Evaluation of the costs and benefits of household energy and health interventions at global and regional levels

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Abbreviations

ALRI	acute lower respiratory infection
BCR	benefit–cost ratio (economic return per unit of currency spent)
CBA	cost–benefit analysis
CBR	cost–benefit ratio
CEA	cost–effectiveness analysis
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
g/l	grams per litre
GHG	greenhouse gas
GNI	gross national income
IAP	indoor air pollution
LPG	liquefied petroleum gas
MDG	Millennium Development Goal
MJ	megajoules
NO_2	nitrogen dioxide
NPV	net present value (present value of economic benefits minus costs)
OECD	Organisation for Economic Co-operation and Development
PM	particulate matter
WHO	World Health Organization

Foreword

Worldwide, more than three billion people cook with wood, dung, coal and other solid fuels on open fires or traditional stoves. The resulting indoor air pollution is responsible for more than 1.5 million deaths due to respiratory diseases annually – mostly of young children and their mothers. Effective solutions to reduce levels of indoor air pollution and to improve health do exist. They include cleaner and more efficient fuels, improved stoves that burn solid fuels more efficiently and completely, and better ventilation practices. However, for these solutions to be effective and sustainable in the long-term, they must be accompanied by changes in behaviour.

In addition to preventing death, improving health and reducing illness-related expenditures, household energy interventions have many impacts that, at the household level, improve family livelihoods and, at the population level, stimulate development and contribute to environmental sustainability. These benefits include time savings due to less illness, a reduced need for fuel collection and shorter cooking times. Cost–benefit analysis is a tool that takes into account all the costs and benefits of household energy interventions to reduce indoor air pollution from a societal perspective. It can thus play an important role in guiding public policy-making and investments in household energy interventions.

The World Health Organization (WHO), in collaboration with the Swiss Tropical Institute, has developed a publications package on CBA of household energy and health interventions, consisting of three publications: *Guidelines for conducting cost–benefit analysis of household energy and health interventions* are intended for economists and professionals interested in conducting CBA at the national and subnational levels. WHO has conducted a global CBA based on these guidelines and published the results in *Evaluation of the costs and benefits of household energy and health interventions at global and regional levels*. This technical report is intended for professionals working on household energy, environment and health. Also, a *Summary* provides a synopsis of the key findings for policy-makers in the energy, environment and health sectors at the subnational, national and international levels.

This publication outlines the methods and data sources that form the basis for CBA of household energy and health interventions, and presents the results for eight intervention scenarios of relevance to energy policy in the context of the Millennium Development Goals. It concludes that the health and productivity gains far outweigh the overall cost of interventions. Demonstrating the economic benefits of investments in improving access to cleaner and more efficient household energy practices should contribute to sound policy-making and to overcoming the constraints on implementing household energy interventions.

Executive summary

Cost–benefit analysis (CBA) is a recognized analytical tool for decision-making in the development field, and is used most frequently by public policy-makers in deciding how to allocate public funds between competing projects or programmes. The aim of the present study is to quantify the costs and benefits of selected household energy and health interventions. Results are presented separately for urban and rural populations at the global level and for 11 developing and middle-income subregions of the World Health Organization (WHO).

Interventions were chosen based on their relevance to the voluntary household energy target proposed by the Millennium Project in the context of the Millennium Development Goals (MDGs), also taking into account amenability to a global-level analysis.

Two main intervention approaches were selected:

- reducing exposure through changing from solid fuels to cleaner fuels; and
- reducing exposure through a cleaner-burning and more efficient improved stove.

Costs and benefits are modelled under eight different intervention scenarios, covering three specific interventions (liquefied petroleum gas (LPG), biofuels (ethanol) and a chimneyless "rocket" stove) at two levels of population coverage (to reduce by 2015, by either 50% or 100%, the population not served in 2005). Two alternative scenarios modelled a pro-poor option for halving the population without access to LPG and ethanol, targeting first those with the most polluting and least efficient solid fuels. The base year used in the study is 2005, and the first year of intervention is 2006, giving an intervention period of 10 years until the end of 2015.

The benefit–cost ratio is calculated as the annual average economic benefits of the intervention divided by the annual average economic net costs of the intervention. Net intervention costs are calculated as absolute intervention costs minus cost savings as a result of fuel-efficiency gains. Economic benefits include reduced health expenditure due to less illness, the value of assumed productivity gains due to less illness and death, time savings due to less time spent on fuel collection and cooking, and environmental impacts at the local and global level. Local environmental effects are assessed as fewer trees cut down, whereas the global environmental effects considered are lower emissions of carbon dioxide (CO_2) and methane (CH_4). Some intervention benefits were not modelled, such as health effects where the current evidence for indoor air pollution as a cause is inconclusive; improved food safety; better quality of the home environment; as well as additional environmental impacts such as improved soil fertility and reductions in emissions of other greenhouse gases.

Given the global and regional nature of the analysis, sources of appropriate cost and impact data were identified to apply to these levels. Country-level data were assessed for relevance at global and regional levels, and compared with other available evidence to make a judgement on the appropriate value for each input variable. Prices of goods available internationally were adjusted for insurance and freight, using an average price multiplier available for the 11 WHO subregions.

In presenting the results, this study focuses on the 50% coverage scenarios for LPG and improved-stove interventions. Given the time horizon, 50% coverage scenarios are more realistic than 100% coverage scenarios, and biofuels, while representing an important cleaner fuel option for the future, are currently not widely used as household fuels.

In general, the results show favourable benefit–cost ratios: for some scenarios and regions, net intervention costs turned out to be negative. In reducing by half the population without access to LPG, the total economic benefits amount to roughly US$ 90 billion per year compared to net intervention costs of only US$ 13 billion. A pro-poor approach to reduce the population without access to LPG generates US$ 102 billion in economic benefits, with a price tag of US$ 15 billion. The improved-stove scenario (50% reduction of those using traditional stoves) generates US$ 104 billion in economic benefits, and at the same time has a negative net intervention cost of US$ 34 billion. In other words, the net present annual value is US$ 138 billion. For all scenarios modelled, the net intervention costs were found to be higher for rural populations, as the urban population already purchases a higher proportion of their fuel, thus giving a greater cost saving when switching to an alternative fuel.

Economic benefits also varied considerably between urban and rural areas. This holds particularly true for time savings due to the higher proportion of the rural population that collects rather than purchases their fuels. In all three scenarios, the majority of the urban benefits accrue to WPR-B,[1] while the rural benefits are more evenly distributed among other WHO subregions (e.g. AMR-B and SEAR-D). The contributors to overall economic benefits at global level for the LPG 50% scenario are the following: time savings (48.6%), health-related productivity (44.5%), environmental benefits (6.7%), and health-care savings (0.2%). For the improved stove 50% scenario, time savings (84.3%) and health-related productivity (13.5%) represent the major economic benefits, followed by environmental benefits (2.2%), and health-care savings (< 0.1%).

The summary results presented in the table opposite bear witness to considerable variations in cost–benefit ratios between scenarios and WHO subregions, ranging from a negative ratio (i.e. net costs are negative) to a positive value of 136 for EMR-B (improved stove in urban setting). The majority of the results are cost-beneficial, i.e. the benefit–cost ratio is either negative or ranges from 1.0 to 10. An important exception is the WPR-B region which has even more favourable ratios. Only the LPG pro-poor scenario leads to a higher net cost than benefit, and it does so only in the urban setting of two regions (SEAR-B and AMR-D). The results for ethanol, on the other hand, are less favourable than those for LPG, given the assumption of higher fuel cost used for ethanol.

The large variation in results between WHO subregions is the result of differences in regional characteristics and the resulting data and assumptions, such as type of solid fuel used, economic value of time and intervention costs. A higher benefit–cost ratio can be explained both by a smaller denominator (net cost) and a larger numerator (benefit), where the former has a relatively greater impact on the benefit–cost ratio than on the latter. Consequently, the divergence in benefit–cost ratios between urban and rural areas can be largely attributed to the different ways in which fuel cost savings and time savings influence the benefit–cost calculation (fuel savings are subtracted from the intervention cost in the denominator, while time savings are added to the economic benefits in the numerator).

Sensitivity analysis was performed to evaluate the impact of changes in assumptions on results and conclusions. Twelve different sensitivity analyses were run, based on changing key variables. In fact, the benefit–cost ratios showed a high amount of sensitivity, i.e. they varied substantially with changes in the underlying assumptions. However, within the range of optimistic and pessimistic alternatives tested, the base-case results turn out to be relatively robust. Therefore, the overall conclusions of the study appear realistic. However, the sensitivity analyses highlight the high level of uncertainty in some of the variables included in the model, thus pointing to the need for further study and analysis.

In conclusion, the present study shows that, using a simplified model applied at global and regional levels, it is potentially cost-beneficial and, in some cases, cost-saving to invest in household energy and health interventions. Under the assumptions of the model, improved stoves lead to the greatest overall economic benefits. Improved stoves can potentially be provided at a negative net intervention cost, especially in urban settings where the

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[1] WHO distinguishes between the following geographical regions: African Region (AFR); Region of the Americas (AMR); Eastern Mediterranean Region (EMR); European Region (EUR); South-East Asia Region (SEAR); Western Pacific Region (WPR). WHO also differentiates between the following mortality strata: very low child, very low adult (A); low child, low adult (B); low child, high adult (C); high child, high adult (D); high child, very high adult (E).

Benefit–cost ratios for selected scenarios (US$ return per US$ 1 invested)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario II (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	26.5	3.7	3.3	3.2	Neg	Neg
AFR-E	Neg	6.2	12.7	6.9	Neg	Neg
AMR-B	14.3	3.8	6.9	3.7	Neg	Neg
AMR-D	Neg	1.8	0.9	3.6	Neg	Neg
EMR-B	4.9	4.2	4.9	4.3	136.1	89.9
EMR-D	Neg	2.2	16.1	2.1	Neg	Neg
EUR-B	Neg	3.0	Neg	2.9	Neg	Neg
EUR-C	Neg	3.4	Neg	3.1	Neg	Neg
SEAR-B	Neg	2.7	0.2	3.4	Neg	Neg
SEAR-D	2.6	1.5	1.4	1.8	Neg	Neg
WPR-B	27.0	21.2	68.5	14.6	Neg	Neg
World (non-A)	**22.3**	**3.2**	**15.1**	**3.7**	**Neg**	**Neg**
World (non-A)	**6.9**		**6.7**		**Neg**	

Neg, a negative ratio means that intervention cost savings exceed intervention costs.

LPG, liquefied petroleum gas.

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

majority of the population already pays for their fuel. LPG and biofuel interventions also generate large economic benefits in relation to the net intervention costs. These results should help promote household energy and health interventions nationally and internationally. Demonstrating the economic benefits of investments in improving access to cleaner and more efficient household energy should contribute both to sound decision-making for development and to overcoming the constraints in the implementation of household energy interventions.

