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Annex A. Methodology for Health Cost Estimation

This annex provides technical details on the methodology used to estimate health impacts and subsequent costs associated with environmental health risks (urban air pollution, inadequate water supply and sanitation, and indoor air pollution).

METHODOLOGY: URBAN AIR POLLUTION

Particulate Matter Pollution

Research in the United States in the 1990s and most recently by Pope et al. (2002) provides strong evidence that it is even smaller particulates ($PM_{2.5}$) that have the greatest health effects. Gaseous pollutants (SO_2, NO_x, CO and ozone) are generally not thought to be as damaging as fine particulates. However, SO_2 and NOx may have important health consequences because they can react with other substances in the atmosphere to form particulates.

Dose Response Coefficients

In order to estimate health impacts, we have used work by Ostro (1994), Abbey et al. (1995) and Pope et al. (2002). Ostro and Abbey et al. used dose response coefficients to analyze morbidity effects and provide estimates of dose response of PM (PM_{10}) to chronic bronchitis. A survey of the current status of worldwide research shows that the risk ratios or dose-response coefficients by Pope et al. (2002) are likely to be the best available evidence of the mortality effects of ambient particulate pollution ($PM_{2.5}$). These coefficients were applied by WHO in the World Health Report 2002, which provided a global estimate of the health effects of environmental risk factors. The mortality and morbidity coefficients from the above studies are presented in Table A.1.

Table A.1: Urban air pollution dose-response coefficients

Annual Health Effect	**Dose-response Coefficient**	**Per 1 μg/m^3 annual average ambient concentration of:**
Mortality (% change in cardiopulmonary and lung cancer mortality)	0.8%	$PM_{2.5}$
Chronic bronchitis (% change in annual incidence)	0.7%	PM_{10}
Respiratory hospital admissions (per 100,000 population)	1.2	PM_{10}
Emergency room visits (per 100,000 population)	24	PM_{10}
Restricted activity days (per 100,000 adults)	5,750	PM_{10}
Lower respiratory illness in children (per 100,000 children)	169	PM_{10}
Respiratory symptoms (per 100,000 adults)	18,300	PM_{10}

Source: Pope et al. (2002) for the mortality coefficient. Ostro (1994) and Abbey et al. (1995) for the morbidity coefficients.

Pope et al. (2002) provide the most comprehensive and detailed research study to date on the relationship between air pollution and mortality. The study confirms and strengthens the evidence of the long-term mortality effects of particulate pollution found by Pope et al. (1995) and Dockery et al. (1993). Pope et al. (2002) used ambient air quality data from metropolitan areas across the United States for 1979–1983 and 1999–2000, and information on certified causes of mortality of adults from the American Cancer Society (ACS) database over a period of 16 years. The ACS database has individual specific information for more than one million adults that was obtained through questionnaires. The study could therefore control for a large set of factors that may also affect variations in mortality rates across metropolitan areas, such as age, smoking behavior, education, marital status, body weight, occupational risk factors and dietary indexes.

The study found a statistically significant relationship between levels of $PM_{2.5}$ and mortality rates, controlling for all the factors discussed above. All-cause mortality was found to increase by 4–6 percent for every 10 μg/m^3 increase in $PM_{2.5}$. The increase in cardiopulmonary mortality was 6–9 percent, and 8–14 percent in lung cancer. No statistically significant relationship was found between levels of $PM_{2.5}$ and all other causes of mortality (see Table A.2).

The share of cardiopulmonary and lung cancer deaths in total mortality sometimes varies substantially across countries. Therefore, it may reasonably be expected that the risk ratios for cardiopulmonary and lung cancer mortality provide more reliable estimates of mortality from $PM_{2.5}$ than the risk ratio for all-cause mortality when the risk ratios are applied to countries other than the United States. The former two risk ratios are therefore used in this report. The mortality coefficient in Table A.1 is a combination of the cardiopulmonary and lung cancer mortality risk ratios in Table A.2.

Table A.2: Mortality risk associated with a 10 μg/m^3 change in $PM_{2.5}$

	Adjusted Relative Risk Ratios (RR)		
Cause of Mortality	**1979–1983**	**1999–2000**	**Average**
All-cause	1.04	1.06	1.06
Cardiopulmonary	1.06	1.08	1.09
Lung cancer	1.08	1.13	1.14
All other cause	1.01	1.01	1.01

Reproduced from Pope et al. (2002).

In order to use the mortality coefficients in Table A.1 to estimate mortality from urban air pollution in Nicaraguan cities, baseline data on total annual cardiopulmonary and lung cancer deaths are required. Data from the Nicaraguan Ministry of Health, combined with WHO data by cause of deaths, were also used. Data from the above two sources showed an average rate of 30 percent of total deaths due to cardiopulmonary and lung cancer. To estimate the mortality effects, following the procedure used by the 202 World Health Report (WHO), a threshold level of 7.5 $\mu g/m^3$ of $PM_{2.5}$ has been applied, below which it is assumed there are no mortality effects. No threshold level has been applied for morbidity.

An estimate of annual incidence of chronic bronchitis (CB) is required in order to apply the CB coefficient in Table A.1. In the absence of data on CB incidence for Nicaragua, we have used the rate from WHO (2001) and Shibuya et al. (2001) for the AMRO D region of WHO, of which Nicaragua is a part. Therefore, it has not been possible to use city-specific CB incidence rates. Other morbidity health end-points considered are hospital admissions of patients with respiratory problems, emergency room visits (or hospital outpatient visits), restricted activity days, lower respiratory infections in children, and respiratory symptoms. The coefficients are expressed as cases per 100,000 in the absence of incidence data for Nicaragua, though it would be preferable to have incidence data and use coefficients that reflect the percentage change in incidence. Increases in asthma attacks among asthmatics have also been related to air pollution in many studies. But these data are on the population subgroup that is asthmatic and the frequency of asthma attacks is not readily available for Nicaragua.

The health effects of air pollution are then converted to disability adjusted life years (DALYs) to facilitate a comparison to health effects from other environmental risk factors. DALYs per 10,000 cases of various health end-points are presented in Table A.3.

Table A.3: DALYs for health effects

Health Effect	**DALYs lost per 10,000 cases**
Mortality	75,000
Chronic bronchitis (adults)	22,000
Respiratory hospital admissions	160

Emergency room visits	45
Restricted activity days (adults)	3
Lower respiratory illness in children	65
Respiratory symptoms (adults)	0.75

Note: DALYs are calculated using a discount rate of 3 percent and full age weighting based on WHO tables. Estimates of DALYs for the morbidity end-points are from Larsen (2004a, b).

Table A.4 presents the disability weights and average duration of illness used in this report to calculate DALYs, as presented in Table A.5. The weights for lower respiratory illness (LRI) and chronic bronchitis (CB) are average disability weights.[1] Disability weights for the other morbidity end-points are not readily available, and are estimated by Larsen (2004a) based on weights for other comparable illnesses.[2] Average duration of CB is estimated based on age distribution in Nicaragua and age-specific CB incidence in Shibuya et al. (2001). Years lost to premature mortality from air pollution is estimated from age-specific mortality data for cardiopulmonary and lung cancer deaths, and have been discounted at three percent per year. Average duration of illness for the other health end-points is from Larsen (2004a).

[1] See: http://www.dcp2.org/pubs/GBD

[2] The disability weight for mortality is 1.0.

Table A.4: Calculation of DALYs per case of health effects

	Disability Weight	Average Duration of Illness
Mortality	1.0	(7.5 years lost)
Lower respiratory Illness – children	0.28	10 days
Respiratory symptoms – adults	0.05	0.5 days
Restricted activity days – adults	0.1	1 day
Emergency room visits	0.30	5 days
Hospital admissions	0.40	14 days*
Chronic bronchitis	0.2	20 years

* Includes days of hospitalization and recovery period after hospitalization.

Estimated Health Impacts

The total annual costs associated with the health effects described above were computed from the total cost per case (see Table A.5) and the number of estimated cases. For morbidity, the cost of illness alone has been estimated. In the case of respiratory symptoms, the estimated cost per occurrence is zero and hence the total annual estimated cost due to respiratory symptoms in Table A.5 is zero.

Table A.5: Estimated unit cost by health end-point

Health categories	Cost-of-Illness Per Case (NIO)
Chronic bronchitis	13,060
Hospital admissions	4,800
Emergency room visits/Outpatient hospital visits	560
Restricted activity days (adults)	330
Lower respiratory illness in children	45
Respiratory symptoms (adults)	0

The baseline data used to estimate the cost per case of illness is presented in Table A.6. The opportunity cost of time lost because of illness for adults is estimated based on urban wages. The average urban wage in Nicaragua is about 5,000 NIO per month.[3] In the case of both income-earning and non-income-earning individuals, 75 percent of the average urban wage rate has been imputed as the opportunity cost of time lost due to illness. In the case of non-income-earning individuals, the above rate is justified because most of these individuals provide a household

[3] http://www.bcn.gob.ni/estadisticas/indicadores/3-4.htm

function that has a value associated with it; equally, they could choose to join the paid labor force.

Overall, there is very little information about the frequency of doctor visits, emergency visits and hospitalization for CB patients in developing countries. However, Schulman et al. (2001) and Niederman et al. (1999) provide some information on frequency of doctor visits, emergency visits and hospitalization for CB patients in the United States and Europe.[4] In the absence of country-specific data, results from the above studies have been applied to Nicaragua. Lost workdays per year are estimated based on frequency of estimated medical treatment plus an additional seven days for each hospitalization and one extra day for each doctor visit and emergency visit. These days are added together to reflect the total time needed for recovery from illness.

To estimate the cost of a new case of CB, the medical cost and value of time losses have been discounted over a period of 20 years of illness. An annual real increase of two percent in medical cost and value of time lost has been applied to reflect an average expected increase in annual labor productivity and real wages. The costs are discounted at three percent per year, a rate commonly applied by WHO for health effects.

Table A.6: Baseline data for estimation of cost of health impact due to air pollution

	Baseline	**Source:**
Cost Data for All Health End-Points:		
Cost of hospitalization (NIO per hospitalization)	500	Per consultations with medical service providers and health authorities
Cost of emergency visit (NIO) – urban	200	
Cost of doctor visit (NIO) (mainly private doctors) – urban	150	
Value of time lost to illness (NIO per day)	180	75% of urban wages in Nicaragua
Chronic Bronchitis (CB):		
Average duration of Illness (years)	20	Based on Shibuya et al. (2001)
% of CB patients being hospitalized per year	1.5%	From Schulman et al. (2001) and Niederman et al. (1999)
Average length of hospitalization (days)	10	
Average number of doctor visits per CB patient per year	1	
% of CB patients with an emergency doctor/hospital outpatient visit per year	15%	
Estimated lost work days (including household work	2.6	Estimated based on frequency

[4] CB is a major component of COPD, which is the focus of the referenced studies.

days) per year per CB patient		of doctor visits, emergency visits, and hospitalization
Annual real increases in economic cost of health services and value of time (real wages)	2%	Estimate
Annual discount rate	3%	Applied by WHO for health effects
Hospital Admissions:		
Average length of hospitalization (days)	6	Estimates
Average number of days lost to illness (after hospitalization)	4	
Emergency Room Visits:		
Average number of days lost to illness	2	
Restricted Activity Days:		
Average number of days of illness (per 10 cases)	2.5	
Lower Respiratory Illness in Children:		
Number of doctor visits	1	
Total time of caregiving by adult (days)	1	Estimated at 1–2 hours per day

METHODOLOGY: INADEQUATE WATER SUPPLY, SANITATION AND HYGIENE

Inadequate water supply, sanitation and hygiene result in a variety of diseases, such as diarrhea, that result in deaths (predominantly in children under age five) as well as illness. Esrey et al. (1991) provide a comprehensive review of studies documenting this relationship for diseases such as schistosomiasis (bilharzia), intestinal worms, diarrhea, etc. Fewtrell and Colford (2004) provide a meta-analysis of studies of water supply, sanitation and hygiene that updates the findings on diarrheal illness by Esrey et al. (1991). Water, sanitation and hygiene factors also influence child mortality. Esrey et al. (1991) find in their review of studies that the median reduction in child mortality from improved water and sanitation is 55 percent. Shi (1999) provides econometric estimates of the impact of potable water and sewerage connection on child mortality, using a data set for about 90 cities around the world. Literacy and education level are also found to be important determinants of parental protection of child health against environmental risk factors. Esrey and Habicht (1988) report from a study in Malaysia that maternal literacy reduces child mortality by about 50 percent in the absence of adequate sanitation, but only by 5 percent in the presence of good sanitation facilities.

