3.1
Unimproved stoves and LPG stoves	1.6	-
Improved stoves and LPG stoves	1.6	-

Table 3.10 presents the baseline parameters that were used to estimate the cost of switching to commercial energy. These parameters are based on data from UPME and results of a study by the National University of Colombia, as well as Honduras national statistics.

Table 3.10: Baseline Parameters for Estimating the Cost of Fuel Substitution

<i>Fuel Wood</i>	
Average gross energy content of fuel wood (MJ per kg)	19
Average net energy content of fuel wood (MJ per kg)	11
<i>Propane (LPG)</i>	
Average stove efficiency (propane)	55%
Average energy content of propane (Btu/gallon)	92000
Cost per bottle (25 lb bottles) - Ls	199*
<i>Electricity</i>	
Average stove efficiency	80%
Cost of electricity (Ls./kWh)	2**

Sources: Energy content of LPG and natural gas, and prices of LPG, natural gas and electricity are based on data from UPME. Gross and net energy content of fuel wood (gross and net heating content) and stove efficiencies are from a study by the National University of Colombia provided by UPME. *IDEM; **Dussan M. *et. al.*, 2007, "Estrategia de Energía para Honduras: Opciones", Banco Mundial

Capital costs and annualized costs of improved stoves and LPG stoves are presented in Table 3.11. Capital costs are adapted from Conway et al, 2006. While simple improved stoves used in many developing countries are found to be quite inexpensive, as presented in Figure 3.3, the type of improved stoves commonly used in Latin-America is far more expensive as indicated in Table 3.11. Annualized costs are calculated by using a useful life of 10 years and an annual discount rate of 10 percent.

Table 3.11: Cost Estimates of Improved Wood Stoves and LPG Stoves

	Lempiras (US \$)	
	Low	High
<i>Capital Cost:</i>		
Improved stove	280 (US \$15)	1600 (US \$85)
LPG stove	2150(US \$115)	2150 (US \$115)
<i>Annualized Cost:</i>		
Improved stove	40	240
LPG stove	320	320

Benefit-Cost Analysis

Four interventions scenarios considered for Honduras represents four stylized situations commonly found in most developing countries. These stylized situations reasonably well represent reduction of pollution loads from solid fuel use. However, actual pollution exposure can vary substantially in each scenario, and depend on additional factors such as household ventilation practices, housing characteristics and household behavior.

Table 3.12: Interventions

<i>Scenarios:</i>	<i>Description:</i>
From I to II	From Unimproved Stove to Improved Stove
From II to V	From Improved Stove to LPG
From III to V	From Unimproved Stove and LPG mix to LPG only
From IV to V	From Improved Stove and LPG mix to LPG only

A benefit-cost analysis is undertaken for the five interventions presented in Table 3.12 for rural areas of Honduras. They are based on the stylized situations in Table 3.4. The estimated benefits and costs of these interventions are presented in Table 3.13-3.14 for rural and urban areas. Avoided cases of ARI and COPD are estimated from the

relative risk ratios in Table 3.5 and baseline estimates of annual cases of ARI and COPD. Baseline cases in are presented in Strukova (2007). The monetary benefits of avoided cases are calculated from the estimated unit costs of ARI and COPD morbidity and mortality, also presented in Strukova (2007). Unit costs of morbidity include medical treatment cost, and value of time losses (at 75 percent of wages). Child mortality is valued by using the human capital approach (HCA) of discounted life earnings losses. Adult mortality is valued by the HCA as a lower bound and the value of statistical life (VSL) as a higher bound. VSL is derived from benefit transfer from the United States and other high-income countries using an income elasticity of 1.0, based on the mid-point value from the range of US \$2-5.4 million as in Strukova (2007). As seen in Table 3.13 the total health benefits of the interventions are greatly influenced by the choice of valuation technique for adult mortality.

An estimate of the value of time savings from reduced fuel wood collection is also included in Table 3.13 for each intervention. As a base case, it is assumed that 80 percent household using an unimproved wood stove spends on average 30 minutes per day on fuel wood collection. In Table 3.13, time is valued at 75 percent of average rural wages. Also, it is estimated that 20 percent of rural households save money from reduced fuel wood purchase. In total, the estimated benefits of time and fuel wood savings exceed health benefits of all interventions.