1. Introduction

Economic analysis involves explicit and quantitative comparison of the costs and consequences of different interventions, enabling conclusions to be drawn about the relative efficiency of these interventions. There are principally two types of economic evaluation: cost–benefit analysis (CBA) and cost–effectiveness analysis (CEA). The major difference between CBA and CEA is the unit of measure of the intervention outcome. In the field of health evaluation, CEA measures the benefits of health interventions in health units, either as numbers of cases or deaths averted, or in terms of generic health units, which is referred to as cost–utility analysis. In 2004, WHO published a global cost–effectiveness analysis which presented the cost per disability-adjusted life year (DALY) averted, of reducing population exposure to indoor air pollution (Mehta & Shahpar, 2004).

In valuing only the health benefits of reducing exposure to indoor air pollution, CEA potentially undervalues the societal benefit of these interventions. The goal of CBA is to identify whether the economic benefits of an intervention exceed its economic costs. A positive net social benefit indicates that an intervention is worthwhile. However, as public funds are limited, some ranking of the alternatives is necessary to enable the interventions that have the highest return and/or bring the greatest benefit to the target populations to be chosen. Therefore, one primary output of a CBA is the cost–benefit ratio, which shows the factor by which economic benefits exceed economic costs, covering the entire period of the intervention and its major impacts.[1] Alternatively, the net present value (NPV) shows the amount by which net present benefits exceed net present costs.

This study estimates the costs and benefits of selected household energy and health interventions, implemented at different levels of assumed coverage. This is the first such global study in relation to household energy interventions, although some context-specific studies have been published, such as an economic analysis of improved stoves (Habermehl, 1999; Smith, 1998; Hughes et al., 2001). This study follows closely the recently elaborated WHO guidelines for the cost–benefit analysis of household energy and health interventions (Hutton & Rehfuess, 2006).

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[1] In fact, given that the cost–benefit ratio traditionally presents the economic benefit per unit of currency spent on an intervention, it is more relevant to talk about the benefit–cost ratio (BCR).

2. Methods

2.1 Cost–benefit framework

The present study adopted a general benefit–cost framework for household energy and health interventions (Hutton & Rehfuess, 2006). Given that the aim of the present study is to identify the costs and benefits of reducing exposure to indoor air pollution at the WHO subregional and global levels, the intervention options and evaluation methods were defined to meet this aim. For some variables, data available at the country level were used in the model to reflect a likely value for the subregion to which a particular country belongs. However, the results presented in this study do not reflect precise cost–benefit estimates at country level. Further applications of the model, using more detailed country-level data, would therefore give a better indication of the cost–benefit implications of investing in modern fuels or improved stoves at the national or subnational levels. This section describes and justifies the methods chosen for the study.

2.2 Interventions modelled

Interventions were chosen based on their relevance to the voluntary household energy target proposed by the Millennium Project in the context of the Millennium Development Goals (MDG), also taking into account amenability for a global-level analysis. The Millennium Project highlights the role of modern cooking fuels as a prerequisite for development, and calls on countries to adopt the target "by 2015, to reduce the number of people without effective access to modern cooking fuels by 50 per cent, and make improved cook stoves widely available" (United Nations Millennium Project, 2005). The existing MDG indicator 29 "proportion of population using solid fuels" can be used to assess progress towards this voluntary target.[1] Furthermore, from the health and development perspectives, it is desirable for more of the world's population to use efficient and modern cooking fuels. Therefore, the scenario of complete (100%) access is also modelled.

Intervention options are essentially based on two main improvements (see Box 1):

- Reducing exposure through changing from solid fuels to liquefied petroleum gas (LPG) or biofuels (including purchase of an LPG or biofuel stove). This study refers to the latter option as "ethanol", or "ethanol and other processed biofuels".
- Reducing exposure through a cleaner burning and more efficient improved stove that produces lower levels of indoor air pollution.

Therefore, the focus of this study is on modifications to the source of pollution, as opposed to altering the living environment and changing user behaviour, which are alternative interventions for reducing exposure to indoor air pollution (Bruce et al., 2006). Based on current evidence, cleaner fuels and improved stoves are likely to lead to the highest reductions in exposure to indoor air pollution and are most easily applicable across different continents and settings. In contrast, experience with implementing interventions that improve ventilation or influence user behaviour is limited. Moreover, these solutions are highly specific to local climatic and cultural circumstances and therefore difficult to scale up. Finally, more so than do the other interventions, changes to fuel and stoves not only impact on exposure to indoor air pollution and on health but also contribute to overall development.

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[1] http://millenniumindicators.un.org/unsd/mi/mi_goals.asp

BOX 1

What is a "biofuel" and an "improved stove"?

What is a biofuel?

A biofuel is any processed fuel in gas or liquid form that derives from biomass, especially plant biomass and treated municipal and industrial wastes. A longer list of possible biofuel sources includes wood, wood waste, wood liquors, peat, railway sleepers, wood sludge, plant oils, spent sulfite liquors, agricultural waste, straw, tyres, fish oils, sludge waste, waste alcohol, municipal solid waste, landfill gases, other waste, and ethanol blended into motor gasoline. Ethanol and methanol are two well-known and widely used biofuels.

What is an improved stove?

While the term "improved" stove suggests a degree of homogeneity in improved stoves, there is in fact a wide range of improved stoves with different physical characteristics and performance (MacCarty & Still, 2005). For the purposes of global modelling, it is easier to select one or a few stoves with similar characteristics, namely that they:

- reduce indoor air pollution levels;
- lead to greater fuel-use efficiency; and
- have the potential to reduce average cooking times.

Households that obtain an improved stove are assumed to switch away completely from their previous – traditional – stove and to continue using the same fuel they were using previously. Although it is likely that some households would continue to use their traditional stove or open fire for certain tasks, data are lacking on the exact practices of households in different countries and settings.

Costs and benefits are modelled under eight different intervention scenarios,[1] shown in Table 1. The results are presented at the WHO subregional level for 11 developing and middle-income regions (i.e. non-A subregions). Country classification is provided by subregion in Annex Table A1 and on the WHO-CHOICE web site.[2]

Table 1. Intervention scenarios modelled

Intervention	**Reduction in lack of access (percentage of population without access)**		
	50%	**50% pro-poor**	**100%**
Liquefied petroleum gas	I	IV	VI
Biofuel	II	V	VII
Improved stove	III		VIII

In a first assessment of 50% scenarios, the intervention converts equal proportions of each group of users of different solid fuels to using a cleaner fuel (scenarios I and II) or improved stove (intervention III). In a second assessment a pro-poor approach is adopted, thus targeting first those who are using the most polluting and least efficient solid fuels (first dung and crop residues, second firewood, third charcoal and finally coal) (scenarios IV and V). While from a practical (implementation) perspective a pro-poor approach faces considerable challenges, from a hypothetical (policy) perspective it is important to understand what the potential costs and benefits of adopting this approach would be. All intervention options are also modelled under 100% coverage (scenarios VI, VII and VIII).

For scenarios II, V and VII, ethanol was selected as a representative biofuel. Ethanol, usually obtained from the residues from sugar production, is the most common biofuel and its production has been steadily increasing since the 1980s. It is used as an alternative to diesel for running cars in many countries throughout the world (IEA, 2004). However, ethanol is largely equivalent to methanol, and the results for these interventions could equally apply to methanol. In a sensitivity analysis, methanol was modelled, substituting values where evidence exists for differences between the two biofuels, such as market price and fuel efficiency. The lack of clear evidence means that other differences, such as greater toxicity of methanol, could not be reflected.

This study did not model other cleaner fuels, such as kerosene or paraffin, as intervention options, due to the difficulty in taking a clear health position on these alternatives. In favour of promoting a switch to kerosene or paraffin is the fact that these fuels reduce levels of indoor air pollution and the associated risk of respiratory disease among chil-

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[1] The following eight scenarios are modelled:
I. 50% of population to LPG;
II. 50% of population to biofuels (ethanol);
III. 50% of population to improved stove;
IV. 50% of population to LPG pro-poor;
V. 50% of population to biofuels pro-poor (ethanol);
VI. 100% of population to LPG;
VII. 100% of population to biofuels (ethanol);
VIII. 100% of population to improved stove.

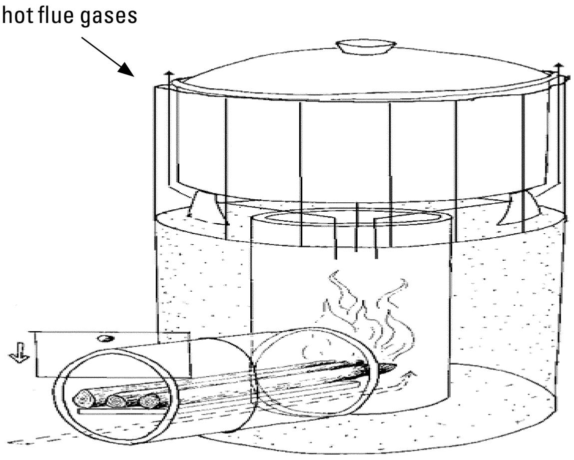
[2] http://www3.who.int/whosis/cea/region/region.cfm?path=evidence,cea,cea_regions&language=english

dren and women. Furthermore, these fuels have potential for further expansion, given their current widespread use and availability. At the same time, there is mounting evidence on the health hazards related to the unsafe use of kerosene and paraffin, in particular burns (Mabrouk et al., 2000; Laloe, 2002; Ahuja & Bhattacharya, 2002; Maghsoudi et al., 2006), poisonings (Abu-Ekteish, 2002; Basu et al., 2005; Hamid et al., 2005) and other unintentional injuries to children, as well as suicides. Calls for a Global Clean Cooking Fuel Initiative therefore place kerosene below LPG/natural gas/electricity on the energy ladder (Goldemberg et al., 2004). Although the positive health impacts of switching from biomass fuels to kerosene or paraffin are likely to exceed the negative consequences, the preference for achieving the 2015 target would be to increase coverage through the use of cleaner and safe modern fuels. Consequently, this study treated kerosene and paraffin as "neutral" fuels. In other words, any population currently using these fuels was classified as having access to cleaner fuels, but the interventions modelled in this study did not actively promote an increase in the number of people using these fuels.

Due to data constraints and the complexities of attempting to reflect different stove options in different parts of the world, it was decided to assume a single improved stove as the intervention for scenarios III and VIII. A chimneyless "rocket" stove (see Diagram 1) was chosen as a relatively cheap but functional improved stove that is widely used in Latin America, Africa and parts of Asia (Still et al., in press).[1] As there are hundreds of different stove models and distinct features for local cooking preferences, this approach is certainly an oversimplification. The features of simpler and cheaper stove models available in Africa as well as of the more sophisticated and more costly stove models in use in Latin America provide the basis for the sensitivity analysis.