Literacy is also found to reduce child mortality by 40 percent if piped water is present, suggesting that literate mothers are better at taking advantage of water availability for hygiene purposes to protect child health. Findings from the Demographic and Health Surveys from various developing countries further confirm the role of literacy in child mortality reduction. Rutstein (2000) provides a multivariate regression analysis of infant and child mortality in developing countries, using Demographic and Health Survey data from 56 countries from 1986 to 1998. The study finds a significant relationship among infant and child mortality rates and piped water supply, flush toilet, maternal education, access to electricity, medical services, oral rehydration therapy (ORT), vaccination, dirt floor in household dwelling, fertility rates and malnutrition. Similarly, Larsen (2003) provides a regression analysis of child mortality, using national data for year 2000 from 84 developing countries representing 95 percent of the total population in the developing world. A statistically significant relationship between child mortality and access to improved water supply, safe sanitation, and female literacy is confirmed.

Baseline health data for estimating the health impacts of inadequate water supply, sanitation and hygiene are presented in Table A.7. WHO estimates that 12 percent of child mortality was due to diarrhea in 2006. This is used for diarrheal mortality estimation. In the case of diarrheal morbidity, it is very difficult or practically impossible to identify all cases of diarrhea because a substantial share of cases are not treated or do not require treatment at health facilities, and therefore are never recorded. Furthermore, those cases that are treated by private doctors or clinics are often not reported to public health authorities. Therefore, household surveys provide the most reliable indicator of total cases of diarrheal illness. At the same time, the surveys only reflect diarrheal prevalence at the time of the survey. Because there is often high variation in diarrheal prevalence across seasons of the year, extrapolation to an annual average will result in either an over- or underestimate of total annual cases; correcting this bias is often difficult without knowledge of seasonal variations.

ENDESA 2006–2007 provides data on diarrheal prevalence (preceding two weeks) in children under age five, at rates of 13.2 percent in urban areas and 17.6 percent in rural areas. This rate is used to estimate the number of annual cases per child under age five, and then the total annual

cases in all children under five. The procedure applied is to multiply the two-week prevalence rate by 52/2.5 to arrive at an approximation of the number of annual cases per child. The prevalence rate is not multiplied by 26 two-week periods (i.e., 52/2), but multiplied by 52/2.5 for the following reason: the average duration of diarrheal illness is assumed to be three to four days. This implies that the two-week prevalence captures a quarter of the diarrheal prevalence in the week prior to and a quarter in the week after the two-week prevalence period.

Table A.7: Baseline data on health

	Urban	Rural	Source:
Under-age-5 child mortality rate in 2006 (per 1000 live births)	31	40	ENDESA 2006–2007
Diarrheal 2-week prevalence in children under age 5	13.2%	17.6%	ENDESA 2006–2007
Estimated annual diarrheal cases per child under age 5	2.8	3.7	Estimated from ENDESA 2006–2007
Estimated annual diarrheal cases per person (> age 5)	0.3	0.3	Estimated from EMNV 2005 and Fewtrell et al. 2007
% of diarrheal cases attributable to inadequate water supply, sanitation and hygiene	87%	88%	Estimated from Fewtrell et al. 2007

Since ENDESA does not provide information on diarrheal illness in the population above age five, estimations from another survey (EMNV 2005)[5] and approximations from Fewtrell et al. 2007 were used. The survey provides data on the prevalence of diarrhea by age during last 30 days.

Diarrheal illness sometimes requires hospitalization. However, there are no available centralized records in Nicaragua that provide data on the annual number of diarrheal hospitalizations. Thus, the number of hospital admissions due to diarrhea was estimated using information on hospitalization rates provided in Baschieri and Falkingham (2007). A hospitalization rate of 0.5 percent was applied to all cases of diarrhea estimated from ENDESA 2006–2007 to equal the figure on total number of hospitalizations due to diarrheal diseases.

The burden of disease methodology is used to estimate the number of DALYs lost because of inadequate water supply, sanitation and hygiene (see Table A.8). The disability weight for diarrheal morbidity is 0.119 for children under age five and 0.086 for the rest of the population, and the duration of illness is assumed to be the same (i.e., three to four days). However, the DALYs per 100,000 cases of diarrheal illness are much higher for the population over age five. This is because DALY calculations involve age weighting that attaches a low weight to young children and a higher weight to adults, corresponding to physical and mental development stages.[6] For diarrheal child mortality, the number of DALYs lost is 34. This reflects an annual discount rate of three percent of life years lost.

Table A.8: Calculation of DALYs per case of health effects

[5] EMNV 2005 estimates are somewhat higher than those in other LAC countries for populations over age five. We applied these estimates in this report. This explains relatively lower health losses in Nicaragua associated with inadequate WSSH than in other LAC countries.

[6] It should be noted that some researchers elect not to use age weighting, or report DALYs with and without age weighting.

	Urban	Rural	Source:
DALYs per 100,000 cases of diarrhea in children under age 5	40	40	Estimated from WHO tables using age weighting and an average duration of illness of 4 days, and age weighting and 3% discount rate for mortality
DALYs per 100,000 cases of diarrhea in persons > age 5	130	130	
DALYs per case of diarrheal mortality in children under age 5	34	34	

Baseline data used for the estimation of the cost of morbidity are presented in Table A.9. The percentage of diarrheal cases in the population older than five years treated at medical facilities is estimated from the percentage of treated cases among children (ENDESA 2006–2007) and adults (EMNV 2005). The cost of medical services reflects the cost of estimated private health care (WHO-CHOICE) and is a better indication of the economic cost of health services than public services, which are subsidized in Nicaragua.

Table A.9: Baseline data for estimating health effects due to lack of improved water sanitation and hygiene

	Urban	Rural	Source:
% of diarrheal cases treated at medical facilities (children < 5 years)	46%	41%	ENDESA 2006–2007
% of diarrheal cases treated with ORS (children < 5 years)	97%	95%	ENDESA 2006–2007
% of diarrheal cases (children < 5 years) treated with use of pharmacy	46%	41%	ENDESA 2006–2007
% of diarrheal cases treated at medical facilities (population > 5 years) and with medicines	45%	40%	Estimated from EMNV 2005
Average cost of health services (NIO per visit)	150	130	Per consultations with pharmacies, medical service providers and health authorities
Average cost of medicines for treatment of diarrhea (NIO)	70	70	
Average cost of ORS per diarrheal case in children (NIO)	10	10	
Average duration of diarrheal illness in days (children and adults)	4	4	Assumption
Hours per day of caregiving per case of diarrhea in children	2	2	Assumption
Hours per day lost to illness per case of diarrhea in adults	2	2	Assumption
Value of time for adults (caregiving and ill adults) NIO/hour	20	10	75% of urban and rural wages in Nicaragua
% of diarrheal cases attributable to inadequate water, sanitation and hygiene	87%	88%	Estimated from Fewtrell et al. 2007

The value of time lost for adults is imputed based on urban and rural wages. The analysis used 75 percent of urban and rural wages in Nicaragua as the imputed value for both income-earning and non-income-earning adults. It may be noted here that non-income-earning adults are engaged in a household function that has value and they also have an opportunity to join the paid labor force.[7]

[7] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

METHODOLOGY: INDOOR AIR POLLUTION

There are two main steps in quantifying the health effects of indoor air pollution. The first step is to estimate the number of people or households exposed to pollution from solid fuels, and to measure the extent of pollution, or concentration. The second step is to quantify the health impacts from the exposure based on epidemiological assessments. Once the health impacts are quantified, the value of this damage can be estimated.

Data from ENDESA 2006–2007 on household use of fuels for cooking is used for this estimation. According to this survey, about 38 percent of urban and 92 percent of rural households used fuelwood for cooking in 2006–2007 in Nicaragua.

Desai et al. (2004) provide a review of research studies around the world that have assessed the magnitude of health effects of indoor air pollution from solid fuels. The odds ratios for ARI and COPD are presented in Table A.11. The odds ratios represent the risk of illness for those who are exposed to indoor air pollution, compared to the risk for those who are not exposed. The exact odds ratio depends on several factors such as concentration level of pollution in the indoor environment and the amount of time individuals are exposed to the pollution. A range of "low" to "high" ratios is presented in Table A.11, which reflects the review by Desai et al. (2004).

Studies around the world have also found linkages between indoor air pollution from traditional fuels and increased prevalence of tuberculosis and asthma. It is also likely that indoor air pollution from such fuels can cause an increase in ischemic heart disease and other cardiopulmonary disorders. As discussed in the methodology for urban air pollution, Pope et al. (2002) and others have found that the largest effect of urban fine particulate pollution on mortality is for the cardiopulmonary disease group. Because indoor smoke from traditional fuels is high in fine particulates, the effect on these diseases might be substantial. However, more research is required in order to draw a definite conclusion about the linkage and magnitude of effect.

The odds ratios in Table A.11 have been applied to young children under the age of five (for ARI) and adult females (for ARI and COPD) to estimate the increase in mortality and morbidity associated with indoor air pollution.[8] It is these population groups who suffer the most from indoor air pollution. This is because they spend much more of their time at home, and/or more time cooking than older children and adult males.

[8] Although Desai et al. (2004) present odds ratios for lung cancer. This effect of pollution is not estimated in this report because the incidence of lung cancer among rural women is generally very low. The number of cases in rural Nicaragua associated with indoor air pollution is therefore likely to be minimal.

Table A.11: Health risks of indoor air pollution

	Odds Ratios (OR)	
	"Low"	"High"
Acute respiratory illness (ARI)	1.9	2.7
Chronic obstructive pulmonary disease (COPD)	2.3	4.8

Source: Desai et al. (2004).

To estimate the health effects of indoor air pollution from the odds ratios in Table A.11, baseline data for ARI and COPD need to be established (see Table A.12). Data on COPD mortality and especially on the incidence of morbidity, according to international disease classifications, are not readily available for Nicaragua. Regional estimates from WHO (2001) and Shibuya et al. (2001) for the AMRO D region are therefore used.[9]

The national average of the two-week prevalence rate of ARI in children under age five reported in ENDESA 2006–2007 was used to estimate total annual cases of ARI in children under age five. The procedure applied is to multiply the two-week prevalence rate by 52/3 to arrive at an approximation of the annual cases of ARI per child.[10] The EMNV 2005 provides information on ARI prevalence in the last month by age in adults. ARI mortality in children under age five is 14 percent of total estimated child mortality (WHO 2006).