Annual costs of interventions include program cost, stove cost and LPG cost. LPG represents 80-90 percent of total cost in interventions (2) to (4), while the annualized cost of LPG stove is from 10 percent of total cost (interventions (3)) to 50 percent (intervention (1)). A tentative estimate of the program cost of promoting, implementing improved stoves and LPG fuel switching, and sustaining a stove inspection and maintenance program is also included in Table 3.13-3-14.

Table 3.13-3.14 also presents estimated benefit-cost ratios for the four interventions in rural and urban areas. Two ratios are estimated for each intervention. One ration includes only the health benefits and another include both health benefits and benefits of time and fuel wood savings from reduced fuel wood collection and consumption, i.e., total benefits.

Table 3.13: Benefits and Costs of Rural Indoor Air Pollution Control in Rural Honduras

	Improved stove from unimproved stove	LPG from Improved Stove	LPG from mix of unimproved stove & LPG	LPG from mix of improved stove & LPG
Population receiving intervention (million)	1.6	1.6	0.02	0.02
ARI cases averted per year (thousand)	270	280	32	18
ARI deaths in children averted per year	132	135	15	10
COPD cases averted per year	330	350	40	20
COPD deaths averted per year	55	60	6	3
Annual health benefits (million Ls.)	280	290	35	20
Annual time and fuel wood saving (million Ls.)	280	570	50	30
Program cost (million Ls.)	40	40	5	5
Annualized stove cost, (million Ls.)	45	100		
Annual cost of LPG (million Ls.)	0	1000	60	60
Benefit-cost ratio (health benefits only)	3.3	0.3	0.5	0.3
Marginal cost (million Ls. per 1% of IAP health cost reduction)	4	44	21	39
Benefit-cost ratio (total benefits)	6.6	0.8	1.3	0.8

Table 3.14 : Benefits and Costs of Urban Indoor Air Pollution Control in Honduras

	Improved stove from unimproved stove	LPG from Improved Stove	LPG from mix of unimproved stove & LPG	LPG from mix of improved stove & LPG
Population receiving intervention (thousand)	240	240	170	170
ARI cases averted per year (thousand)	40	40	28	15
ARI deaths in children averted per year	22	22	15	10
COPD cases averted per year	100	110	75	40
COPD deaths averted per year	15	15	10	5
Annual health benefits (million Ls.)	60	65	45	25
Annual time and fuel wood saving (million Ls.)	60	115	60	40
Program cost (million Ls.)	7	7	5	5
Annualized stove cost, (million Ls.)	7	15		
Annual cost of LPG (million Ls.)	0	175	60	60
Benefit-cost ratio (health benefits only)	4.3	0.3	0.7	0.4
Marginal cost (million Ls. per 1% of IAP health cost reduction)	3	34	17	30
Benefit-cost ratio (total benefits)	8.6	0.9	1.6	1.0