Due to the large quantity of results produced by the model, the results section focuses on scenarios I, III and IV, which cover the 50% coverage LPG and LPG pro-poor as well as improved stove interventions. Given the time horizon, 50% coverage scenarios are more realistic than 100% coverage scenarios. Biofuels, while representing an important cleaner-fuel option for the future, are currently not widely used as household fuels. Annex B presents the full results for the five remaining interventions.

Diagram 1. A simplified illustration of the rocket stove



2.3 Time horizon and population targeted

The base year is 2005, and the first year of intervention is 2006, giving an intervention period of 10 years until the end of 2015. All input data are based on the latest data available, adjusted to reflect these start and end dates, and, where necessary, predictions for the next 10 years. Most intervention costs and benefits are immediate or short-term in nature and are measured in terms of the target coverage in the 10-year period 2005–2015; on the other hand, the economic impacts related to the lagged health benefits of reduced COPD and lung cancer are discounted to 2005 values, and only for the population affected during the intervention period.

Population coverage targets refer to the world's population at the end of the year 2015, using UN Population Division data on expected population growth by country.[2] The fuel and stove coverage of additions to the population (population growth) are assumed to be equal to the starting coverage levels in 2005. Table 2 presents the proportion of rural and urban households using different solid fuels and traditional stoves, by WHO subregion. The data are based on the reporting of MDG indicator 29 (Rehfuess et al., 2006) and the various underlying sources, and reflect 2003 coverage. It was not considered appropriate to adjust these coverage figures to the year 2005, given the lack of

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[1] http://www.efn.org/~apro/AT/atrocketpage.html.

[2] http://www.un.org/esa/population/unpop.htm.

Table 2. Percentage of households using solid fuels and traditional stoves

WHO subregion	Solid fuel								Traditional stove	
	Coal/lignite		Charcoal		Firewood		Dung and agricultural residues			
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
AFR-D	2.8	0.6	16.2	4.0	28.1	41.0	31.5	49.5	92.0	98.6
AFR-E	8.8	1.6	15.1	15.0	24.6	57.9	4.4	12.1	86.6	94.3
AMR-B	0.7	3.2	0.5	2.1	3.0	46.5	0.6	0.8	91.6	75.4
AMR-D	9.6	0.1	11.7	2.2	0.7	66.8	2.8	6.2	99.8	98.0
EMR-B	0.7	0.7	0.0	0.0	0.1	0.1	18.6	51.1	89.2	89.2
EMR-D	0.4	0.5	0.5	1.1	20.8	47.8	1.2	8.8	95.3	97.5
EUR-B	0.4	0.4	0.1	0.1	4.6	31.7	0.7	1.7	36.5	13.7
EUR-C	0.9	1.1	0.2	0.4	4.9	6.0	0.2	0.0	12.4	0.9
SEAR-B	0.4	0.0	25.7	0.3	0.0	85.4	0.0	0.0	96.0	90.3
SEAR-D	3.5	1.2	7.2	1.3	16.2	71.1	1.4	16.1	95.0	93.8
WPR-B	7.1	3.3	12.4	14.3	14.6	44.5	1.2	4.6	97.8	97.6

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Sources: for 49 countries, from World Health Survey 2003; for 33 countries, from other available sources; for the remaining 36 developing and middle-income countries, estimates based on modelled data.

reliable data on rates of change over this period. This approach risks overstating the cost estimates for achieving the 2015 targets, given that the percentage of households using solid fuels and traditional stoves in 2005 is likely to be lower than the 2003 figures used.

The fuel-use figures presented in Table 2 also require some interpretation. It should be noted that in reality households often use more than one type of cooking fuel, resulting in a large range of fuel combinations (e.g. Sinton et al., 2004). This study reflects the main cooking fuel type for each household, based on the data sources cited in Table 2.

Given that some variables (intervention coverage, use of time, average household size, population growth, and total population) can vary considerably between rural and urban areas, a rural/urban distinction is maintained throughout the analysis, including benefit–cost ratios. Furthermore, given that the incidence and economic impact of diseases related to exposure to indoor air pollution will vary between different age groups, a distinction is made between four major age groups throughout the analysis (0–4 years, 5–14 years, 15–29 years and 30+ years). Given that input data for some costs and benefits are estimated at the household level, population size was converted to number of households using an average household size, by WHO subregion. This is likely to be a conservative estimate, as poorer, solid-fuel-using households tend to have higher fertility rates than better off, cleaner-fuel-using households. The subregional household size estimates presented in Table 3 are based on weighted average country-level estimates, and were calculated for rural and urban populations separately.

All costs and benefits are estimated on an annual basis, and relate to the achievement of the voluntary MDG target in 2015. Therefore, assuming a gradual scaling up of the interventions, the costs and benefits presented would not be realized in full until 2015. For the purposes of the cost–benefit analysis, this approach is simpler than any attempt to model a gradual scaling up of the interventions. For estimates of the actual costs and benefits relating to small improvements in coverage, intermediate outputs of the model (such as cost per household reached) would have to be used.

Table 3. Average household size, by WHO subregion

WHO subregion	Average number of persons per household	
	Urban	Rural
AFR-D	5.11	5.45
AFR-E	3.83	4.92
AMR-B	4.17	4.69
AMR-D	5.30	5.13
EMR-B	5.96	6.41
EMR-D	5.93	5.95
EUR-B	4.00	4.59
EUR-C	2.88	2.89
SEAR-B	4.54	4.52
SEAR-D	4.60	5.02
WPR-B	4.23	4.58

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Source: UN Statistics Division.

2.4 Costs and benefits included

As stated in the WHO cost–benefit guidelines for household energy and health interventions (Hutton & Rehfuess, 2006), costs and benefits are many and diverse. A key step in the analysis is the selection of which costs and benefits to include or exclude. Those selected depend on the perspective of the research. CBA is traditionally undertaken from a societal perspective, and should therefore include all important economic costs and benefits arising from an intervention (Sugden & Williams, 1978). Table 4 summarizes the costs and impacts modelled, and their time horizon.

In the identification of key intervention costs, the guidelines distinguish between investment costs and recurrent costs. For the interventions being modelled in this study, major investments include the cost of the stoves and their installation, and programme costs which are assumed to be borne by the government or a donor (e.g. advertising, dissemination, education, financing/credit programmes). The major recurrent costs are fuel costs. Maintenance costs are assumed to be zero, given that the rocket stove has a relatively short average length of useful life of 3 years and requires no external maintenance, but must be cleaned daily by the user. Section 2.5 describes the methods to estimate intervention costs.

In terms of economic benefits, the WHO cost–benefit guidelines distinguish between eight categories of impact:[1]

1. health effects;
2. health expenditure related to health effects;
3. health-related income effects;
4. time impact;
5. household environment;

Table 4. Overview of costs and impacts, and time horizon of modelled impacts

Variable	Immediate cost or impact	Delayed cost or impact[a]
Intervention costs	Stove purchase cost and house alterations (investment), fuel recurrent costs, programme costs	NA
Health benefits and health care cost savings	ALRI	COPD Lung cancer
Productivity gains due to morbidity	Related to ALRI	Related to COPD and lung cancer
Value of deaths averted	NA	Related to ALRI for children,[b] and to COPD and lung cancer for adults > 30 years
Time savings	Fuel-collection time and cooking time	NA
Environmental benefits	Local and global environmental benefits[c]	NA

NA, not applicable; ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease.

[a] Costs and impacts are discounted at a rate of 3% by the number of years into the future when they are predicted to occur.

[b] The economic impact of preventing ALRI is delayed because income-earning life is assumed to start at the age of 15 years.

[c] The environmental benefits can also be indirect and long-term, but only short-term impacts are included.

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[1] Intervention effects are termed “impact” and not “benefit” because an intervention may result in negative as well as positive economic consequences.

6. fuel and equipment savings;
7. local-level environmental impacts; and
8. global-level environmental impacts.

This study includes all these categories of impact except impacts on the household environment (e.g. impact of improved lighting). These are difficult to quantify at the global level and are more relevant to switching to electricity as a source of household fuel than to the fuels modelled in this study. Category 6 – fuel and equipment savings – are not classified as a benefit in this study, and are instead deducted from intervention costs to estimate "net" intervention costs. Sections 2.6–2.10 describe the methods used to estimate intervention benefits.

It should be noted, however, that several types of benefit, which would add to the general profitability of the interventions modelled, have not been included in the present study. These include, for example, other health impacts, such as reduced incidence of burns, tuberculosis, cataract, asthma (Smith et al., 2004) and improved food safety and nutrition which affects malnutrition (WHO, 2006). Household energy interventions are also likely to reduce health risks related to fuel collection, such as snake bites, dehydration, overloading/backache, physical stress and violence. Furthermore, interventions are expected to decrease child labour (collecting biomass) and thereby to enhance school attendance, and to increase safety for children and improve working conditions for their mothers in a more comfortable kitchen environment. Additional benefits at the level of the local environment include higher soil fertility (on the one hand by preserving trees which function to protect agricultural land against natural forces, on the other hand through feeding dung back into the natural soil-fertility cycle rather than burning it as fuel) and reduced destruction of habitats and biodiversity. Additional benefits to the global environment include reduced emissions of greenhouse gases, such as black carbon or nitrogen dioxide (NO_2), that are not considered in the present analysis.

2.5 Intervention costs

2.5.1 Overview

Intervention costs were estimated as net costs based on the costs of the improved coverage option minus the costs saved by switching away from solid fuels and traditional stoves. For example, coal, charcoal and wood (where purchased) are paid for by households; therefore, these costs are assumed to be avoided when the switch to LPG or ethanol is made. Also, improved stoves can be more fuel-efficient, which translates into changes in solid-fuel consumption. In the case of decreased wood use, potential savings to households are valued using two parallel methods:

- for those assumed to pay for their supply of wood, the resulting financial saving is captured in the net intervention cost calculation;
- for those assumed to collect their supply of wood, the resulting time saving is captured under time impacts and valued accordingly as an intervention benefit (see section 2.9).

The direct costs of cleaner fuels are calculated based on estimated annual consumption and unit prices per fuel type. The programme cost data available from Mehta & Shahpar (2004) assume a 50% increase in access to improved stoves and cleaner fuels. For the 100% coverage scenario, the cost per household reached is assumed to be the same as for the 50% scenario. Economies of scale in expanding programme coverage are likely to exist up to a given threshold (perhaps 80%, 90% or even 95%), but expanding coverage to the remaining population is likely to cost considerably more per unit. In the absence of evidence on behaviour of unit costs above 50% coverage, programme costs per household reached were assumed to remain constant with an increase in coverage.