Table A.12: Baseline data for estimating health impacts of indoor air pollution

	Urban	Rural	Source
Female COPD mortality rate (% of total female deaths)	1.4–2.1%	1.4–2.1%	WHO GBD (2004) and Shibuya et al. (2001)
Female COPD incidence rate (per 100,000)	94	94	
ARI 2-week prevalence in children	28%	30%	ENDESA 2006–2007
Estimated annual cases of ARI per child under age 5	4.9	5.2	Estimated from ENDESA 2006–2007
Estimated annual cases of ARI per adult female (> 30 years)	1.7	2.6	Estimated from EMNV 2005
ARI mortality in children under age five (% of child mortality)	14%	14%	WHO 2006

Estimated Health Impacts

Annual new cases of ARI and COPD morbidity and mortality (D_i) from fuelwood smoke were estimated from the following equation:

$$D_i = PAR * D_i^B \quad ; \qquad (A.1)$$

where D_i^B is baseline cases of illness or mortality, i (estimated from the baseline data in Table A.12), and PAR is given by:

$$PAR = PP*(OR-1)/(PP*(OR-1)+1) \qquad (A.2)$$

[9] Nicaragua belongs to the AMRO-D region of WHO.

[10] A factor of 52/3 is applied for the following reason: the average duration of ARI is assumed to be about seven days. This implies that the two-week prevalence captures half of the ARI prevalence in the week prior to and the week after the two-week prevalence period.

where PP is the percentage of population exposed to fuelwood smoke (38 percent of urban and 92 percent of rural households according to ENDESA 2006–2007), and OR is the odds ratios (or relative risk ratios) presented in Table A.11.

The methodology described above is used to estimate the number of DALYs lost associated with cases of ARI and COPD attributed to indoor air pollution. The disability weight for ARI morbidity is the same for children and adults (0.28), and the duration of illness is also assumed to be the same (seven days). However, the DALYs per 100,000 cases of ARI are much higher for adults. This is because DALY calculations involve age weighting that attaches a low weight to young children, and a higher weight to adults that corresponds to physical and mental development stages.[11] For ARI child mortality, the number of DALYs lost is 34. This reflects an annual discount rate of three percent of life years lost.

DALYs lost per case of COPD morbidity and mortality are based on life tables and age-specific incidence of the onset of COPD reported by Shibuya et al. (2001) for the AMRO-D region. A disability weight of 0.2 has been applied to COPD morbidity.[12] A discount rate of three percent is applied to both COPD morbidity and mortality.

Table A.13: Calculation of DALYs per case of health effects from indoor air pollution

	Baseline		***Source***
	Urban	**Rural**	
DALYs per 100,000 cases of ARI in children under 5	165	165	Estimated from WHO tables
DALYs per 100,000 cases of ARI in female adults (>30)	700	700	
DALYs per case of ARI mortality in children under 5	34	34	
DALYs per case of COPD morbidity in adult females	2.25	2.25	
DALYs per case of COPD mortality in adult females	6.8	6.8	

Estimating Costs

Treatment costs are estimated based on costs of health care services offered by the private sector, because these are likely to better reflect the true economic costs. The percentage of ARI cases in the age group older than five years treated at medical facilities is estimated from EMNV (2005).

The time lost in the case of adults is valued at 75 percent of average hourly wages. There is very little information about the frequency of doctor visits, emergency visits and hospitalization for COPD patients in developing countries. Since such data are not available for Nicaragua, data derived from Schulman et al. (2001) and Niederman et al. (1999) on the United States and Europe are used in this analysis. The lost workdays per year are estimated based on the frequency of estimated medical treatment, an additional seven days for each hospitalization and one extra day for each doctor visit and emergency visit. These days are added to reflect time needed for recovery from illness.

To estimate the cost of a new case of COPD, the medical cost and value of time losses are discounted over a 20-year duration of illness. An annual real increase of two percent in medical costs and value of time has been applied to reflect an average expected increase in annual labor

[11] It should be noted that some researchers elect not to use age weighting, or report DALYs with and without age weighting.
[12] See: http://www.dcp2.org/pubs/GBD

productivity and real wages. The costs are then discounted at three percent per year, a rate commonly used by WHO for health effects.

Baseline data used to estimate the cost of morbidity are presented in Table A.14. The treatment costs are based on costs of private sector health care services, because these are likely to better reflect economic cost. Cost of mortality is discussed below. The percentage of ARI cases in the age group older than five years, treated at medical facilities, is estimated using EMNV (2005). The time lost due to illness in the case of adults is valued at 75 percent of the average hourly wage for urban and rural workers. The rationale for this valuation of time is discussed in the previous sections.

Table A.14: Baseline data for estimation of costs of health impacts from indoor air pollution

	Rural	**Urban**	***Source***
% of ARI cases treated at medical facilities (children < 5 years)	60%	68%	ENDESA 2006–2007
%age of cases with use of pharmacy (children < 5 years)	60%	68%	ENDESA 2006–2007
Cost of medicines for treatment of acute respiratory illness (population < 5 years) (NIO)	70	70	Per consultations with pharmacies
% of ARI cases treated at medical facilities (females > 30 years)	30%	30%	EMNV (2005)
% of COPD patients being hospitalized per year	1.5	1.5	Assumption based on Schulman et al. (2001) and Niederman et al. (1999)
% of COPD patients with an emergency doctor/hospital outpatient visits per year	15	15	
Avg. number of doctor visits per COPD patient per year	1	1	
Estimated lost workdays (including household work days) per year per COPD patient	2.6	2.6	Estimated based on freq. of doctor visits, emergency visits and hospitalization
Cost of doctor visit (NIO per visit)	150	130	Per consultations with pharmacies, medical service providers and health authorities
Cost of hospitalization (NIO per day)	500	500	
Cost of emergency visit (NIO per visit)	200	200[13]	
Average duration of ARI in days (children and adults)	7	7	Assumption
Hours per day of caregiving per case of ARI in	2	2	Assumption

[13] These costs include charges for a bed and costs of medicines including what the government incurs for these services

children			
Hours per day lost to illness per case of ARI in adults	3	3	Assumption
Value of time for adults (caregiving and ill adults) – NIO/hour	10	20	75% of wages in Nicaragua
Average length of hospitalization for COPD (days)	10	10	Larsen (2004b)

METHODOLOGY: VALUATION OF MORTALITY

Two distinct methods of valuation of mortality are commonly used to estimate the social cost of premature death: the Human Capital Approach (HCA) and the Value of Statistical Life (VSL). Although both approaches are being used, the VSL approach has been more commonly used in the last few decades. In this report, the HCA has been applied as a lower bound and the VSL approach as the higher bound in estimating the cost of adult mortality. However, the HCA has been used in the case of child mortality.

Human Capital Approach

The HCA is based on the economic contribution of an individual to society over the lifetime of the individual, and death results in an economic loss that is approximated by the loss of all future income of the individual. Future income is discounted to reflect its value at the time of death. The discount rate commonly applied is the rate of time preference. Thus the social cost of mortality, according to the HCA, is the discounted future income of an individual at the time of death. If the risk of death, or mortality risk, is evenly distributed across income groups, average expected future income is applied to calculate the social cost of death. Mathematically, the present value of future income is expressed as follows:

$$PV_0(I) = \sum_{i=k}^{i=n} I_0 (1+g)^i / (1+r)^i \qquad \text{(A.3)}$$

where PV_0 (I) is present value of future income (I) in year 0 (year of death), g is annual growth in real income, and r is the discount rate (rate of time preference). As can be seen from (1), the equation allows for income to start from year k, ending in year n. In the case of children, we may have $i \in \{20, 65\}$, assuming the lifetime income on average starts at age 20 and ends at retirement at age 65. An annual growth of real income and the discount rate used in this study are two percent and three percent, respectively.

Two important issues are often raised with respect to the application of the HCA. The first issue relates to the application of this valuation approach to individuals who do not participate in economic activities, i.e., to individuals such as the elderly, family members taking care of the home, and children who do not earn an income. One may think of an extension of the HCA that recognizes the value of non-paid household work at the same rate as the average income earner, or at a rate equal to the cost of hiring a household helper. In this case, the HCA can be applied to the death of non-income earners and children (whether or not children will become income earners or take care of the home during their adult life). In the case of the elderly, the HCA would not assign an economic value to older individuals who have either retired from the workforce or do not make significant contributions to household work. This obviously is a serious shortcoming of the HCA approach.

The second issue regarding the HCA is that the social cost of mortality is limited to the economic contribution of an individual or the value of household work if the individual takes care of the home. Alternative approaches (such as the value of statistical life) to the valuation of mortality, or social cost of mortality, have therefore been developed and have increasingly been applied in the past few decades.

The estimated cost of mortality in Nicaragua based on HCA, using Eq. A.3, is presented in Table A.15. Average annual income is approximated by GDP per capita, at about 18,800 NIO per year.

Table A.15: Cost of mortality (per death) using HCA

	Average Number of Years Lost	Thousand NIO
Adults:		
Mortality from urban air pollution	7	132
Mortality from indoor air pollution	6.8	128
Children:		
Mortality from indoor air pollution	65	580
Mortality from diarrheal illness	65	580

Value of Statistical Life (VSL)

While the HCA involves valuation of the death of an individual, the VSL is based on valuation of mortality risk. Everyone in society is constantly facing a certain risk of dying. Examples of such risks are occupational fatality risk, risk of traffic accident fatality, and environmental mortality risks. It has been observed that individuals adjust their behavior and decisions in response to such risks. For instance, individuals demand a higher wage (a wage premium) for a job that involves a higher-than-average occupational risk of fatal accident, individuals may purchase safety equipment to reduce the risk of death, and/or individuals and families may be willing to pay a premium or higher rent for properties (land and buildings) in a cleaner and less polluted neighborhood or city.

Therefore, by observing individuals' choices and willingness to pay for reducing mortality risk (or minimum amounts that individuals require to accept a higher mortality risk), it is possible to measure or estimate the value to society of reducing mortality risk, or, equivalently, to measure the social cost of a particular mortality risk. For example, if a certain health hazard has a mortality risk of 1/10,000, i.e., one individual (on average) for every 10,000 individuals dies every year from that particular health hazard. If each individual on average is willing to pay 10 NIO per year for eliminating this mortality risk, then every 10,000 individuals are collectively willing to pay 100,000 NIO per year for eliminating the mortality risk. This is the VSL for eliminating the mortality risk. Mathematically it can be expressed as:

$$VSL = WTP_{Ave} * 1/ R \qquad (A.4)$$

where WTP_{Ave} is the average willingness to pay (NIO per year) per individual for reducing the mortality risk of magnitude R. In the example above, R=1/10.000 (or R=0.0001) and WTP_{Ave}= 10 NIO. Thus, if 10 individuals die each year from the health risk illustrated above, the cost to society is 10* VSL = 10*100,000 NIO = 1 million NIO.

Estimating VSL

The main two approaches used to estimate the VSL are the revealed preference and stated preference analyses. Most of the studies that use revealed preferences are hedonic wage studies, which estimate labor market wage differentials associated with differences in occupational mortality risk. The stated preference studies use contingent valuation methods (CVM), which estimate individuals' willingness to pay for mortality risk reduction.