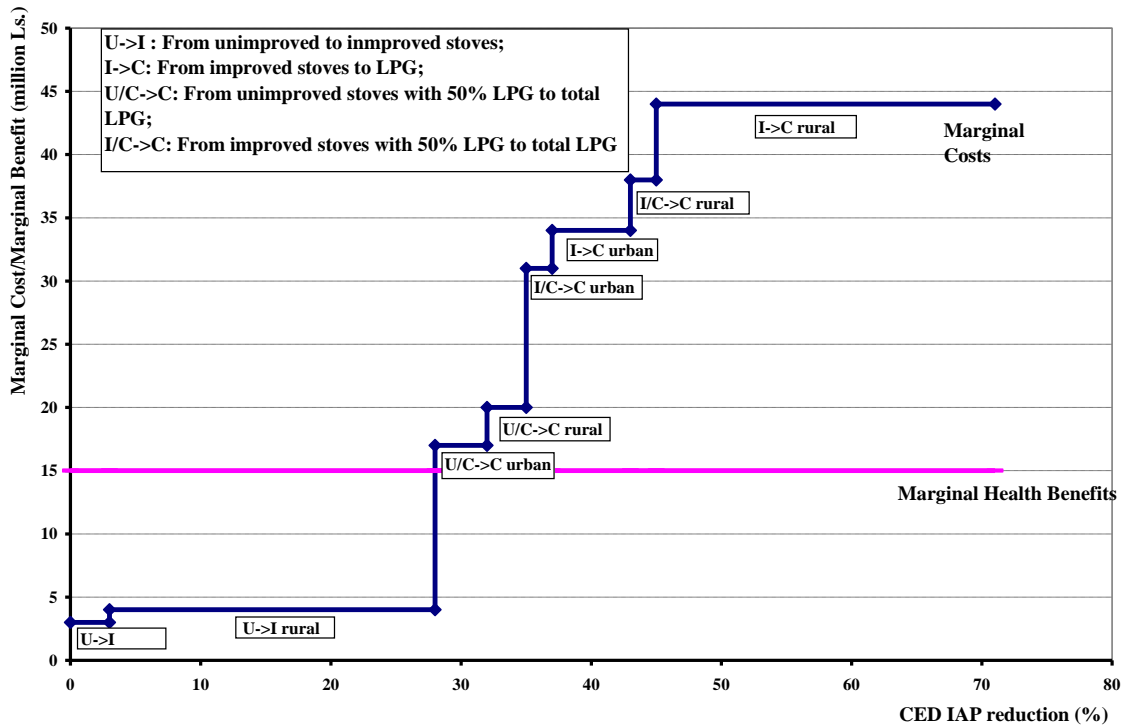
Substitution from unimproved and improved stoves in individual households is found to have substantially higher benefits than costs (Table 3.13-3.14). The benefit-cost ratio is estimated at 3.3-4.3 for substitution from unimproved stoves to improved stoves, and 6.6-8.6 when time benefits are included. Benefit cost ration is higher than 1 if household already using 50 percent of LPG to cook at an unimproved stove if only health

benefits are considered. The reasons for the high benefit-cost ratios are substantial health and time gains accompanied by lower improved stove cost. However, for households with improved stoves, the health benefits alone are not large enough to outweigh the cost of switching to LPG. While promotion of improved stoves is a very attractive intervention, the merits of promoting LPG in individual rural households are uncertain. LPG prices would have to be reduced dramatically for the estimated benefits to exceed costs. Therefore, it seems that LPG will have a chance of success only in better-off households. However, if the benefits include both health improvements and time saving from reduced fuel wood collection then benefit cost ratio is exceeds 1 or is close to 1 for all interventions.

The various interventions are summarized in terms of their contribution to reduced environmental damages and costs per one percent of health damages reduction (marginal cost)⁸, as was done for the water and sanitation programs (Figure 3.5). Marginal cost reflect only program cost and private household cost, without taking into account time and wood fuel saving. Marginal benefit is approximated by the value of one percent of indoor air pollution cost reduction, estimated at 15 million Ls. Household substitution from unimproved to improved stoves has the largest reduction in damages in rural areas. This is followed by household switching to LPG alone from a mix of unimproved stove and LPG in urban and rural areas. Each of these measures contributes a smaller amount of reduction in environmental damages, marginal costs for these two interventions slightly exceed marginal benefits; in total, the former four interventions reduce the cost of health effects by about 37 percent per year. This reflects a substitution to improved stoves in 42 percent of rural households, and 7 percent of urban households; switching to LPG alone from a mix of unimproved stoves, and LPG in 5 percent of rural and 5 percent of urban households.

⁸ Approximated by the average cost to implement intervention per one per cent of IAP cost reduction

Figure 3.5: Ranking of Interventions for IAP Cost Reduction in Honduras



The analysis presented here supports the unqualified recommendation to shift households who have unimproved stoves to improved ones. The results of other interventions, such as from unimproved stoves to LPG or from improved stoves to LPG, depend on the costs and benefits used. Hence, a more detailed analysis needs to be carried out for such changes, looking at specific cases and taking into account other benefits.