Overall intervention costs are calculated by multiplying the cost per household reached by the difference between the current coverage and the target coverage under the different scenarios. Costs are presented in United States dollars (US$), as recommended by the Disease Control Priorities in Developing Countries project (Jamison et al., 2006), and for the year 2005. International dollars (I$) are not used in this study, given that the measure of interest to donors or national governments is the actual monetary cost of the selected interventions, and the actual economic benefit resulting from the programme, such as productivity gains or health-care costs saved. These figures can be translated into I$, if the non-traded component of cost is identified and adjusted by a measure of purchasing power for each WHO subregion compared to the purchasing power of the US$.

2.5.2 Stove costs

Stove costs are estimated for LPG/biofuel stoves and improved biomass stoves. These costs include annualized stove purchase costs based on an initial price and expected length of useful life, and annual programme costs (Mehta & Shahpar, 2004).

Stove prices are based on both internationally- and nationally-obtained prices. Where reliable national-level price data are available and are likely to reflect subregional prices, these are used instead of the international prices. As discussed above, the chimneyless rocket stove was chosen as the intervention for this global study[1] (see section 2.2). For internationally traded stoves, this approach may overstate the eventual intervention cost at the national and subnational levels, given that the international market price of a stove is higher than the expected cost of a locally-made stove. However, it is also important to note the probable price/quality trade-off in improved stoves. Assuming internationally traded stoves are higher in price but of a better quality, this would have an equalizing effect on the annualized cost of the stove due to an expected longer length of useful life and cheaper daily operating costs of higher quality stoves (i.e. fuel efficiency). In order to convert international prices ("free on board" (f.o.b.), which reflects stove prices on the international market) to prices of the same goods in the country of import ("cost, insurance and freight"(c.i.f.)), a price adjustment is used (Tan-Torres Edejer et al., 2003; Hutton & Baltussen, 2005). This adjustment is made using the WHO price multiplier, which reflects the average difference in price between medical goods before and after they enter a country.[2] The price-multiplier values for each WHO subregion are presented in Annex Table A1.2.

Prices for the rocket stove are available for several countries, and range from US$ 6 to US$ 8, with a reported expected length of useful life of 1–4 years (Still et al., 2006).[3] Therefore, the analysis assumes a purchase cost of US$ 6 and an average 3-year life giving a range of US$ 7.34 to US$ 8.71 after importation (see Annex Table A2.1). Given that lower prices have been reported for other improved stoves, in particular in Africa, the sensitivity analysis tests a lower bound cost of US$ 2 (Brinkmann & Klingshirn, 2005 – for Southern Africa). On the other hand, improved stoves in other parts of the world, such as Latin America, have different features for local cooking preferences, in particular a chimney, often making the stove considerably more costly. Therefore, in the sensitivity analysis an upper bound cost of US$ 80 is used.

For the LPG stove, the assumptions on global prices and length of useful life made in Mehta & Shahpar (2004) were used, namely, US$ 60 for the burner, US$ 50 for the cylinder, and a 10-year life. Where LPG stove prices (including burner and cylinder) were available for subregions, these were used instead: AFR US$ 58; AMR US$ 60; SEAR-B and WPR-B US$ 100; SEAR-D US$ 46 (see Annex Table A2.2 for country-level data and Annex Table A2.3 for values used for each subregion). In other words, the higher international price of US$ 110 was applied mainly in middle-income subregions. After adjustment, LPG stove costs varied from US$ 57.50 (SEAR-D) to US$ 151.80 (EMR-D).

The costs of biofuel stoves vary depending on the type of stove: the international price of a pressure stove varies from approximately US$ 55 to US$ 100. However, due to the limitations of pressure stoves, it is likely that the main future potential for biofuel stoves will be evaporative stoves.[4] Again, these costs vary depending on the size, manufacturing quality and materials used. The international price of a two-burner stainless steel evaporative stove with a 10-year life and 60% efficiency is predicted to be US$ 35, which is the value used in the analysis (US$ 25–US$ 50 in the sensitivity analysis). Stove costs are presented for biofuel stoves in Annex Table A2.4. After adjustment, the costs ranged from US$ 42.84 (EUR-B) to US$ 50.79 (AFR-D).

Programme costs for stove dissemination are based on WHO data (Johns et al., 2003), as presented by Mehta & Shahpar (2004), and are adjusted to 2005 values by a subregional gross domestic product (GDP) price deflator.[5] While considerable variations are evident between WHO subregions in programme costs per household, these are mainly

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[1] This study could not collect detailed information on the availability and prices of stove types in different countries and regions, nor is comprehensive information available on stove performance (e.g. GHG emissions, fuel efficiency and cooking time).

[2] The WHO price multiplier is a good and available proxy for the difference between international prices (f.o.b.) and prices following importation (c.i.f.) of stoves.

[3] http://www.efn.org/~apro/AT/atrocketpage.html.

[4] Personal communication: The Stokes Consulting Group, Florida, USA.

[5] A GDP price deflator is defined as the price index that measures the change in the price level of GDP to real output. It allows comparison of the real economic value of goods and services in different time periods.

due to the specificities of the country representing each region. For example, EMR-B (represented by Lebanon) had programme costs per household of US$ 31.6 compared to US$ 1.2 in AFR-D. Such a difference is partly explainable by the differences in unit labour costs between subregions (as labour costs make up the majority of programme costs) and the difference in the number of improved stoves disseminated (economies of scale). While it is unclear whether Lebanon is truly representative of the EMR-B subregion, there is concern that these high programme costs would inflate cost figures beyond likely costs, and thus disadvantage EMR-B in the cost–benefit analysis. Therefore, it was considered appropriate to adjust the figures from Mehta & Shahpar (2004) for EMR-B for both cleaner fuel and improved stove programmes downwards to the programme costs of the next most expensive subregion, i.e. AMR-B. Annex Table A2.5 presents the annual stove-improvement and fuel-change programme costs per household; these range from US$ 0.22 (SEAR-B) to US$ 1.26 (AMR-B, EMR-B) for fuel changes, and from US$ 0.02 (WPR-B) to US$ 3.85 (AMR-B, EMR-B) for improved stoves.

2.5.3 Fuel use

The information on average fuel consumption of households for cooking purposes was collected from several sources. For 2002, the UN Statistics Division (Energy Section) reports data on total household consumption of *solid* fuels (charcoal, firewood and several types of coal and coke) for selected countries. For countries for which data were available, the average consumption per household was calculated by dividing the total household consumption by the number of households estimated to use each fuel source as the primary cooking fuel. The results of this exercise are presented in Annex Tables A3.1, A3.2 and A3.3 for coal, charcoal and firewood, respectively. However, these data show major (and unlikely) variation between countries, which cannot be fully explained by the location or income of a country (e.g. temperate countries where more fuel is used in space-heating). Therefore, these results were consolidated and a judgement made on realistic fuel-consumption figures for each subregion (as detailed in Annex Tables A4.1, A4.2 and A4.3). This study assumes that any reduction in the burning of biomass for cooking purposes as a result of the interventions leads to an overall reduction in biomass burning, i.e. the biomass is not instead burned in the field (for example, crop residue burning or tree clearance).

Very few sources were found in the literature that could be used to estimate fuel consumption for *cleaner* fuels. Smith et al. (2005) present total residential LPG consumption in the 10 largest developing countries (representing roughly 70% of the developing world in 2001). Based on this publication, Annex Table A4.4 presents the estimated consumption in litres per household per day. Data for Nigeria and Bangladesh, however, are disregarded, as the reported consumption is unrealistically low. In the absence of data from an African country, the value from Viet Nam is used. For WPR-B the average of China and the Philippines is used. The values vary from 0.285 (AFR-D and AFR-E) to 1.087 litres (EMR-B) per household per day. These values are in part validated by a large-scale country study that presents data on monthly household consumption of LPG in India (D'sa & Narasimba Murthy, 2003), obtained from Indian National Sentinel Surveillance data in 1999–2000. The average LPG consumption for urban and rural areas in India was 13.3 kg and 11.3 kg per month, respectively. This gives an average LPG use of roughly 0.436 litres per day for urban areas and 0.370 litres per day for rural areas, which is slightly less than the value for India of 0.530 litres per day presented in Table A4.4.

For biofuels, no published studies were found. However, the factor difference in energy content of LPG and ethanol can be used to estimate the probable consumption of biofuels. According to D'sa & Narasimba Murthy (2003), LPG provides 45.5 MJ of energy per litre, compared with 25.0 MJ of energy per litre for ethanol. Hence, the predicted biofuel use is a factor of 1.82 (i.e. 45.5/25) higher than LPG, giving 0.794 litres per day for urban areas and 0.674 litres per day for rural areas. In the absence of any other studies that present comprehensive and good-quality data, these figures were applied globally.[1]

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[1] The considerable differences in daily consumption between modern fuels and traditional fuels is supported by a literature review that showed that the average Indian household uses 222 kg per month of biomass fuels compared to 7.8 litres (6.5 kg) of cleaner fuels (Dutta, 2005).

2.5.4 Fuel prices

Fuel prices also vary by country and region. For the purposes of estimating representative fuel prices for each WHO subregion, fuels are categorized into those that are principally traded on the international market and for which international prices are available (LPG, biofuels and coal) and those which are only traded domestically (charcoal and firewood). Agricultural waste products (crop residues and dung) are assumed to be collected or made by each household.[1] On the other hand, some traded fuels are also produced and sold locally, at a lower price than the international price. For this global study, it was too complex a task to compile fuel-source data for every country. Therefore, international prices are applied in the model, and lower local price assumptions tested in the sensitivity analysis.

For LPG and ethanol, a global market price is identified, and adjusted for assumed domestic transport costs, approximated by WHO subregional price multipliers (Annex Table A1.2). LPG prices on the world market vary between suppliers and over time. For example, in the second quarter of 2005, the price is reported to vary from US$ 373 per tonne of butane for UK North Sea Contract LPG to US$ 438 per tonne of butane in the Japanese spot market (World LP Gas Association, 2006). In converting from cost per tonne to cost per litre, a gravity of 0.504 and 0.582 is applied for propane and butane, respectively (i.e. 0.582 kg of butane equals 1 litre). At the highest world price for butane, this gives a price per litre of US$ 0.255, which is used in the analysis. For all fuels, the WHO price multiplier was applied to adjust for cost, insurance and freight, and unit prices in rural areas were adjusted upwards by 20% to account for additional transport costs and likely lower level of competition among suppliers. The resulting prices vary from US$ 0.31 to US$ 0.37 per litre in urban areas and from US$ 0.38 to US$ 0.44 for rural areas (see Annex Table A5.1). In the sensitivity analysis, a low price reflects recent years, where the LPG price was as little as half the 2005 prices, and a high price reflects possible future trends of rising oil prices, where LPG may be sold at a 50% higher price than in 2005.