Mrozek and Taylor (2002) provide a meta-analysis of VSL estimates from labor market studies from around the world. They identify a "best-practice" sample and control for industry characteristics other than occupational mortality risk that also affects inter-industry wage differentials. The study concludes that a lower estimate of US$2 million for VSL can be reasonably inferred from labor market studies when "best practice" assumptions are used. However, it should be noted that the VSL range inferred by Mrozek and Taylor (2002) is substantially lower than average VSL estimated in some other meta-analyses where the mean VSL is as high as US$6 million. As a higher bound for VSL, a mean estimate of VSL meta-analysis of US$5.4 million was applied. The latest meta-analysis of VSL estimates is by Kochi et al. (2006) and uses the empirical Bayes pooling method to combine and compare estimates of VSL data from 40 selected studies published between 1974 and 2002, containing 197 VSL estimates.

Benefit Transfer

No studies on VSL have been undertaken in Nicaragua; the overwhelming majority of VSL studies have been conducted in countries with substantially higher income levels. Hence, the VSL estimates from these countries must be adjusted through a benefit transfer to suit the conditions in Nicaragua. One commonly used approach in benefit transfer is to use income elasticities.[14] Viscusi and Aldi (2002) estimate an income elasticity of VSL in the range of 0.5 to 0.6 from a large sample of VSL studies. However, the range in income elasticity is influenced by three unusually high estimates of VSL from labor market data in one state in India. Leaving out these three studies provides an income elasticity of about 0.80.

However, the most appropriate income elasticity to use for low-income countries such as Nicaragua remains uncertain because the income level in Nicaragua falls far outside the range of income in the sample of countries from which the income elasticities of VSL are estimated in the empirical literature. A prudent approach might be to apply an elasticity of 1.0 in order to reduce the risk of overstating the cost of mortality in Nicaragua.

Table A.16 presents the VSL for Nicaragua from benefit transfer based on the range of VSL reported by Mrozek and Taylor (2002) as the lower bound, and that reported by Kochi et al. (2006) as the upper bound, and an income elasticity of 1.0. These figures are substantially higher than the ones from the HCA, especially for adult mortality due to urban air pollution and indoor air pollution. A comparison is presented in Table A.17.

Table A.16: Estimated value of statistical life in Nicaragua

[14] The income elasticity is the percentage change in VSL per percentage change in income.

	"High"	"Low"	*Source:*
Average VSL in high-income countries (US$ million)	5.4	2	Kochi et al. (2006), Mrozek and Taylor (2002)
Average GDP/capita in high-income countries (US$)	30 000	30 000	World Bank*
GDP per capita in Nicaragua (US$ in 2007)	1020	1020	WDI 2009
Income elasticity	1.0	1.0	
Estimated VSL in Nicaragua (million NIO)	3.39	1.26	Benefit transfer

* Weighted average GDP per capita, based on the sample in Mrozek and Taylor (2002).

Table A.17: A comparison of HCA and VSL estimates applied to Nicaragua

	Ratio of VSL/HCA
Adult mortality	18
Children mortality	4

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Annex B. Methodology for Cost-Benefit Analysis

I. INTRODUCTION

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

A full range of potential interventions could conceptually be evaluated in terms of their benefits and costs to society. However, data and resource limitations constrain the level of detail and the number of interventions that can be evaluated practically 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 resource availability for the study. Nevertheless, it is 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, 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 Nicaragua.

Environmental cost-benefit analysis (CBA), the primary focus of this report, is extensively used in environmental policy, for example in 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. However, it should 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 more extensive data collection and in-depth analysis.

II. WATER, SANITATION AND HYGIENE

This section presents the damage cost of inadequate water supply, sanitation and hygiene and provides estimates of the benefits and costs of interventions to reduce this damage cost.

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 B.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 B.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 B.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 includes open pit latrines, public latrines, service or bucket latrines, and the absence of any facilities. Improved water supply refers to house connections, 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 the 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 B.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 B.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. With regard to 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 therefore tend 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

Prüss et al. (2002) provided a framework for estimating the burden of disease from water, sanitation and hygiene. This is presented in Table B.2. Prüss et al. applied this framework to estimate the global burden of diarrheal disease, but it can also be applied conveniently 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 three to five times higher than in North America and high-income countries in Europe, and as much as six times higher in Sub-Saharan Africa. These figures are relatively consistent with Table B.2 and suggest 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 B.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 Prüss et al. 2002.

Prüss et al. derived the relative risks of diarrheal illness from international literature (Table B.3).

Table B.3: Reductions in diarrheal illness used by Prüss 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 Prüss et al. (2002) is applied in this report to estimate the benefits and costs of interventions to reduce diarrheal illness and diarrheal mortality in Nicaragua. The relative risks in Table B.2, or reductions in diarrheal illness in Table B.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 Prüss 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 IIId is therefore added in Table B.4.

To allow for a comparison to Table B.2, the relative risk for Scenario VI without point-of-use disinfection is also 11.0 in Table B.4. The relative risks in Vb and Va is derived by multiplying the relative risk in VI by the relevant relative risk ratios in Table B.1. As in Prüss et al., there is no difference between Va and IV. The difference between IV and IIId is a relative risk ratio of 0.9, reported in Fewtrell and Colford (2004) for household water supply connection. The difference between IIId and IIIc is the relative risk ratio of 0.891 presented in Table B.1.

The difference between with and without point-of-use disinfection for Scenarios VI to IIId is a relative risk ratio of 0.53. This corresponds to the relative risk ratio for rural water supply in Table B.1. This ratio may be considered more appropriate to apply than the urban relative risk ratio because Scenarios IV–VI are typically found in rural areas, and water quality in Scenarios IIId to VI is on average likely to involve higher disease risk than urban treated piped water supply. The relative risk for Scenarios IIIc and IIId 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 B.2). The provision of 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 for those segments of the population without these services.

Table B.4: Exposure scenario application to Nicaragua

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
IIId	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 Prüss 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 Nicaraguan population shares in each of the scenarios. Three sources of data from Nicaragua are used for this purpose, i.e., the ENDESA 2006–2007 household survey with data on the water and sanitation situation in urban and rural areas, Censos Nacionales (National Censuses) 2005, and WHO/UNICEF Joint Monitoring Program (JMP 2008) as well as household drinking water disinfection data, and data from Nicaraguan water supply authorities on the piped water network and water treatment plants (Estrategia Sectorial de Agua Potable y Saneamiento 2005).

The water supply and sanitation situation is presented in Tables B.5 and B.6. As discussed in relation to Tables B.2 to B.4, unimproved or no basic sanitation mainly refers to households with no sanitation facilities or with open pit latrines. Similarly, no improved water supply refers mainly to surface water, tanker trucks and unprotected well or spring water.

Table B.5: Water supply and sanitation (% of households): Different sources

	ENDESA 2006–2007			Censos Nacionales 2005		
Water Service by:	**Total**	**Urban**	**Rural**	**Total**	**Urban**	**Rural**
Pipe inside HH	30.7	49.5	5.1	39.7	62.7	10.4
Pipe outside HH in lot	32.0	41.4	19.0	20.6	24.1	16.0
Public fountain	3.7	1.0	7.5	3.2	1.5	5.4
Public/private well	14.9	3.3	30.9	16.7	5.6	30.8
Purchase/tanker	0.8	1.0	0.8			
River, watershed	13.1	0.6	30.2	13.2	0.5	29.3
Other	4.8	3.2	6.5	6.7	5.6	8.1
Sanitation Service by:						
Toilet w/sewer connection	56.7	44.9	72.9	60.0	53.0	68.0
Sewage connection in HH	23.2	39.5	0.9	17.5	33.0	0.0
Toilet w/septic tank	7.7	12.1	1.7	6.0	11.0	2.0
River	0.2	0.3	0.1	0.5	0.3	0.1
No sanitation	12.2	3.2	24.4	16.0	3.0	30.0

Source: ENDESA 2006–2007; Resumen Censal (Census Summary) 2005

Table B.6: Water supply and sanitation in Nicaragua (% of households) as in JMP 2006

		Total	Urban (58% of the population)	Rural (42% of the population)
Water	Broad definition	79	90	63
	House connections	60	84	27
Sanitation	Broad definition	47	56	34
	Sewerage	13	22	0

Source: WHO/UNICEF Joint Monitoring Program (JMP/2006).

The latter was selected as the basis for the analysis. In order to use the data in Table B.6 to estimate the population shares in each of the scenarios in Table B.4, a set of allocation "rules" were applied. These "rules" are presented in Table B.7. Data from Nicaragua's 2005 Estrategia Sectorial de Agua Potable y Saneamiento (Sectoral Strategy for Drinking Water and Sanitation) were used to provide an estimate of the urban population share with piped water supply that is treated. According to these data, 100 percent of drinking water was disinfected at the source in urban and rural areas in 2005.

Table B.7: Scenario allocation rules

Scenario/ Situation	Allocation rule
VI	Lesser population share without improved water supply and without basic sanitation.
Vb	Diff. between population share w/o basic sanitation and w/o improved water, if difference is > 0.
Va	Diff. between population share w/o improved water supply and w/o basic sanitation, if difference is > 0
IV	Lesser population share with improved water supply and basic sanitation minus population share with piped water.
IIId	Population share with piped water supply.
IIIc	

Table B.8: Rural water supply and sanitation in Nicaragua (% of rural population)

Scenario/ Situation	Description	Share of rural population
VI	No improved water supply and no basic sanitation	37%
Vb	Improved water supply and no basic sanitation	2%
Va	Basic sanitation but no improved water supply	0%
IV	Improved water supply and basic sanitation	34%
IIId	IV and water supply piped to household (no source treatment)	27%
IIIc	IV and water supply piped to household (source treatment)	

Table B.9: Urban water supply and sanitation in Nicaragua (% of urban population)

Scenario/ Situation	Description	Share of urban population
VI	No improved water supply and no basic sanitation	10%
Vb	Improved water supply and no basic sanitation	6%
Va	Basic sanitation but no improved water supply	0%
IV	Improved water supply and basic sanitation	28%
IIId	IV and water supply piped to household (no source treatment)	56%
IIIc	IV and water supply piped to household (source treatment)	

Table B.10: Water treatment at point of use in Nicaragua (% of households)

Type of water treatment	Urban[15]	Rural
Boiling	5	1.5
Chlorination	10	40
Filtering	5	1.5

Source: Estimated based on World Bank 2008

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 are therefore applied uniformly to each of the scenarios.

Strukova (2009) presents the estimated number of diarrheal illness cases in Nicaragua based on the ENDESA 2006–2007 (Table B.11). The total number of annual cases was estimated at close to seven million, or 1.2 cases per person.

Table B.11: Estimated annual cases of diarrheal illness in Nicaragua in 2005

	National	Urban	Rural
2-week diarrheal prevalence (children < 5 years)	21.7%	13.2%	17.6%
2-week diarrheal prevalence (population > 5 years)	3.7%	1.2%	1.5%
Annual diarrheal cases in children under 5 (000)	2970	898	1212
Annual diarrheal cases in population > 5 (000)	3778	697	664
Total annual diarrheal cases	6748	1595	1876
Diarrheal cases per person (all population)	1.21	0.51	0.76

Source: Strukova 2009

Estimated cases of diarrheal illness per person per year in Nicaragua are estimated for Scenarios IIIc to VI from the relative risks in Table B.4, the scenario population distribution in Tables B.8–B.9, and the average diarrheal cases per person in Table B.11. Tables B.12–B.13 indicate that cases per person average 0.40 in households with piped water supply and basic sanitation that practice disinfection of drinking water, and 1.2 to 1.3 per year in households that do not have improved water supply, have no basic sanitation and do not practice drinking water disinfection.