REFERENCES

- Analisis Sectorial De Agua Potable Y Saneamiento De Honduras. 2003. OPS-OMS, SANAA. <http://www.ersaps.gob.hn/NR/rdonlyres/E00C38FA-2351-4E4C-8223-17D19F379E42/722/AnalisisdelSectordeAguaPotable.pdf>
- Ahmed K, Awe Y, Barnes, D, Cropper M, and Kojima M. (2005). *Environmental Health and Traditional Fuels Use in Guatemala*. Directions in Development. ESMAP. World Bank.
- Albalak, R., Bruce, N., McCracken, J., Smith, K., and De Gallard, T. (2001). *Indoor Respirable Particulate Matter Concentrations from an Open Fire, Improved Cook Stove, and LPG/Open Fire Combination in a Rural Guatemalan Community*. Environmental Sciences and Technology. Vol. 35, No. 13.
- Albalak, R., Frisancho, AR., and Keeler, GJ. (1999). *Domestic biomass fuel combustion and chronic bronchitis in two rural Bolivian villages*. Thorax. Vol. 54.
- Analisis Sectorial De Agua Potable Y Saneamiento De Honduras. 2003. OPS-OMS, SANAA. <http://www.ersaps.gob.hn/NR/rdonlyres/E00C38FA-2351-4E4C-8223-17D19F379E42/722/AnalisisdelSectordeAguaPotable.pdf>
- Baranzini, A. and Goldenberg, J. (1996). *Desertification, energy consumption, and liquefied petroleum gas use, with an emphasis on Africa*. Energy for Sustainable Development. Vol. II, No. 5. January 1996.
- Borghini, J., Guinness, L, Ouedraogo, J., and Curtis, V. (2002). *Is Hygiene Promotion Cost-Effective? A Case Study in Burkino Faso*. Tropical Medicine and International Health, Vol 7 No11. November 2002.
- Boy, E., Bruce, N., Smith, K., and Hernandez, R. (2000). *Fuel efficiency of an improved wood-burning stove in rural Guatemala: Implications for health, environment and development*. Energy for Sustainable Development. Vol. IV, No. 2. August 2000.
- Brugman, A. (2004). *Diseno De Un Programa De Instrumentos Economicos Para El Manejo Y Control De La Contaminacion Atmosferica Urbana En Colombia*. Prepared for MAVDT, Colombia. December 2004.
- Comisión Presidencial para la Modernización del Estado/CONASA (2007), *Formulacion Programa de Inversiones del sector APS*, Pedro Serrano, p. 3.

Conway S., Africano S., Hao J. (2006). *Honduras Micro-Enterprise Stove Project: A Market-Based Pilot Project for Increasing the Use of Safer Cook Stoves*. Partnership for Clean Indoor Air Bulletin, Oct. 2006, No 9

Countness, R. (2003). *Reconciling Fugitive Dust Emission Inventories with Ambient Measurements*. Presented at the 12th International Emission Inventory Conference. San Diego, CA, April 29-May 1, 2003.

Curtis, V. and Cairncross, S. (2003). *Effect of Washing Hands with Soap on Diarrhoea Risk in the Community: A Systematic Review*. Lancet Infectious Diseases. Vol 3.

Cruz A., and Centro G. (2001). *Estudio de casos sobre combustibles forestales. Honduras*. Proyecto Informacion Y Analisis Para El Manejo Forestal Sostenible: Integrando Esfuerzos Nacionales E Internacionales En 13 Paises Tropicales En America Latina (Gcp/Rla/133/Ec). FAO.

Desai MA, Mehta S, and Smith K. (2004). *Indoor Smoke from Solid Fuels: Assessing the Environmental Burden of Disease at National and Local Levels*. Environmental Burden of Disease Series, No. 4. World Health Organization.

Esrey, S.A., Potash, J.B., Roberts, L., and Shiff, C. (1991). *Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm infection, Schistosomiasis, and Trachoma*. WHO Bulletin, Vol. 69, No. 5.

Esrey, S.A. (1996). *Water, Waste and Well-being: A Multicountry Study*. American Journal of Epidemiology, Vol. 143, No. 6.

Ezzati, M. and Kammen, D. (2002). *The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs*. Discussion Paper No. 02-24. Resources For the Future. Washington DC.