The prices of ethanol and other processed biofuels were also found to vary. The International Energy Agency reports that ethanol prices can fluctuate dramatically, and estimates three cost scenarios: a "near-term base case" of US$ 0.36, a "near-term best industry case" of US$ 0.29 per litre, and a "future costs post-2010" case based on potential technical advances of US$ 0.19 (IEA, 2004). Production costs of US$ 0.23 per litre have been reported for Brazil (IEA, 2004). In the analysis, the near-term base case of US$ 0.36 per litre was used. According to international market data, the international price of methanol is lower than that of ethanol. The value used in the sensitivity analysis is US$ 0.25 per litre. Annex Tables A5.2 and A5.3 show the price information for ethanol and methanol, respectively.

For coal, international prices were sought from the World Bank commodity price web site, and were found to vary depending on the source of coal. Australian export coal was priced at US$ 51 per metric tonne in 2005, giving US$ 0.051 per kg. The WHO price multiplier was then applied to adjust for cost, insurance and freight, giving between US$ 0.062 and US$ 0.074 per kg depending on the subregion; urban and rural prices were assumed to be the same (Annex Table A5.4). Although coal is produced domestically in most developing countries where there is significant household use, there was insufficient data to include nationally- or regionally-representative costs. However, based on the available data, domestic coal costs correspond roughly to those of traded coal. For example, the prices quoted above correspond to coal prices from Bangladesh of between US$ 0.064 and US$ 0.086 per kg in urban areas, and from US$ 0.059 to US$ 0.071 per kg in rural areas.[2]

For purchased biomass fuels assumed not to be traded internationally (i.e. firewood and charcoal), local prices were collected from both the international literature[3] and through selected country contacts of the study team (in Bangladesh, Burkina Faso, China, India, Niger, Rwanda, Tajikistan and

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[1] However, it should be noted that local markets for agricultural residues do exist in urban as well as rural areas (e.g. in Bangladesh, local prices have been found for straw, sawdust, paddy husk and leaves). Due to lack of evidence on the proportion of agricultural residues purchased, and the likelihood that the majority is not purchased, the assumption of 100% self-collection is justifiable.

[2] Shakil Ahmed, personal communication, January 2006.

[3] A review of documented information was conducted on the Internet and through bibliographic databases in economic, environmental and forestry journals, covering JSTOR (Journal Storage – a Journal Scholarly Archive), Forestry Ecology and Management, Journal of Environmental Economics and Ecological Economics, Agriculture Ecosystem and Environment. Key word searches were performed in English, French and Spanish, combining fuel types with cost and price search terms.

the United Republic of Tanzania). Annex Table A5.5 shows the country-level data that were used to inform the subregional price inputs in Annex Tables A5.6 and A5.7 for charcoal and wood, respectively. All households were assumed to purchase rather than produce their charcoal. 75% of urban dwellers and 25% of rural dwellers were assumed to purchase fuel wood.[1]

2.5.5 Stove efficiency

In analysing fuel consumption and related costs, it is important to account for stove efficiency, as switching from open fires and traditional stoves to improved stoves can reduce the quantity of fuel burnt due to less heat loss. As noted above (under stove costs), this study uses the rocket stove, which is a relatively cheap but efficient stove available on the international market. Studies have compared the fuel-use characteristics of selected improved stoves with open fires, in terms of boiling water, simmering water, and total predicted cooking time for a typical meal. These data show that the rocket stove reduces fuel use by 34% (224 g/l to 147 g/l), compared to an open fire (Still et al., in press). Other studies have also demonstrated that improved stoves lead to fuel savings. For example, stoves disseminated by China's National Improved Stove Programme were shown to be 5 percentage points more efficient than traditional stoves (an increase of 56%, from 9% efficiency to 14% efficiency) (Smith et al., 1993; Sinton et al., 2004). Furthermore, an assessment of GTZ's Programme for Biomass Energy Conservation in Southern Africa showed that 45% of households using improved stoves reported fuel savings (Brinkmann & Klingshirn, 2005). In the absence of other quantitative data, the fuel-saving rate (stove efficiency gain) applied in the CBA is 34% for the improved stove. In the sensitivity analysis, a range of 20–60% efficiency gain is used (Kelta, 2006).

In addition to the design of the stove, it should be noted that fuel savings can be achieved through a number of other household energy conservation measures. These include (but are not limited to) cutting and splitting of firewood, use of dry firewood, and preparative cooking activities (for example, soaking maize and beans). These measures are often incorporated in stove-dissemination programmes.

2.6 Health benefits of reductions in exposure to indoor air pollution

There are many possible adverse health impacts of exposure to indoor air pollution from solid-fuel combustion, including acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease (COPD), lung cancer, tuberculosis, asthma, cataracts, adverse pregnancy outcomes and low birth weight, cancer of the upper aerodigestive tract, interstitial lung disease and ischaemic heart disease (Smith et al., 2004; Valent et al., 2004; Viegi et al., 2004; Girod & King, 2005; Bruce et al., 2006; Ceylan et al., 2006). However, to date there is a varying degree of scientific evidence for links between the risk factor and the diseases listed above; furthermore, the strength of scientific evidence varies according to population group (men, women and children). According to Smith et al. (2004), there is strong scientific evidence that indoor air pollution is a major risk factor for ALRI among children younger than 5 years old, and for COPD and lung cancer among women above 30 years of age (lung cancer only in relation to coal use). For men, the evidence is only moderate for COPD and lung cancer. For other diseases and risk factors, the evidence is not yet sufficient for burden-of-disease calculation.

Given the levels of evidence for the diseases and risk factors stated above, it is prudent to include health impacts of exposure to indoor air pollution where the evidence is strong and relative risk calculations have been made.[2] Therefore, the health outcomes included in WHO's comparative risk assessment – ALRI (children under 5 years), COPD (women and men over 30 years) and lung cancer (women and men over 30 years) – serve as the basis for modelling the health impacts of interventions in this analysis (Smith et al., 2004). For these diseases and population groups, incidence and deaths were calculated for each WHO subregion for the year 2002, including the IAP-attributable fraction of incidence and deaths (WHO, 2006 and underlying unpub-

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[1] It is not unrealistic to expect some urban dwellers to collect rather than purchase wood for cooking, as they may either live in a wooded area or travel to collect their wood supply. One study from rural areas of five Southern African countries found that 41/220 (18.6%) of the households surveyed paid for their fuel wood either with money (36/41) or other goods (5/41) (Brinkmann & Klingshirn, 2005).

[2] Note, however, that the resulting analysis gives only conservative estimates of the health benefits and the health and other economic losses averted due to reduced exposure to IAP.

lished data based on methodology in WHO, 2002; Smith et al., 2004). For COPD and lung cancer, the WHO estimates are especially uncertain for less developed countries, given the low reporting and diagnosis of these diseases, and it is likely the rates are higher than those used in this study (Celli et al., 2003; Halbert et al., 2003; Kim et al., 2005). The WHO incidence and mortality estimates for 2002 are adjusted to 2005 by applying the disease rates per 100 000 population to the 2005 population figures. The figures for cases of disease and deaths due to exposure to indoor air pollution are presented in Annex Tables A6.1, A6.2, and A6.3 for ALRI, COPD and lung cancer, respectively.

The health impacts of the cleaner-fuel interventions are relatively easy to model. It is assumed that switching to LPG or biofuels eliminates exposure to indoor air pollution and thus reduces the risk of diseases attributable to such pollution to the baseline risk in the population (Smith et al., 2004). An increased incidence of ALRI and COPD is associated with all types of solid fuels, whereas the scientific evidence available to date shows an increased risk for lung cancer only in association with coal use (Smith et al., 2004).

The time period when the health impacts of an intervention become manifest also has to be defined. Removing or reducing sources of exposure to IAP will have an immediate impact on acute diseases, such as ALRI. In other words, the cleaner-fuel interventions will reduce to zero the number of IAP-attributable ALRI from the first year that such an intervention is put into place. For the two adult-health outcomes, COPD and lung cancer, a distinction must be made between cases that are *completely* prevented and individuals who continue to have a highly elevated risk due to many years of exposure to indoor air pollution or, in the case of COPD, who have already developed the early stages of the disease. In the case of the former, removing or reducing sources of exposure to IAP will delay negative health impacts with a time lag. This time lag of development of COPD and lung cancer is determined as the difference between the average age at exposure and average age at disease onset, which is approximately 20 years. In the case of the latter, it is difficult to establish to what extent the risk (of the onset of disease or disease progression) is reduced in an individual who has been exposed to IAP over the course of many years and then stops being exposed, compared to an individual who continues to be exposed. Little information on this is available for IAP exposure itself, but, given the similarity with tobacco smoking, the risk profiles for ex-smokers may provide a reasonable indication of risk profiles for individuals formerly exposed to IAP. A study from the National Cancer Institute shows that the relative risk for lung cancer during the 5 years following stopping smoking is still high but, as cessation continues, it declines steeply (Shopland, 1996; Calverley & Walker, 2003). Forty years after giving up smoking, among those who had smoked fewer than 10 cigarettes per day, the risk approximated that of never smokers. However, due to their lagged and highly uncertain impact, it was decided not to include the benefits of reduced exposure on individuals with an already elevated risk of COPD and lung cancer in the study. Therefore, only the number of completely prevented cases of COPD and lung cancer was quantified, and formed the basis for any subsequent economic valuation.

The health impacts of improved stoves are more difficult to model, given the lack of clear evidence in this regard. Small particles are likely to be the most harmful pollutants contained in indoor smoke, and several studies have demonstrated reductions in indoor levels of PM_{10} (particles with an aerodynamic diameter of less than 10 micrometres) of 80% or more where improved stoves are used (Ahmed, 2005; Bruce et al., 2006). However, these reductions are not a good predictor of the health impact, given possible changes in behaviour (e.g. a less smoky environment may lead to more time spent indoors) and the non-linear relationship between exposure and relative risk of health impact (the dose–response relationship is unknown for exposures to PM_{10} levels above 50 µg per m^3). Few studies are available that link the use of a particular cooking technology to health risks over time. A retrospective cohort study from China with follow-up of more than 20 000 subjects from 1976 to 1992 compared the COPD risk of individuals living in coal-using households with and without a chimney (Chapman et al., 2005). A reduction in risk was noted in households with a chimney, with an overall relative risk of COPD of 0.58 in men and 0.75 in women. Relative risks decreased with time with a clear risk reduction becoming apparent about 10 years after installation of a chimney. In a related study, Lan et al. (2002) compared the risk of lung cancer in the two groups of households and found risk ratios of 0.59 in men and 0.54 in women. Levels of indoor air pollution in households with a chimney were less than 35% of those in households without a chimney. Although the rocket stove used in this study has no chimney, it is reported to burn cleanly and to reduce personal exposure levels (Still et al., in press).