Table B.12: Estimated annual cases of diarrheal illness per person in urban Nicaragua

Scenario/ Situation	Description	WITHOUT Point-of Use Disinfection	WITH Point-of-Use Disinfection
VI	No improved water supply and no basic sanitation	1.31	0.69
Vb	Improved water supply and no basic sanitation	0.98	0.52
Va	Basic sanitation but no improved water supply	0.89	0.47
IV	Improved water supply and basic sanitation	0.89	0.47
IIId	IV and water supply piped to household (no source treatment)	0.8	0.42
IIIc	IV and water supply piped to household (source treatment)	0.71	0.42

Table B.13: Estimated annual cases of diarrheal illness per person in rural Nicaragua

Scenario/ Situation	Description	WITHOUT Point-of Use	WITH Point-of-Use

15 For estimates of periurban settlements.

		Disinfection	Disinfection
VI	No improved water supply and no basic sanitation	1.22	0.65
Vb	Improved water supply and no basic sanitation	0.92	0.49
Va	Basic sanitation but no improved water supply	0.83	0.44
IV	Improved water supply and basic sanitation	0.83	0.44
IIId	IV and water supply piped to household (no source treatment)	0.75	0.40
IIIc	IV and water supply piped to household (source treatment)	0.67	0.40

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 wells or boreholes) and sanitation facilities (improved pit latrines 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 1.5 million people with improved sanitation, and one that provides 1.2 million people with an improved water supply both in rural and urban areas.

Using information about incremental service increase and corresponding investment needs from the 2005 Estrategia Sectorial de Agua Potable y Saneamiento (Sectoral Strategy for Drinking Water and Sanitation), annualized per capita investment costs are estimated at about US$12–19 for improved sanitation and US$30–40 for improved water supply. This is based on a ten percent annual discount rate, annual five percent O&M and five percent promotion/water source protection cost, and US$6 in annual sewage cost.[16] The population receiving improved water supply and sanitation is calculated from Tables B8 and B.9. Diarrheal cases averted are calculated from Table B.13. Deaths averted are calculated based on an estimated case fatality rate of 0.3 per 1,000 cases in children under age five, using data presented in Strukova 2009. 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 US$8–14 per case of diarrhea. The mortality costs are calculated based on the Human Capital Approach (HCA) as presented in Strukova 2009. 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, and time saved is valued at 75 percent of the average rural wage (Strukova 2009).

[16] Per capita investment costs represent average costs in South America (WHO/UNICEF 2000). O&M refers to operations and maintenance.

Table B.14: Benefits of reductions in diarrheal morbidity and mortality in rural Nicaragua

	Improved Sanitation Facilities	Improved Water Supply
Population (million) receiving improved sanitation*	0.96	
Population (million) receiving improved water supply**		0.9
Percent reduction in diarrheal illness per person (from Fewtrell and Colford 2004)	32%	25%
Diarrheal cases (million) averted per year	0.3	0.2
Deaths in children averted per year	60	40
Annual health benefits of improved services (US$ million)	4	3
Annual value of time savings from improved services (US$ million)	26	5
Annualized cost of service provision (US$ million)	12	24
Benefit-cost ratio (health benefits only)	0.35	0.1
Marginal cost (million NIO per 1% of WSSH health cost reduction)	26	69
Benefit-cost ratio (health benefits and time savings)	2.6	0.32

Table B.15: Benefits of reductions in diarrheal morbidity and mortality in urban Nicaragua

	Improved Sanitation Facilities	Improved Water Supply
Population (million) receiving improved sanitation*	0.5	
Population (million) receiving improved water supply**		0.2
Percent reduction in diarrheal illness per person (from Fewtrell and Colford 2004)	32%	25%
Diarrheal cases (million) averted per year	0.1	0.07
Deaths in children averted per year	17	12
Annual health benefits of improved services (US$ million)	2	1
Annual value of time savings from improved services (US$ million)	16	2
Annualized cost of service provision (US$ million)	9	10
Benefit-cost ratio (health benefits only)	0.2	0.1
Marginal cost (million NIO per 1% of WSSH health cost reduction)	45	70
Benefit-cost ratio (health benefits and time savings)	1.9	0.3

The data reveal that programs to improve sanitation have a benefit-to-cost ratio greater than 1.0 when the time savings of improved water are included. For water supply program benefit cost ration is less than 1. For water supply/sanitation programs in urban areas the costs are higher and the benefits lower due to lower diarrheal mortality among children under age five and to lower diarrheal prevalence.

Marginal cost[17] would be higher than marginal benefits[18] (health damage reduction) for all four investment programs considered.

[17] Approximated by average cost per one percent of WSSH cost reduction.
[18] Value of one percent of WSSH cost reduction, estimated at about nine million NIO.

Benefit-Cost Analysis of Hygiene Improvements

In many studies, the single most effective hygiene intervention is 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. In their meta-analysis, Fewtrell and Colford (2004) report a mean reduction in diarrheal illness of about 45 percent from hand-washing interventions (Table B.1). About two-thirds of the studies reviewed in the two meta-analysis studies assessed the effect of hand washing on diarrheal illness in children under age five. The meta-analyses do not report the effect of hand washing on diarrheal illness in children under age five versus older children and adults. A pooled analysis of the studies reviewed in the two meta-analyses was therefore undertaken in this report, but no statistically significant difference in diarrheal reduction was found 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.

A benefit-cost analysis of hygiene improvement (hand-washing programs) involves an assessment of several key parameters and outcomes. These are listed in Table B.16. The costs of improved hand washing practices are twofold. 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 the 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 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 2009 for Nicaragua.

Table B.16: 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 starts regular hand-washing)
Program sustainability	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 B.17. The program in Guatemala was national in scope and targeted households with children under age five (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 subsets of the villages (Pinford and Horan 1996). The program in Burkina Faso involved one

city and targeted households with children under age three (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 costs 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 costs 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 a major impact on the overall cost of hygiene programs that aim to achieve substantial reductions in the overall number of cases of diarrheal illness in a country.

The program cost per target household with behavioral change is the most relevant unit cost in Table B.17 for a benefit-cost analysis. This cost can then be compared to the reduction in (and thus the benefits of) diarrheal illness in the target population with behavioral change.

Table B.17: A review of costs and effectiveness of hand-washing programs

	Guatemala	Thailand		Burkina Faso
Target area	National	25 rural villages		One City
Intervention level		"Low"	"High"	
Target population	HH w/children under age 5	All HHs	All HHs	HH w/children under age3
Number of target households	1,570,000	10,000	6,550	38,600
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$)	561,400	5,960	7,715	194,000
Program cost per target household (US$)	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), Pinfold and Horan (1996), and Borghi et al. (2002).

A benefit and cost analysis of rural and urban hand-washing programs is provided for diarrheal reduction in children under age five. 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 caretakers 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 to US$5.0 per targeted household or primary caretaker (US$4.0–US$25.0 per household or primary caretaker with behavior change). This range of program effectiveness and costs is based on the figures in Table B.17. The "high' scenario corresponds to the experience in one city in Burkina Faso. However, it is possible that a national program will benefit from economies of scale and therefore achieve a 20 percent effectiveness at a lower unit cost than US$5.0 per primary caretaker of children under age five. It is therefore possible that the "high" scenario represents a higher bound of program cost. The diarrheal illness baseline data and cost of illness per case of diarrhea and diarrheal mortality are from Strukova (2009). 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 who start regular hand washing or improve hand-washing practices is from Curtis and Cairncross (2003) and Fewtrell and Colford (2004), as presented in Table B.1. Regarding the private cost of hand washing, the

quantity of increased water and soap consumption reflects the assessment of experts in Nicaragua. The rural and urban price of water is communicated by experts from Nicaragua, and the cost of soap is based on a spot survey of retail prices for soap in Nicaragua.

A benefit and cost analysis of rural and urban hand-washing programs is presented in Tables B.18–B.19. Three scenarios are provided for diarrheal reduction in children under age five.

The estimated reduction in annual cases of diarrheal illness is about 0.1 million in children under age five. With morbidity and mortality costs estimated in Strukova 2009, the total program benefit is about US$2 million. The total first year program cost is about US$1 million for the "medium" scenario.

Table B.18: Benefits and costs of a rural hand-washing program

	Rural Households with Children Under Age 5		
	"Low"	"Medium"	"High"
Program Effectiveness			
Program target (million households)*	0.3	0.3	0.3
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 (US$ million)	0.1	0.4	1.7
Private Costs			
Cost of water and hygiene products per year (US$ million)	0.1	0.2	0.2
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	30	45	60
Deaths in children averted per year	9	13	18
Total annual health benefits (US$ million)	0.5	0.8	1.0
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	2.2	1.4	0.6
MEDIUM: If behavioral change lasts 2 years**	3.0	**2.1**	1.0
HIGH: If behavioral change lasts 3 years**	3.4	2.6	1.3
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		10	

* There are about 0.3 million rural children under the age of five in Nicaragua. It is assumed there is one child under five in each household (thus the program target is 0.3 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under five. ** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

Table B.19: Benefits and costs of an urban hand-washing program

	Urban Households with Children Under Age Five		
	"Low"	"Medium"	"High"
Program Effectiveness			
Program target (million households)*	0.3	0.3	0.3
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 (US$ million)	0.1	0.4	1.6
Private Costs			
Cost of water and hygiene products per year (US$ million)	0.1	0.2	0.2
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	30	50	60
Deaths in children averted per year	9	14	19
Total annual health benefits (US$ million)	0.7	1.0	1.4
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	2.9	1.9	0.8
MEDIUM: If behavioral change lasts 2 years**	3.9	2.8	1.3
HIGH: If behavioral change lasts 3 years**	4.5	3.4	1.7
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		7	

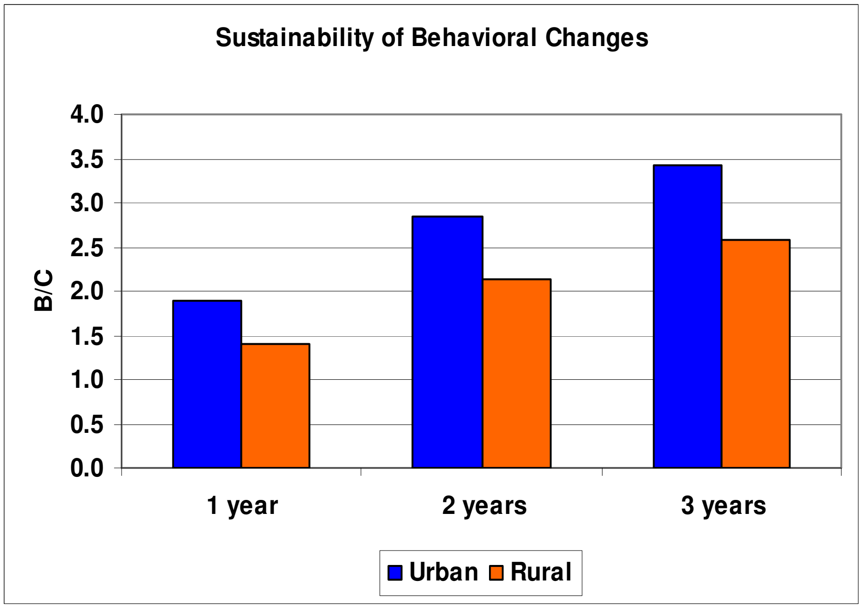
* There are about 0.4 million urban children under the age of five in Nicaragua. It is assumed there is one child under five in each household (thus the program target is 0.4 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under five. ** 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 ranges from 4.5 in the "low" scenario to about 0.6 in the "high" scenario. Benefit-cost ratios are higher for the urban population since medical treatment cost and annual wages are higher in urban areas.