Fewtrell, L. and J. Colford Jr. (2004). *Water, Sanitation and Hygiene: Interventions and Diarrhoea – A systematic review and meta-analysis*. HNP Discussion Paper. World Bank.

Huttly, S., Morris, S. and Pisani, V. (1997). *Prevention of Diarrhoea in Young Children in Developing Countries*. WHO Bulletin. Vol. 75, No. 2.

Larsen, B. (2004). *Cost of Environmental Damage: A Socio-Economic and Environmental Health Risk Assessment*. Prepared for MAVDT, Colombia.

Larsen, B. (2005). *Cost of Environmental Damage: Analysis by Department*. Prepared for MAVDT, Colombia.

Larsen, B., Strukova, E. (2005). *Peru. Cost of Environmental Damage: A Socio-Economic and Environmental Health Risk Assessment*. Prepared for the World Bank.

Luo, Z. and Hulscher, W. (1999). *Woodfuel Emissions*. RWEDP, Bangkok. May 1999.

McCracken, J. and Smith, K. (1998). *Emissions and Efficiency of Improved Woodburning Cookstoves in Highland Guatemala*. Environment International. Vol. 24, No. 7.

Mead, P. et al (1999). *Food-Related Illness and Death in the United States*. Emerg Infect Dis. Vol. 5, No. 5.

Mrozek, J. and Taylor, L. (2002). *What Determines the Value of Life? A Meta Analysis*. Journal of Policy Analysis and Management. Vol 21 (2): 253-270.

Naeher LP, Leaderer BP, Smith KR. (2000). *Particulate matter and carbon monoxide in highland Guatemala: indoor and outdoor levels from traditional and improved wood stoves and gas stoves*. Indoor Air. Vol. 10, No. 3.

Perez-Padilla, R. et al (1996). *Exposure to biomass smoke and chronic airway disease in Mexican women: A case-control study*. Am. J. Respir. Crit. Care Med. Vol. 154, No. 3.

Pinfold, J. and Horan, N. (1996). *Measuring the Effect of a Hygiene Behaviour Intervention by Indicators of Behaviour and Diarrhoeal Disease*. Transactions of the Royal Society of Tropical Medicine and Hygiene, Vol 90.

Pruss, A., Kay, D., Fewtrell, L., and Bartram, J. (2002). *Estimating the Burden of Disease from Water, Sanitation and Hygiene at the Global Level*. Environmental Health Perspectives. Vol 110, No. 5.

Quick, R.E. et al (1999). *Diarrhoea Prevention in Bolivia through Point-of-use Treatment and Safe Storage: A Promising New Strategy*. Epidemiol Infect. Vol. 122.

Saade, C., Bateman, M., and Bendahmane, D. (2001). *The Story of A Successful Public-Private Partnership in Central America: Handwashing for Diarrheal Disease Prevention*. Published by BASICS II, EHP, Unicef, USAID, and World Bank.

Saatkamp, B., Masera, O., and Kammen, D. (2000). *Energy and health transitions in development: Fuel use, stove technology, and morbidity in Jaracuaro, Mexico*. Energy for Sustainable Development. Vol. IV, No 2. August 2000.

Scarborough J, Clinton N, Gong P (2002). *Creating a Statewide Spatially and Temporally Allocated Agricultural Burning Emissions Inventory Using Consistent Emission Factors*. Prepared for the Air Resources Board, California EPA.

Smith K, Mehta S, and Feuz M. (2004). *Indoor Air Pollution from Household Use of Solid Fuels*. In: Ezzati M, Rodgers AD, Lopez AD, and Murray CJL (eds): Comparative

Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors. World Health Organization, Vol.2.

Strukova, E. (2007). *Honduras. Health Costs of Environmental Damage*. Working Paper. World Bank.

University of Andes (2004). *Diseno E Implementacion De Un Modelo De Calidad De Aire Para Bogota*. Informe Semestral 6. Civil Engineering and Environment Department. CIIA.

WHO/Unicef. (2000). *Global Water Supply and Sanitation Assessment 2000 Report*.

WSP 2004, p. 2