In summary, quantitative evidence for the health impacts of improved stoves is limited and it is not clear whether findings from an intervention implemented in one country can easily be applied to other countries. The most scientific approach is thus to use reductions in personal exposure as a proxy for likely reductions in adverse health outcomes. The average used in this study is based on three published studies that have compared personal exposures of children living in homes using open fires with those of children living in homes using improved stoves, giving a 35% reduction in personal exposure (Naeher et al., 2000; Bruce et al., 2002; Bruce et al., 2004).[1] Therefore, the model used a 35% reduction in all three health impacts associated with indoor air pollution for the improved stove intervention, and a range of 10–60% to be tested in the sensitivity analysis. As this estimate is based on reductions in children's personal exposure rather than in the cook's personal exposure, the assumption is likely to be conservative.

2.7 Health-care cost savings related to health impact

2.7.1 Overview

Health-care costs are measured separately for the health system (outpatient consultations or inpatient admissions) and for the patient (health-care seeking, home treatment or traditional practitioner). Patient charges for health care (e.g. outpatient fee, admission charge and charge per procedure) are included only under health-system costs to avoid double-counting of these costs. A cost per case of each disease averted is calculated, based on data for each WHO subregion (e.g. treatment seeking, unit costs of care) and severity of each disease. For those seeking modern health care, an outpatient cost is estimated for a typical case plus a hospitalization cost for a proportion of patients who are admitted to hospital. All cost estimates refer to primary facilities. For those not seeking modern health care, a general cost assumption is made (see below).

Health-system unit costs of outpatient and inpatient care were extracted from a study that estimated health-care unit costs at subregional level (Mulligan et al., 2005), which were adjusted to 2005 prices. These costs are presented in Annex Table A7.1. Costs of specific treatments related to the diseases modelled are not included in these costs, and therefore additional costs of medicines and procedures are estimated separately and included, based on health-seeking behaviour rates, assumed protocol compliance by doctors and assumed adherence to treatment regime by patients. The prices of drugs are derived from the *International Drug Price Indicator Guide 2005* and represent the median international price adjusted by the WHO subregional price multipliers. An average length of inpatient stay for patients hospitalized was assumed for each disease and level of severity (see Annex Table A7.2).

In estimating health-care cost savings, the question arises of whether the analysis should try to estimate actual cost savings (according to procedures currently applied in each setting), or cost savings that would arise if the health provider was following the correct treatment guidelines. Given lack of data on the former, and the questionability of including cost savings from lack of or incorrect diagnoses or treatments, it is considered best to estimate health-care costs by assuming that appropriate guidelines for a given setting are followed. However, to avoid the overestimation of expected cost savings, actual or expected treatment-seeking rates are used for each disease (discussed below).

2.7.2 Acute lower respiratory infections

Pneumonia among children under 5 years of age can be classified as non-severe, severe and very severe, with an estimated distribution of cases among the three categories of 86%, 12% and 2%,

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[1] Personal exposures were usually found to have been reduced proportionately less than area pollution levels. For example, in Kenya, where stove hoods with flues achieved a 75% reduction in 24-hour mean kitchen concentrations of $PM_{3.5}$ and carbon monoxide (CO), the woman's mean 24-hour CO exposure was reduced by only 35% (Bruce et al., 2002). Similar results were found for exposure of children in a study of improved wood stoves in Guatemala (Bruce et al., 2004: 30% reduction in child's personal exposure in homes with improved chimney stove relative to that in homes with an open fire). We are aware of only one study that has used direct measurement of personal exposure to particulates in very young children (Naeher et al., 2000). This study, also in Guatemala, reported mean 10- to 12-hour (daytime) $PM_{2.5}$ levels for children aged less than 15 months of 279 mg/m^3 (±SD of 19.5) for the open fire and 170 mg/m^3 (±SD of 154) for the plancha stove, a 40% reduction.

respectively (Stenberg et al., in press). Treatment guidelines provided by WHO are summarized in Annex Table A7.5.

To estimate the cost of commodities provided during case management of pneumonia by a health worker who follows the Integrated Management of Childhood Illness (IMCI) guidelines, the following inputs were assumed: amoxicillin for 3 days (5 days in high HIV burden settings), six doses of paracetamol and, in 10% of cases, salbutamol given three times a day for 3 days. Based on median international prices, this costs between US$ 0.14 and US$ 0.17 per case, and is higher at between US$ 0.23 and US$ 0.27 per case in settings with a high incidence of HIV as the treatment should be longer (see drug and procedural costs in Annex Table A7.6). The analysis classifies the two subregions located in sub-Saharan Africa (AFR-D and AFR-E) as having a high HIV burden. One outpatient visit per person seeking care is assumed. The proportion of people seeking care varies by region from 33% to 77% (WHO sources; Gouws et al., 2004; see Annex Table A7.4).

Similarly, for estimating the cost of treating severe and very severe cases at the first referral level, Annex Table A7.5 shows the list of commodities expected to be used in treating an average patient under 5 years old. For a child with severe pneumonia, the material cost per inpatient admission for the antibiotics, salbutamol (for 50% of cases) and chest X-ray varies from US$ 7.3 to US$ 16.3 per case plus an outpatient visit cost. For a child with very severe pneumonia the material cost varies from US$ 13.6 to US$ 22.6 per case. 20% of patients seeking care are assumed to be hospitalized, with an average length of stay of 3 days for severe and 5 days for very severe pneumonia.

2.7.3 Chronic obstructive pulmonary disease

COPD is an irreversible chronic disease, classified according to the stage of progression. Treatment costs saved include only the cases that are completely prevented, where future costs saved are discounted to the base time period. For cases that are halted at their stage of progression, costs saved are not included as the available evidence does not permit an estimate to be made of the numbers of cases (see section 2.6). This assumption will lead to conservative estimates of the benefits of household energy and health interventions.

A person diagnosed with COPD will continue to live for many years and, as a result, the costs saved for each case of COPD prevented will be considerable. Each case of COPD prevented results in 8.79 equivalent discounted years of life saved. This figure is based on life expectancy of people with and without COPD, and a linear survival curve from baseline (100% alive, mild disease) to 20 years (0% alive) (Cuvelier & Muir, 2001; Gross, 2005; Mannino et al., 2006).

In terms of treatment, the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines for treatment were updated in 2005 (GOLD, 2005). For developing countries, however, there are several major limitations to the implementation of these guidelines, which were developed mostly by physicians in industrialized countries (Chan-Yeung et al., 2004). Ait-Khaled et al. (2001) published developing country-specific guidelines for COPD treatment, which vary according to disease severity (see drug and procedural costs in Annex Table A7.6):

- For mild COPD, the patient is received on an outpatient basis (one visit assumed) and should start a course of bronchodilator-inhaled salbutamol (average 4 puffs a day). International prices were found to vary between US$ 3 and US$ 10 for 200 doses, with a mean of US$ 7. This gives a drug cost per patient per year of US$ 51.1, which is adjusted to each subregion by the WHO price multiplier.
- For moderate COPD, patients are assumed to be hospitalized for 8 days (Masa et al., 2004) and given inhaled ipratropium bromide (average 12 puffs/day) to take regularly, and salbutamol (as above for mild COPD). In 2003, ipratropium bromide cost 125 rupees in India (US$ 2.78). Together, these drug treatments cost US$ 116.8 per year in 2003 prices, which are adjusted to 2005 prices using a GDP price deflator, and to each subregion by the WHO price multiplier.
- For severe COPD the same treatment is given as for moderate cases, and theophylline at low dosage added in patients where the illness is not well controlled. This gives an all-inclusive drug treatment cost of US$ 126.2 per year, which is adjusted to each subregion by the WHO price multiplier. Other treatments such as use of an oxygen ventilator or pulmonary rehabilitation are not included, given their even more limited application and lack of unit-cost data per patient.

Given the high costs of these treatments and lack of availability of drugs, which reduce patient health-seeking behaviour to well below 100%, it is assumed that one fifth (20%) of people with COPD seek care at the different stages of their disease.[1] The distribution of COPD between mild, moderate and severe cases, and number of days of illness per person with COPD, are presented in Annex Table A7.3 (BOLD Initiative, unpublished data, 2006).[2]

2.7.4 Lung cancer

As for COPD, the treatment costs saved for lung cancer include only the cases that are prevented, with future costs saved discounted to the base time period. Most cases of lung cancer in the developing world are diagnosed at a late stage, and palliative care to improve quality of life and to extend marginally the length of life is often the only treatment option. (Boyar & Raftopoulos, 2005). Palliative care consists of managing the symptoms of disease as well as managing the effects of treatment where radiotherapy and/or chemotherapy are given. Palliative care is always symptom-based and the three most common symptoms among lung cancer patients are pain, dyspnoea, and cough. Different treatment options are available. For example, cancer pain can be treated with medicines – non-opioids, opioids, or adjuvant analgesics – and some non-medical therapies.

All the costs of lung-cancer palliation and treatment are assumed to occur within a 1-year time period, given that the average survival time for untreated lung cancer is approximately 6 months. Hence, the following cost assumptions are based on a 6-month survival time following diagnosis (Preiss et al., 2004; see drug and procedural costs in Annex Table A7.6):

- For palliative care, 20% of lung-cancer patients are assumed to seek care and make an average of four outpatient visits in their final 6 months. The cost of outpatient palliative care based on non-opioid drugs is US$ 4.6. For inpatient care, 20% of those seeking outpatient care are assumed to be admitted to hospital. Palliative care of hospitalized patients is assumed to include both opioid and non-opioid drugs, and the cost per case is estimated at US$ 38.4, which is adjusted using the WHO price multiplier.
- In most of the developing world, only a small proportion of patients receive advanced treatments, such as radiation therapy or chemotherapy. However, the actual rate would vary considerably by region, based on likely access to these types of treatment. In the baseline scenario, radiation or chemotherapy costs are not included.

It should be noted, however, that the assumptions on treatment-seeking and treatment options are probably conservative, given that a significant part of the world's population using coal for cooking purposes is based in middle- or low-income countries (e.g. Chile, China, Kazakhstan and South Africa).

2.7.5 Patient costs

For all three diseases, the patient-supported costs are assumed to be the same, given that non-medical patient costs are related to the means of transport and the length of hospital stay, and less related to the type of treatment received. For health-seeking from modern health providers, the patient cost is assumed to be US$ 0.30 per outpatient visit (covering transport, food and non-medical supplies), and US$ 0.50 per inpatient day (mainly food costs) (Adam et al., 2004).

For those not seeking modern health care (see Annex Table A7.4), it is assumed that alternative action is taken, such as traditional care or home treatment including a visit to a pharmacy or provider of folk remedies. In the absence of relevant data, an average cost of US$ 0.50 per case is assumed.