Not only can children under age five benefit from a hand-washing program, but the population over age five can benefit as well. However, these 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 age five.

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, benefit for only one year is clearly a very conservative assumption. If benefits are sustained for two years, the estimated benefit-cost ratios would increase. Note that the benefit-cost ratio does not change for the population over five years of age. This is because of the assumption that behavioral change takes place at no incremental program cost. Figure B.1 presents benefit-cost ratios for children for this target in a program with sustainability of behavioral change lasting from one to three years.

Figure B.1: 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 a 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 take a conservative approach, we did not include this additional benefit while awaiting additional scientific evidence.

Benefit-Cost Analysis of Drinking Water Disinfection

Table B.10 presented data on the share of households in Nicaragua 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. Fewtrell and Colford (2004) report from their meta-analysis that disinfection of drinking water at point of use reduces diarrheal illness by an average of 47 percent in rural areas and 23 percent in urban areas.

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:

$$P_s d + (1-P_s) d(1-r) = d_A \qquad \text{(B.1)}$$

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 0.9 in the rural population

not practicing disinfection, compared to a rural average of 0.8 from Strukova 2009, in urban areas an estimated diarrheal incidence is 0.54 for populations not practicing disinfection, compared to the urban average of 0.51 from Strukova 2009.

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 to 20 percent) have therefore been applied in the cost-benefit analysis. 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 the boiling of drinking water. The private cost of boiling drinking water is estimated at US$5 per year for urban households using commercial fuels and about US$3 for rural households using fuelwood that is collected by the household members. Collection time is estimated at 75 percent of the average wage. The cost of water chlorination is estimated at about US$3 per household based on an average drinking water consumption of 0.75 liters per person per day (Lantagne et al. 2005). The disinfection program benefits are estimated the same way as for hand-washing programs.

In rural areas the disinfection programs are estimated to avert 110,000 to 220,000 cases of diarrhea and 25 to 50 deaths in children per year (Tables B.20 and B.22). The benefit-cost ratio for the central estimate in water boiling programs is 1.9 and for water chlorination is 4.8, corresponding to a 15 percent program response rate with drinking water disinfection sustained for two years. Benefit-cost ratios are lower, but well above one in urban areas. In urban areas the disinfection programs are estimated to avert 70,000 to 130,000 cases of diarrhea and 10 to 25 deaths in children per year. Drinking water chlorination programs both in rural and urban areas have high benefit cost ratios since private program costs are low. Preliminary estimates for the filtration program suggest that the benefits of this program are at the same level as for chlorination, since annual maintenance costs are negligible and the diarrheal reduction rate is at the same level as for chlorination (for background data, see Ramírez 2008).

Table B.20: Benefits and costs of a rural drinking water boiling program

	"Low"	"Medium"	"High"
Program Effectiveness			
Target population – rural population not practicing disinfection (millions)	1.5	1.5	1.5
Target households (millions)	0.3	0.3	0.3
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 (US$ million)	0.1	0.3	1.4
Private Costs			
Cost of boiling drinking water per year (US$ million)*	0.3	0.4	0.5
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	45	65	90
Deaths in children averted per year	<15	<20	25
Total health benefits (US$ million)	0.7	1.1	1.5
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	1.9	1.5	0.7
MEDIUM: If behavioral change lasts 2 years**	2.2	1.9	1.1
HIGH: If behavioral change lasts 3 years**	2.3	2.1	1.4
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		5	

* Estimated based on efficiency of LPG and wood stoves, cost of LPG, fuelwood collection time of 30 minutes per day and 10% of fuelwood 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 B.21: 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%
Program Cost			
Total program cost (US$ million)	0.2	0.2	2.7
Private Costs			
Cost of boiling drinking water per year (US$ million)*	0.2	0.4	0.5
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	30	50	65
Deaths in children averted per year	<10	<10	<15
Total health benefits (US$ million)	0.6	0.9	1.2
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	1.2	0.9	0.4
MEDIUM: If behavioral change lasts 2 years*	1.6	1.2	0.6
HIGH: If behavioral change lasts 3 years*	1.8	1.4	0.8
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		8	

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

Table B.22: Benefits and costs of a rural drinking water chlorination program at the point of use

	"Low"	"Medium"	"High"
Program Effectiveness			
Target households (millions)	0.3	0.3	0.3
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	47%	47%	47%
Program Cost			
Total program cost (US$ million)	2.1	5.3	26.5
Private Costs			
Cost of chlorinating drinking water per year (US$ million)*	0.1	0.1	0.2
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	70	100	130
Deaths in children averted per year	10	20	25
Total health benefits (US$ million)	0.9	1.4	1.9
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	4.5	3.3	1.2
MEDIUM: If behavioral change lasts 2 years**	6.1	4.8	2.0
HIGH: If behavioral change lasts 3 years**	6.9	5.7	2.6
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		2	

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

Table B.23: 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%
Program Cost			
Total program cost (US$ million)	0.2	0.5	2.7
Private Costs			
Cost of chlorinating drinking water per year (US$ million)*	0.15	0.2	0.3
Program Benefits			
Cases of diarrheal illness averted per year (thousands)	30	50	65
Deaths in children averted per year	<10	<10	<15
Total health benefits (US$ million)	0.6	0.9	1.2
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	1.6	1.2	0.4
MEDIUM: If behavioral change lasts 2 years*	2.3	1.8	0.7
HIGH: If behavioral change lasts 3 years*	2.6	2.1	0.9
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		5	

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

Preliminary estimates for the point-of-use filtration program suggest that the benefits of this program are at the same level as for chlorination, since annual maintenance costs are negligible and the diarrheal reduction rate is at the same level as for chlorination (for background data, see Ramírez 2008).

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 are clearly a

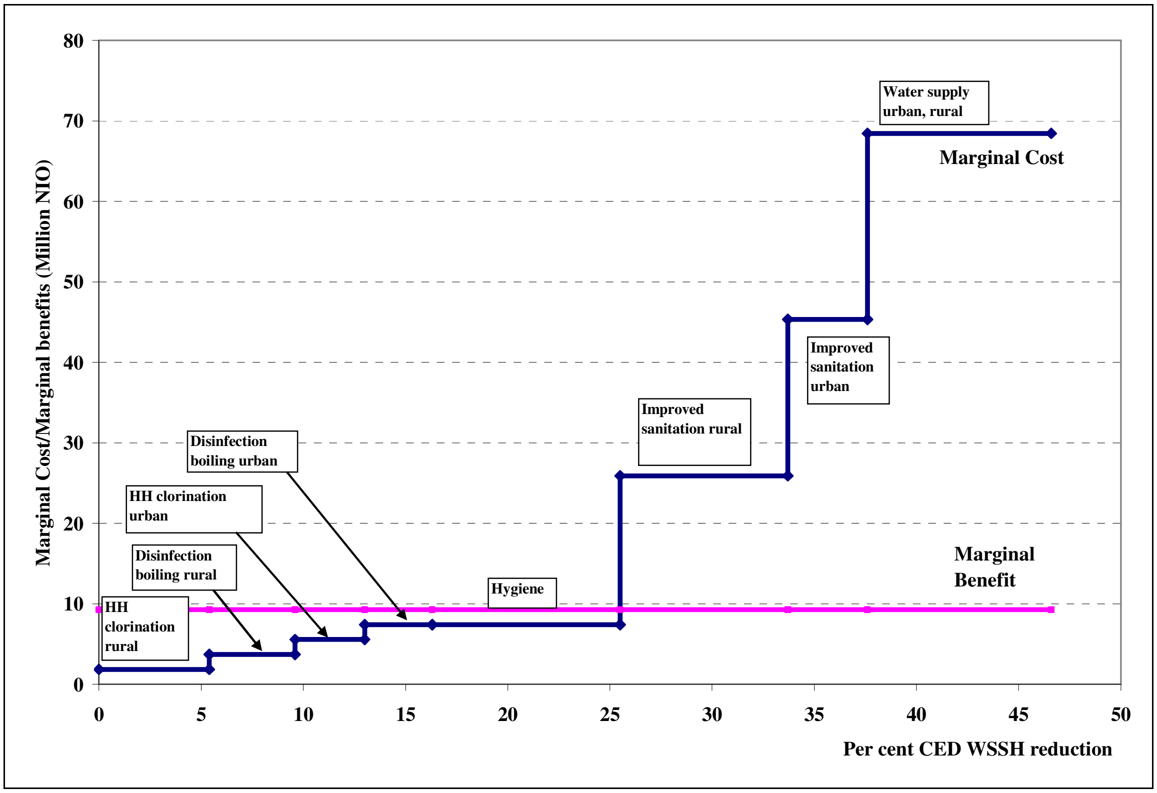
very conservative assumption. If benefits are sustained for three years, the estimated benefit-cost ratios would increase in the same way as for hygiene programs.

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 damage reduction (marginal cost). This is done in Figure B.2. 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 greatest 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 substantial potential to reduce diarrheal illness and mortality, as indicated in Table B.3. However, the challenge is to develop and deliver programs that induce sustained behavioral response at a large scale, while containing program costs at an affordable level.

For sanitation, benefits exceed costs with time-saving benefits taken into account. Finally, the benefits of hand washing among adults are not presented at the graph above. These interventions were estimated to have significantly higher costs than benefits and corresponding benefit-cost ratios lower than one. All interventions that have marginal costs lower than marginal benefits could reduce total WSSH health costs by about 50 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 (less than) 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 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 B.2: Ranking of interventions to reduce WSSH cost in Nicaragua



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 (2009).

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 be most affected 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 (fuelwood, etc.) and coal smoke based on a meta-analysis of available studies. The results are presented in Table B24. 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 age five, 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 groups above age five. This is because most of the studies have concentrated on children under age five. However, Ezzati and Kammen (2002) from a study in Kenya find that the RR for the 5–49 age group is quite similar to the RR for children under age five at various levels of pollution levels.

Table B.24: Relative risks for strong and moderate health outcomes

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

WHO recommends that ventilation level be taken into account while assessing exposure level in the household. Balakrishnan (2004) demonstrated that even with outdoor cooking, the exposure level is substantial. Even when cooking is done outside the house, the resulting indoor levels of

PM and exposure of all family members greatly exceed health guidelines for ambient air. However, resulting PM concentrations are lower than with indoor cooking (Table B.25).

Table B.25: 24-hour exposure concentrations for cooks and noncooks among solid fuel users across kitchen configurations

Type of kitchen	*N*	Mean	Std. error of mean
Cooks			
Enclosed Kitchens			
Enclosed indoor kitchen with partitions	76	520	56
Enclosed indoor kitchen without partitions	73	540	50
Separate enclosed kitchen outside the house	83	439	52
Outdoor kitchen			
Outdoor cooking	70	259*	23
Noncooks			
Enclosed kitchens			
Enclosed indoor kitchen with partitions	232	264	17
Enclosed indoor kitchen without partitions	155	280[a]	17
Separate enclosed kitchen outside the house	264	178	11
Outdoor kitchen			
Outdoor cooking	220	175*	10

*F-statistic significant at $P < 0.05$ as compared to other kitchens.
[a]Significantly different as compared to noncooks in other types of enclosed kitchens.

Source: Balakrishnan (2004)

Table B.25 shows that exposure concentrations are about 50 percent lower for cooks and 30 percent lower for non-cooks. Due to the non-linear character of the concentration-response function, WHO suggests the use of a 0.25 coefficient for the estimation of exposure to account for ventilation for the households with outside kitchens (Desai 2004).

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 B.24 represent averages from many studies, and do not necessarily reflect the pollution exposure situation in households using solid fuels in Nicaragua. Moreover, the pollution load from solid fuels is not uniform across households. Some households use unimproved stoves or open fires while others use improved stoves with chimneys; some households use a combination of solid fuels and clean fuels such as LPG. Substantial numbers of households practice cooking outside the house. 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 purposes of this report, six scenarios were selected that represent six stylized situations commonly found in most developing countries (Table B.26). These stylized situations represent the pollution loads from solid fuel use reasonably well. However, actual pollution exposure can vary substantially in each scenario and can depend on additional factors such as household ventilation practices, housing characteristics, and household behavior.Because data on these factors are not readily available at 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 B.26: Fuels, stove technology and pollution scenarios

Stylized Situation	Stylized Description	Relative Risk
I. Unimproved wood stoves or open fire with kitchen located inside the house	Low energy efficiency. No chimney or ventilation device. Very high indoor pollution load.	Very High
II. Unimproved wood stoves or open fire with kitchen located outside the house	Low energy efficiency. Natural ventilation. Relatively high pollution load.	High
III. 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
IV. Unimproved wood stoves and LPG (or other clean fuel)	Pollution load reduced in proportion to the use of LPG (relative to situation I.).	Medium
V. 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
VI. 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 Prüss 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 B.26. According to ENDESA 2006–2007,[19] about 92 percent of the rural population in Nicaragua relies on fuelwood and charcoal as their main fuel for cooking. In urban areas, about 32 to 38 percent of the population relies on these fuels. There is a total annual fuelwood consumption of 2.6 million tons (Prolenia 2005) A total of nearly 0.6 million households use fuelwood and charcoal as their primary energy for cooking.

Very little information is available in Nicaragua to assign relative risks to each of the stylized situations in Table B.26. While some information is available from Prolenia 2005) and 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 B.27. It is almost exclusively the rural population in Nicaragua that uses solid fuels as its main cooking fuel. Rural and urban population shares are applied in Table B.27. Shares of improved stoves and outdoor kitchens were estimated using Prolenia 2005.

[19] Estimates are slightly different in Censo 2005 and Prolenia 2005.

Table B.27: Base case estimation of scenario-specific relative risks in Nicaragua

Stylized Situations	Rural			Urban		
	Pop. Share	RR for ARI	RR for COPD in Women	Pop. Share	RR for ARI	RR for COPD in Women
I. Unimproved wood stoves or open fire inside	43%	2.8	4.1	8%	2.8	4.1
II. Unimproved wood stoves or open fire outside	44%	1.9	2.6	24%	1.9	2.6
III. Improved wood stoves	3%	1.9	2.6	7%	1.9	2.6
IV. Unimproved stoves and LPG (or other clean fuel)	0%	1.5	2.5	5%	1.5	2.5
V. Improved stoves and LPG (or other clean fuel)	2%	1.0	1.8	5%	1.0	1.8
VI. LPG or other clean fuel	8%	1.0	1.0	76%	1.0	1.0
Weighed average risk of I to VI		2.2	2.0		1.3	1.0

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, several studies from around the world present measurements of particulate exposure from solid fuel use, particularly from cooking. Several results from Latin America are presented in Table B.28. The 24-hour average concentration levels from open fire or traditional stoves are many times higher than urban air quality standards in most countries. 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 B.28, 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 those found in most outdoor urban environments.

Table B.28: Particulate (PM) concentrations from cooking stoves

	Open fire/ Traditional Stove	Improved Stove	LPG	
24-hour $PM_{3.5}$	1,930	330	-	Guatemala. Albalak et al. (2001).
24-hour PM_{10}	1,210	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}	600–1,000	300	50	Mexico. Saatkamp et al. (2000)

Table B.29 provides the results of a study by Ezzati and Kammen (2002) that presents odds ratios for ARI in relation to PM_{10} indoor concentrations levels. A halving of PM_{10} levels from 1,000–2,000 to 500–1,000 $\mu g/m^3$ can correspond to the concentration levels associated with the use of an unimproved stove versus an improved stove. This reduction in concentration levels is associated with a reduction in the odds ratio of about 50 percent for children under age five and 25 percent for the 5–49 age groups. The 50 percent risk reduction has therefore been applied in the base case in Table B.27 for ARI to establish the relative order of magnitude of the RR in situation I and III.

Table B.29: Odds ratios for ARI

PM_{10} (μg/m^3)	Children under age five	Age group 5–49
<200	1.0	1.0
200–500	2.42	3.01
500–1,000	2.15	2.77
1,000–2,000	4.30	3.79
2,000–3,500	4.72	-
2,000–4,000	-	4.49
>3,500	6.73	-
4,000–7,000	-	5.40
>7,000	-	7.93

Source: Ezzati and Kammen (2002).

With regard to 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. However, it should be noted 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 Bogotá 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 a study from Mexico for chronic bronchitis, with an even greater difference in prevalence in individuals with longer life exposure to solid fuel pollution (Pérez-Padilla et al. 1996). In a cost-benefit analysis, a 50 percent "excess" risk reduction in COPD is applied for switching from open fire/traditional stove to an improved stove with chimney or to the transfer of a kitchen outdoors.

Using the parameter values discussed above, the estimated RRs are presented in Table B.27. 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, children under age five and women over age 15 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) provides some evidence of similar ARI risk ratios for children under age five and the 5–49 age group.

The population shares and the relative risk ratios in Table B.27 allow a base case estimation of the health benefits of interventions such as improved ventilation, improved stoves and switching to clean fuels (Table B.26). However, in order to estimate benefit-cost ratios, 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. Moreover, for many households the time savings from less fuelwood collection may be an important benefit of switching to improved stoves or clean fuels. Fuelwood consumption must therefore be estimated for the various stylized situations or scenarios in Table B.27. A first step in estimating the costs of interventions is therefore to consider stove efficiencies.

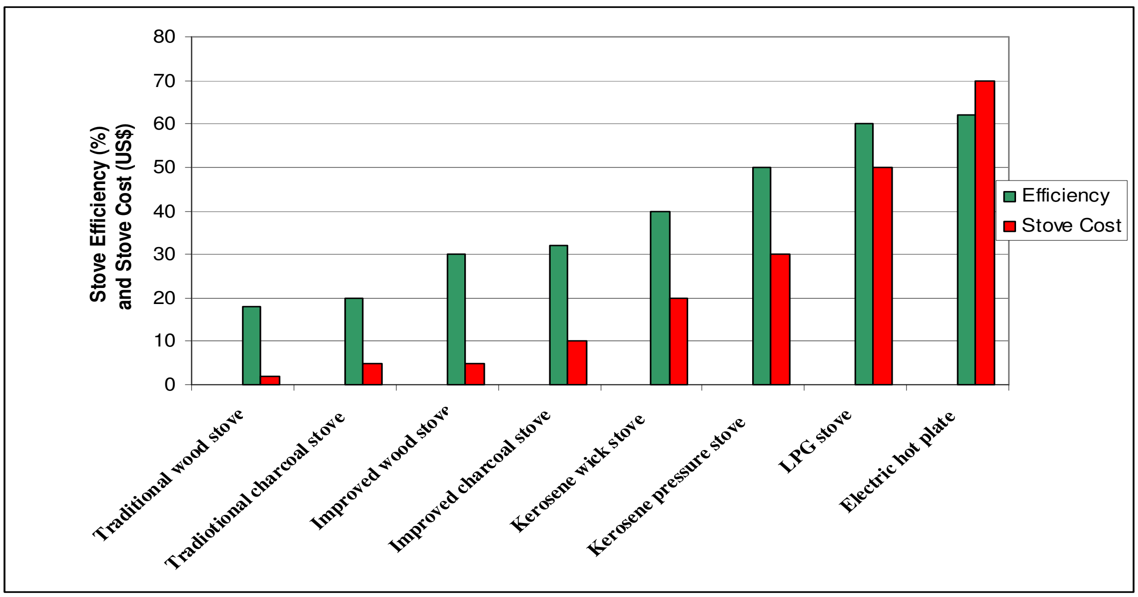
Stove Efficiency

Figure B.3 presents an energy efficiency ladder for stoves and their typical costs; this ladder 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 B.3, improved wood and charcoal stoves are about 50 percent more efficient than traditional stoves, and LPG and electric stoves are twice as efficient than improved wood and charcoal stoves.

A study of stove efficiency in Colombia was conducted by the National University of Colombia's Department of Physics. The results of the study were provided by UPME for the purposes of this report, and are presented in Figure B.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 to 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 "fuelwood," or a traditional open stove, was less than 5 percent for the smaller pots, and 20 percent of the largest pot.

Figure B.3: Stove efficiency and capital costs

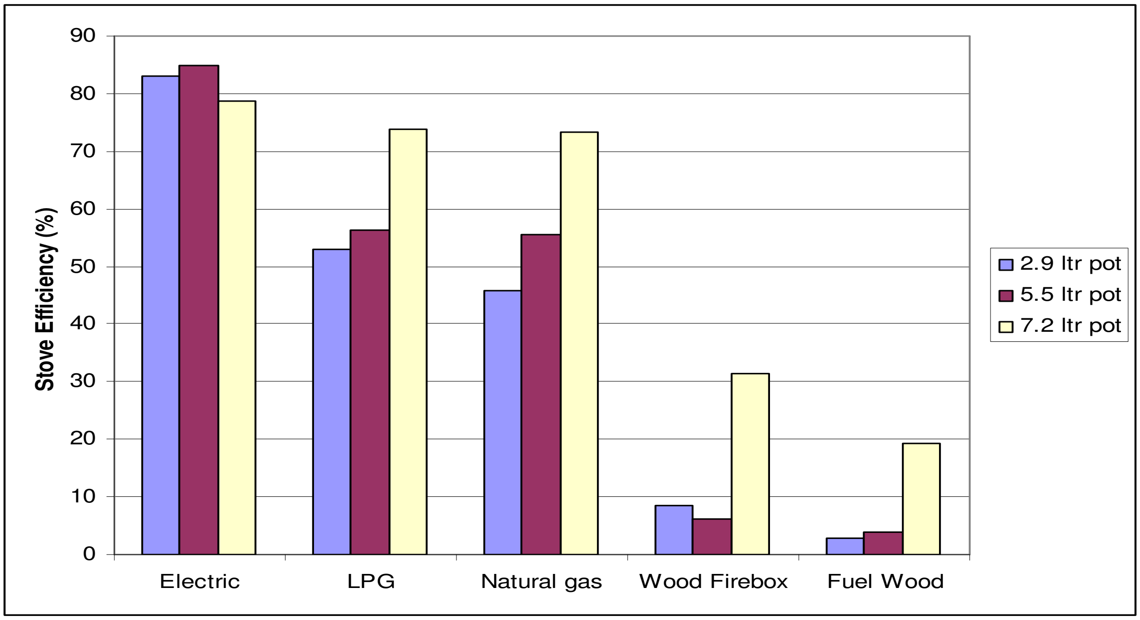


For the most part, the results from this Colombian study are consistent with the generic efficiency ladder in Figure B.4. A notable difference is the wood stove efficiencies for the two smallest pot sizes. However, a study of the *plancha* woodstove in Guatemala found an efficiency of around 10 percent, 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) found an efficiency of 13 to 14 percent for the *plancha* and open fire. Saatkamp et al. (2000) presented estimates of stove efficiencies in Jaracuaro, Mexico, and found that the efficiency of the *lorena* woodstove is not much different than that of 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 there. 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 to 70 percent in 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 (US EPA), 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 Nicaragua was not estimated, but for the purpose of the study was considered in the same range as in Colombia.