2.8 Economic benefits due to improved health

2.8.1 Value of days of illness saved

In addition to the health-care costs saved, there are other economic benefits of improved health due to more time becoming available for productive activities. In evaluating household energy interventions from a societal perspective, these economic benefits should be included in the analysis (Drummond et al., 1997). WHO's cost–benefit analysis guidelines on household energy and health interventions present three main options for valuing illness-free

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[1] This value is likely to be higher for severe cases and lower for mild cases.

[2] Personal communication, Ron Halbert, 2006.

days and other time savings associated with interventions that improve access to household energy services (Hutton & Rehfuess, 2006).

The first approach – the "human capital" approach – uses market prices from the labour market to value changes in health states, including both morbidity and mortality. This approach does not, however, reflect changes in individual or societal welfare, and does not provide information about the willingness to pay for obtaining given time savings or a given reduction in the probability of loss of life.

The second approach – the "revealed preference" approach – values expenditure on activities or goods that reduce morbidity or mortality risks, termed "avertive expenditures" in the literature. One problem with this approach is that expenditure may only partially reflect a response to risk, as the motivation for purchasing a product or service may be due to other factors, such as convenience or quality of the environment. Also, only limited information of relevance to this global study is available.

The third approach – the "contingent valuation" approach – uses hypothetical survey methods to elicit willingness to pay values for goods in a hypothetical market. While this method is flexible and can elicit responses on several different types of goods and services, there can be problems of interpretation, especially given the hypothetical nature of responses to such questions.

Given the global multi-context nature of the present study, a method is required that represents a general economic value of time lost. Despite the many limitations of the human capital approach (Hutton & Rehfuess, 2006), it is the most applicable to such a global study that relies on compilation of evidence from secondary sources. One advantage is that the method can be structured to explicitly account for equity considerations. Given that the link between an individual's health and earning potential will vary between individuals depending on their age, employment status (unemployed, employed or self-employed) and the nature of their work (e.g. management or manual), the human capital approach can assign a value to each individual that equalizes their weight in the analysis. The Organisation for Economic Co-operation and Development (OECD) argues strongly for the explicit recognition of the economic cost of the health burden and other negative impacts on children and women (OECD, 2006). Therefore, this study chooses to value the economic benefits of reduced morbidity as the number of days of illness averted multiplied by an average time value for each WHO subregion. The economic benefits of averted deaths are calculated as the average annual value of time multiplied by the discounted number of years of income-earning life lost (assuming an income-earning life from age 15 to 65 years).

In terms of the economic value of a day of productive time gained (or an incapacitated day averted), the advantage of a cost–benefit study over a purely financial analysis is that a proxy value of time can be used and applied irrespective of what individuals actually do with their time. In fact, whether the time gained is used in income earning, productive but non-income-generating work or leisure activities, there is evidence that people value their time at or close to their hourly wage (Lee & Kim, 2005) or at close to the minimum wage (Shaw, 2004). Begoña et al (2001) find considerable variation between individuals in how they value their leisure time. The importance of valuing leisure time is also supported by the fact that wage rates for overtime work are generally higher than the average wage (Wolfson, 2001), and Isley and Rosenman argue that the market wage rate should be used as the lower bound for valuing leisure time (Isley & Rosenman, 1998). In other words, people need to be paid more than their average wage to give up their leisure time to work. The OECD has also been reported to use GDP per capita as the basis for valuing leisure time.[1]

In the present study, two population groups are distinguished: children and adults, given the different opportunity cost of time for these two groups. Given that children aged 0–4 years are usually being cared for by a family member, it is assumed that a sick child adds to the burden of the carer and makes him or her less productive in other activities. Children 5–15 years of age should attend school; hence any failure to attend school due to an adverse health condition would also require a time value to be attached to missed classes. Therefore, a time value reflecting half the adult value of time can be assigned to cases of childhood illness, as was done in a similar global study on water and sanitation interventions (Hutton & Haller, 2004).

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[1] http://www.economist.com/finance/PrinterFriendly.cfm?story_id=5504103.

However, the present study only includes IAP-attributable ALRI in children under 5 years old, and consequently such a value was not applied, but could be applied in future cost–benefit analyses that include health outcomes in the age group 5–14 years. Whereas the above-mentioned OECD publication argues that the value of children's health is different from that of adults, the authors emphasize the difficulties of eliciting values for children when it comes to economic valuation, and the current lack of reliable estimates to inform a global study (OECD, 2006). Furthermore, the purpose of the present study is not to give an economic value to the implicit value of health or health improvements *per se*, but instead a value representing the social welfare impact.

From an equity perspective, it is appropriate to assign to all adults the same economic value of time, so that high-income earners are not favoured over low- or non-income earners, or men over women. Moreover, variations between different population groups would be difficult to capture in a global study. Therefore, the gross national income (GNI) per capita (in US$) in the year 2005 is used as the average value of time in an economy. A weighted average GNI was calculated at the WHO subregional level, using a population-weighted average for each subregion (see Annex Table A8.2). The annual GNI value is transformed to a daily value. In the sensitivity analysis, the pessimistic scenario valued only adult time and at 30% of GNI per capita, while the optimistic scenario used an average population-weighted minimum wage rate for each subregion (Annex Table A8.2).

2.8.2 Morbidity

The number of days an individual is unable to work is a function of the illness they have, the severity of the illness, and whether or not it is treated (or palliated). Annex Table A8.1 shows the assumptions used in the analysis. The number of days a person is assumed to be incapacitated due to ALRI varies between 5 days (non-severe pneumonia, treated) and 30 days (very severe pneumonia, untreated). For COPD, which is a chronic disease, the time spent incapacitated varies between 10% (stage I, treated) and 100% (stage III, untreated). For lung cancer, it is assumed that following diagnosis, a patient has an average survival time of 6 months, and is incapacitated 100% of the time, whether he or she is given palliative care or not. Treatment-seeking rates and proportion of the affected individuals at different severities/grades are the same as presented for health-care costs saved.

2.8.3 Mortality

In terms of valuing the mortality impact of the interventions, each death is assumed to have an impact on the overall economic output of society. As this happens at some point in the future, these benefits are discounted to the present time based on the current age of the averted case. The calculation of years of lost work per premature death due to ALRI takes into account that those in the younger age groups would not have been economically productive until the age of 15 years. Although children become productive at an early age in developing countries (excluding child labour), economic benefits in the age group below 15 years are excluded due to uncertainties about the actual time spent in household chores, and the fact that such productive value results from the fact that children are not at school, which is highly contestable. An average annual economic value is applied to all cases, using GNI per capita.

2.9 Time savings

The interventions are assumed to lead to two types of time saving – from reduced collection time (or making time) for wood fuel, dung and crop or agricultural residues, and from reduced cooking time. For consistency with the economic benefits of better health, the time savings are valued at the average (weighted) GNI per capita by subregion (see section 2.8.1). No distinction is made between children and adults – all time saved from collecting or preparing fuel and cooking is valued at the full economic value of time.

2.9.1 Fuel-collection time

Data on the time spent collecting fuel are widely available in the literature and from surveys (Listordi & Doumani, 2004; Dutta et al., 2005). The data collected from the literature are presented in Annex Table A9.1, and the estimated averages by subregion are presented in Annex Table A9.2. For some countries such as India, data from several surveys were aggregated to estimate the mean and range. For other countries, data were derived from a single study. In some cases, the available time data were not considered to be representative of either the country or subregion, and therefore adjustments were made in estimating the mean values for the subregion. For example, given that Pakistan is one of the main wood-using countries in EMR-D, data were generalized from the south-east Asian region rather than using the time data from Sudan. Where no data were available for any country in a given subregion, data from similar subregions were generalized. For example, for the two relatively timber-rich regions of AMR and EUR, data from Indonesia were used. For the relatively arid and timber-scarce EMR-B region, the higher collection time value was generalized from AFR-E.

For dung and crop residues, almost no published information on collection time exists. Because collection/preparation of these fuels is closely linked to the agricultural work of a household, it is likely that the collection/preparation time is considerably less than for wood. Nevertheless, crop residues need to be raked up and transported to the home, while dung needs to be collected, moulded and left to dry to make dung cakes. Therefore, in the absence of any quantitative data, it is assumed that these fuels require roughly half the average daily collection and preparation time required for fuel wood.

2.9.2 Cooking time

Estimates of time spent cooking are also available in the international literature and from surveys, although there is less information than for fuel collection, as time spent cooking is usually combined with time spent on other household chores and eating. Cooking time depends partly on the heat-transfer capacity of the fuel and stove. Therefore, it is possible that in an open fire with red-hot embers, cooking time is less than in a more directed and fuel-efficient cooking stove. The stove comparison study made by Aprovecho provides information on cooking time, based on time to boil a given quantity of water (Still et al., in press):

- *Same fuel intervention: changing from cooking on an open fire to a rocket stove.* Time to boil 5 litres of water is reduced from 26.7 to 22.3 minutes. Therefore, the assumed cooking-time reduction is 13.86%.[1]
- *Different fuel intervention: moving from cooking with solid fuels on an open fire to an LPG or biofuel stove.* Time to boil 5 litres of water is reduced from 26.7 to 23.0 minutes. Therefore, the assumed cooking-time reduction is 11.42%. Also, pot cleaning will be quicker when cooking with LPG than with biomass-using traditional stoves. Due to lack of data on the potential time saving, changes in pot-cleaning time are not included in the analysis.[2]

Given that these data come from laboratory as opposed to real-life studies, and are based on a single stove type (rocket stove), it is possible that the actual time savings are considerably greater or less than those used in the model. In fact, cooking times on some stoves with higher fuel efficiency than open fires or traditional stoves can be longer due to less heat transfer. Furthermore, as cooking can be combined with the accomplishment of other household chores, estimated time spent cooking when using traditional stoves should not necessarily be counted as lost time. The sensitivity analysis therefore includes a more conservative estimate, at zero cooking-time savings.

2.10 Environmental benefits

Environmental benefits are estimated at two levels, the local and the global level, which give distinctly different types of benefit.

2.10.1 Local environmental benefits

Local environmental benefits occur as part of a switch away from biomass to cleaner fuels, or when improved and more fuel-efficient stoves lead to less consumption. Essentially, this results in:

(a) fewer trees being cut down in an unsustainable fashion (being used either for firewood or charcoal), and

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[1] Although different types of improved stoves would be used around the world, it is not considered unreasonable to expect time savings. For example, an assessment of GTZ's Programme for Biomass Energy Conservation in Southern Africa showed that 30% of households using the improved stoves reported time savings (Brinkmann & Klingshirn, 2005).

[2] The limitations of the water-boiling test should also be recognized; for example that this test does not measure heat loss from the surface of the water, which can vary between stoves and fuels, and therefore the test does not give a true measure of thermal efficiency. Furthermore, once a pot has come to the boil, LPG and biofuel stoves can be turned down immediately, thus conserving energy compared to the rocket stove.