Figure B.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 offsprings of these stoves have also been developed in order to improve stove efficiency (Conway et al. 2006).

Fuelwood Consumption

Among households that use fuelwood, there are typically three types of situations. Some households use open fire/traditional woodstoves. Others use improved woodstoves. Finally, some households use fuelwood in combination with LPG or another type of cleaner fuel. Based on data from UPME, it is estimated that the average household that uses fuelwood has a consumption of 3.01 tons per year. However, household consumption, for any given household size, will tend to vary depending on the efficiency of the woodstove and whether or not the household also uses other types of fuels for cooking.

Fuelwood consumption was estimated for different scenarios using the corresponding share of population with each stove type and stove efficiency from Figure B.4. The estimates are presented in Table B.30. These estimates are based on the assumption that the groups of households have on average the same demand for cooking energy.

Table B.30: Estimated annual household consumption of fuelwood

Technology:	**Fuelwood 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 fuelwood consumption in these four cases. Saatkamp et al. (2000) estimates fuelwood 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 five, this implies an annual fuelwood 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 fuelwood consumption in Table B.30.

Cost of Interventions

Estimated annual recurrent costs of switching from fuelwood to commercial energy, or from a combination of fuelwood and LPG to LPG only, are presented in Table B.31. At current prices (in 2008) of energies in Nicaragua, LPG and electricity are found to be very close price options. Using electricity to replace fuelwood is found to be slightly 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 B.31 are likely to represent underestimates of the costs of providing commercial energy to distant rural areas. Currently less than 1 percent of rural households in Nicaragua are already using LPG and other commercial energies, according to ENDESA 2006–2007. Thus, supplying these fuels to other rural households may not be substantially more expensive than to those households already using commercial fuels.

Table B.31: Annual recurrent cost of complete fuel substitution

	Annual Cost Per Household (000 NIO)	
	LPG (25 lb bottles)	**Electricity (urban only)**
Unimproved stoves	2.8	2.5
Improved stoves	2.8	2.5
Unimproved stoves and LPG stoves	1.4	-
Improved stoves and LPG stoves	1.4	-

Table B.32 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 Nicaraguan national statistics.

Table B.32: Baseline parameters for estimating the cost of fuel substitution

Fuelwood	
Average gross energy content of fuelwood (MJ per kg)	19
Average net energy content of fuelwood (MJ per kg)	11
Propane (LPG)	
Average stove efficiency (propane)	55%
Average energy content of propane (Btu/gallon)	92,000
Cost per bottle (25 lb bottles) - NIO	175*
Electricity	
Average stove efficiency	80%
Cost of electricity (NIO./kWh)	2**

Sources: Energy contents of LPG and natural gas are based on data from UPME. Gross and net energy content of fuelwood (gross and net heating content) and stove efficiencies are from a study by the National University of Colombia and provided by UPME; * Instituto Nicaragüense de Energía (INE) 2008; **IPC-BCN, Canasta Básica 2008.

Capital costs and annualized costs of improved stoves and LPG stoves are presented in Table B.33. Capital costs are adapted from Prolenia (2005).[20] While simple improved stoves used in many developing countries are found to be quite inexpensive, as presented in Figure B.2, the type of improved stoves commonly used in Latin America is far more expensive, as indicated in Table B.33. Annualized costs are calculated by using a useful life of 10 years and an annual discount rate of 10 percent.

[20] Some traditional stove prices are presented in Estufas Tradicionales (1995) http://www.gtz.de/de/dokumente/es-estufas-en-imag2-1995.pdf.

Table B.33: Cost Estimates of Improved Wood Stoves and LPG Stoves

	NIO	
Capital Cost:	Low	High
Traditional stove	170	
Improved stove	165	220
LPG stove	315	315
Annualized Cost:		
Traditional stove	26	
Improved stove	40	240

Benefit-Cost Analysis

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

Table B.34: Interventions

Scenarios:	*Description:*
From I (50% HH) to II	From unimproved stove inside to better ventilation
From I (50% HH) to III	From unimproved stove inside to improved stoves
From III to V	From improved stove to LPG
From IV to VI	From unimproved stove and LPG mix to LPG only
From V to VI	From improved stove and LPG mix to LPG only

A benefit-cost analysis is undertaken for the three of five interventions presented in Table B.34. They are based on the stylized situations in Table B.26. The estimated benefits and costs of these interventions are presented in Table B.35 and B.36 for rural and urban areas. Avoided cases of ARI and COPD are estimated from the relative risk ratios in Table B.24 and baseline estimates of annual cases of ARI and COPD. Baseline cases are presented in Strukova (2009). The monetary benefits of avoided cases are calculated from the estimated unit costs of ARI and COPD morbidity and mortality, also presented in Strukova (2009). 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 to US$5.4 million, as in Strukova (2009). The total health benefits of the interventions are greatly influenced by the choice of valuation techniques for adult mortality.

Annual costs of interventions include program cost, stove cost and LPG cost. LPG represents 80 to 90 percent of total cost in interventions (3). Interventions (4) and (5) from Table B.34 are not assessed since LPG costs greatly outweigh all benefits from morbidity and mortality reduction. A

tentative estimate of the program cost of promoting and implementing improved stoves and LPG fuel switching, and sustaining a stove inspection and maintenance program, is also included in Tables B.35 and B.36. Only health benefits are included for the benefit-cost ratio estimation.

Table B.35: Benefits and costs of indoor air pollution control in rural Nicaragua

	Better ventilation from unimproved stove inside	Improved stoves from unimproved stoves inside	LPG from improved stoves
Population receiving intervention (million)	0.5	0.5	0.07
ARI cases averted per year (thousand)	400	400	50
ARI deaths in children averted per year	36	36	5
COPD cases averted per year	110	110	20
COPD deaths averted per year	10	10	<5
Annual health benefits (million NIO)	96	96	14
Program cost (million NIO)	13	13	2
Annualized stove cost, (million NIO)	3	22	4
Annual cost of LPG (million NIO)	0	0	40
Benefit-cost ratio (health benefits only)	6.0	2.7	0.3
Marginal cost (million NIO per 1% of IAP health cost reduction)	1.5	3.2	30

Table B.36: Benefits and costs of indoor air pollution control in urban Nicaragua

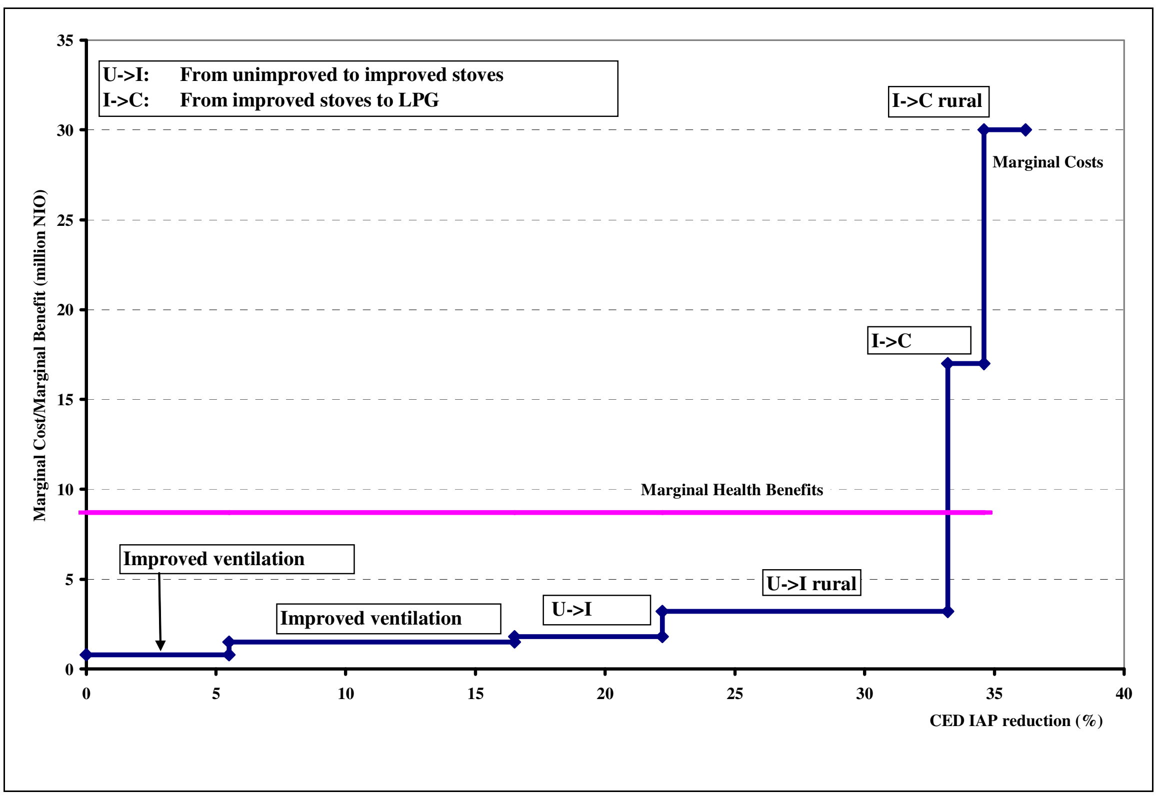
	Better ventilation from unimproved stove inside	Improved stoves from unimproved stoves inside	LPG from improved stove
Population receiving intervention (million)	0.1	0.1	0.03
ARI cases averted per year (thousand)	80	80	20
ARI deaths in children averted per year	10	10	<5
COPD cases averted per year	50	50	15
COPD deaths averted per year	<10	<10	<5
Annual health benefits (million NIO)	50	50	10
Program cost (million NIO)	4	4	1
Annualized stove cost, (million NIO)	1	6	2
Annual cost of LPG (million NIO)	0	0	20
Benefit-cost ratio (health benefits only)	10.6	4.9	0.5
Marginal cost (million NIO per 1% of IAP health cost reduction)	0.8	1.8	17

Improved ventilation and switching from unimproved and improved stoves in individual households is found to have substantially higher benefits than costs (Tables B.35 and B.36). The benefit-cost ratio is estimated at above 3 for all four of these interventions. The benefit-cost ratio is lower than 1 if there is switching to LPG due to high LPG prices. For households with improved stoves, the health benefits alone are not large enough to outweigh the cost of switching to LPG. Although 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.

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),[21] as was done for the water and sanitation programs (Figure B.5). Marginal cost reflects only program cost and private household cost, without taking into account time and fuelwood savings. Marginal benefit is approximated by the value of one percent of indoor air pollution cost reduction, estimated at 9 million NIO. Improved ventilation and household switching from unimproved to improved stoves have the largest reduction in damages in rural areas. This is followed by households switching to LPG alone from improved stoves 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 better ventilation and switching to improved stoves in 43 percent of rural households, and eight percent of urban households; switching to LPG from improved stoves in three percent of rural and one percent of urban households.

Figure B.5: Ranking of interventions for IAP cost reduction in Nicaragua



[21] Approximated by the average cost to implement intervention per one percent of IAP cost reduction.

The analysis presented here supports the unqualified recommendation to shift households that have unimproved stoves to improved ones and to improve ventilation. 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. Therefore, a more detailed analysis needs to be carried out for such changes, looking at specific cases and taking into account other benefits.

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