(b) more fertilizer compounds being available, as dung and crop residues are maintained in the natural soil cycle rather than being burnt for cooking purposes.[1]

These two benefits have different direct and short-term effects, and thus need to be valued in different ways.

The local effects of trees being cut down are soil erosion, desertification and, in hilly areas, landslides. The costs of these are many, but have a high level of uncertainty and are difficult to value in economic terms, as they vary depending on the human interaction with the land (e.g. population density, use of land for farming) and geographical factors (e.g. steepness, presence of rivers). Therefore, an alternative way of attaching an economic value is the cost of replacement of trees to avert the possible future effects of deforestation (avertive expenditure). This essentially means that the replacement cost is the same for trees cut down in a renewable or non-renewable fashion. The replacement cost is the cost of replanting trees in a renewable fashion, which is made up of the labour cost plus the tree sapling cost, adjusted by a wastage factor (defined as the percentage of planted saplings that do not mature). The number of kilograms of wood used annually for domestic cooking purposes is available from the model (average consumption per household multiplied by number of households using firewood). This figure is transformed into the number of tree-equivalents by dividing the kilograms of wood consumption by the average weight of firewood per tree, which is estimated to be 0.167 m^3, or 100 kg (Carneiro de Miranda, 1997). A search undertaken on the Internet and of environmental economics and forestry journals[2] revealed very little information. One study from Brazil estimated the cost to replace one tree at US$ 0.25, including the cost of the seedling, technical assistance, fertilizer, wire, pesticide and administration (Carneiro de Miranda, 1997). This was adjusted to 2005 costs using a 10.2% average inflation rate for Brazil, giving US$ 0.60 (World Bank statistics, 2005). This estimate was applied in the model, as it appears to be more realistic than that of a 1990 study that estimated a cost of US$ 1.33 per tree established in the "third" world (based on a cost of US$ 0.80 per tree planted with 60% survival probability) (Krause & Koomey, 1989).

The local effects of burning dung and crop residues instead of applying them to the land involve a nutrient loss from the land, which in a sustainable agriculture system would need to be replaced with nutrients from alternative sources such as fertilizer. However, given the considerable uncertainty surrounding the comparability of a kilogram of fertilizer with a kilogram of dung/crop residues, and the lack of information available internationally on local fertilizer options and prices, these potential economic benefits are not estimated in this study. It should also be noted that the ash produced by the combustion of biomass can be used as fertilizer, and therefore not all of the nutrients are lost.

2.10.2 Global environmental benefits

The global environmental benefits are related to greenhouse gas (GHG) emissions from the household burning of solid fuels. Relevant GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (NO_2), the three gases with internationally recognized links to global warming. The first two of these are modelled in the present study, as they are included in the Clean Development Mechanism (CDM) of the Kyoto Protocol, and values associated with reductions in the emissions of these gases are more readily available and more reliable. The exclusion from the analysis of NO_2, black carbon and other combustion products that are potentially linked to global warming gives a conservative estimate of benefit.

A good improved stove (with or without a chimney) is designed to minimize the generation of products of incomplete combustion, many of which have a high global-warming potential (IPCC, 2001). The global environmental value is calculated by estimating the total emission reduction achieved by each of the interventions modelled in the present study, based on:

(a) the amount of each fuel burnt per year;

(b) the CO_2 and CH_4 emissions for each kg of fuel burned; and

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[1] Note that the value associated with (a) is different from the value of collecting or purchasing wood (which are valued under cost savings associated with the intervention in section 2.5 or collection-time savings in section 2.9). The value in this section refers to the inherent value of adopting sustainable forestry and agricultural practices, while the values in sections 2.5 and 2.9 relate only to the collection or purchase of a resource that is (usually) available free of charge.

[2] The search used key words in English, French and Spanish on replacement cost, reforestation cost, forestry schemes and tree biomass.

(c) the economic value of averting greenhouse gas emissions.

The first of these (a) is an output of the cost–benefit model, calculated as the number of households using each fuel multiplied by energy use per year. Data on the second variable (b) were extracted from the scientific literature. Where possible, the emission value corresponding to small-scale combustion devices in developing countries was used (Smith et al., 2000a) (Annex Table A10.1). Gaps in the data were filled by other sources which also provided alternative values for the sensitivity analysis (Thomas et al., 2000, and footnotes in Annex Table A10.1). It should be noted that the values in Annex Table A10.1 mask considerable variation between different types of fuel (e.g. different crop residues, different types of wood and different types of coal).

It should also be noted that for charcoal, greenhouse-gas release arises not only from its eventual use as a cooking fuel in the household (for which values are presented in Annex Table 10.1), but also from the initial preparation of charcoal, a process which generates high levels of CH_4 and other products of incomplete combustion. However, neither the scientific literature reviewed nor the results of an Internet search mentioned emission values associated with charcoal manufacture. Therefore, a conservative approach was adopted by excluding the additional release of GHGs during the manufacture of charcoal.

The third variable, the economic value of averting GHG emissions, was identified through various sources. One of these is "carbon trading", promoted by the Clean Development Mechanism, where emission reductions are purchased and sold on the open market (buyers purchase emission reductions in order to meet their climate mitigation targets which were set under the Kyoto protocol). Values depend on the structure of the contract and, during the period January 2004 to April 2005, varied between US$ 0.50 and US$ 7 per tonne of CO_2 emission reduction or tonnes of CO_2 equivalent (tCO_2e) (IETA, 2005). Mean values and ranges for the different contracts are as follows: ER – US$ 1.20 (US$ 0.65 – US$ 2.65); VER US$ 4.23 (US$ 3.60 – US$ 5.00); CER – US$ 5.63 (US$ 3.00 – US$ 7.15); ERU US$ 6.04 (US$ 4.57 – US$ 7.20).[1] Clearly, these figures suggest a high level of uncertainty for the analysis where a single value must be chosen. Also, the International Emissions Trading Authority reported in 2005 that prices had increased 10% for VERs and 21% for CERs over the previous year. The current market values are significantly higher than those cited above, rising to € 15–20 (US$ 20–26) in the European market. Given the volatility and the uncertainty of the emissions trading value in the long-term, a conservative CO_2 emissions trading price of US$ 4 is used, ranging from US$ 1 to US$ 7 in the sensitivity analysis.

For an economic value of reducing CH_4 emissions, a trading value was not found; however, as the instantaneous global-warming potential has been compared between CH_4 and CO_2 (Smith et al., 2000b), the higher potency of CH_4 can be used to derive an approximate value for CH_4, based on the CO_2 carbon trading value. The relative potency of CH_4 compared to CO_2, however, varies according to the time period. The instantaneous relative potency of CH_4 is 21.0 times that of CO_2, increasing to 22.6 over 20 years, and eventually reducing to 7.6 for 100 years and 3.2 for 500 years (Smith et al., 2000b). For the base-case analysis, the 100-year time horizon is chosen, thus giving a value of US$ 30.4 per tonne of CH_4 emissions reduced. In the sensitivity analysis, this value is varied between the 500-year time horizon in the pessimistic case (US$ 13.2 per tonne of CH_4 reduced) and the 20-year time horizon in the optimistic case (US$ 90.4 per tonne of CH_4 reduced).

An alternative source of a value per tonne of CO_2 emission reductions is a carbon tax, such as the one proposed in the DICE99 model (Cline, 2004). The model predicts the hypothetical tax on carbon emissions which would be required to reduce the release of CO_2 to appropriate levels. According to Cline, an optimal carbon tax would be US$ 170 per tonne in 2005, rising steadily to US$ 1300 until the year 2200, and then declining again. However, this value remains largely hypothetical, and is unlikely to be applicable in practice.

For biomass, the analysis takes into account the difference in the global environmental impact of renewably harvested and non-renewably harvested sources, as they have different GHG emission values (Edwards et al., 2004). While it is hard to obtain

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[1] ER, "not for Kyoto" compliance Emission Reductions; VER, Verified Emission Reductions, where the buyer takes the registration risk; CER, Certified Emission Reductions, where the seller takes most of the registration risk; ERU, "for Kyoto" Emission Reduction Unit.

Table 5. Variables included in the sensitivity analysis and their alternative values

Sensitivity analysis	Variable	Pessimistic (conservative)	Mean (base case)	Optimistic (best case)
INTERVENTION COSTS				
Sensitivity analysis 1	Stove costs	LPG: US$ 150 Biofuel: US$ 50 Improved stove: US$ 80	LPG: US$ 46–110 (by subregion) Biofuel: US$ 35 Rocket: US$ 6	LPG: US$ 46 Biofuel: US$ 25 Improved stove: US$ 2
	Stove efficiency	Improved stove fuel saving: 20%	Improved stove fuel saving: 34%	Improved stove fuel saving: 60%
Sensitivity analysis 2	Fuel prices (per litre)	LPG: US$ 0.382 Ethanol: US$ 0.50	LPG: US$ 0.255 Ethanol: US$ 0.36	LPG: US$ 0.127 Ethanol: US$ 0.19
HEALTH BENEFITS				
Sensitivity analysis 3	Health impact of improved stoves	10% reduction in disease incidence	35% reduction in disease incidence	60% reduction in disease incidence
	COPD and lung cancer lag period	30 years	20 years	10 years
TIME SAVINGS				
Sensitivity analysis 4	Time value (all population)	30% GNI per capita	GNI per capita	Minimum wage
Sensitivity analysis 5	Time value (children)	Zero	Half of adults' value	Same as adults' value
Sensitivity analysis 6	Time value (adults and children differently)	30% GNI per capita for adults, children zero	GNI per capita for adults, and half of adults' value for children	Minimum wage, and adults' value for children
Sensitivity analysis 7	Fuel collection time saved per household per day	Half the mean value	0.30–1.94 hours (by subregion)	50% more than the mean value
	Cooking time saved, improved stove and fuel	Zero	Reduction in time to boil 5 litres of water	Double the mean value
ENVIRONMENTAL BENEFITS				
Sensitivity analysis 8	Tree replacement cost	US$ 0.00191 per kg wood not collected	US$ 0.005619 per kg wood not collected	US$ 0.019105 per kg wood not collected
Sensitivity analysis 9	CO_2 emissions	LPG:[a] 3190 Charcoal: 1350 Coal: 952 Wood: 1397 Dung: 974	LPG: 3085 Coal: 2031 Charcoal: 2411 Wood: 1688 Dung: 1005	LPG:[a] 2950 Charcoal: 3300 Coal: 3110 Wood: 1980 Dung: 1063
	CH_4 emissions	Charcoal: 6.7 Wood: 4.0 Dung: 3.0	Charcoal: 7.9 Wood: 8.0 Dung: 10.5	Charcoal: 147.0 Wood: 13.0 Dung: 18.0
Sensitivity analysis 10	CO_2 value ERU	US$ 1	US$ 4	US$ 17
	CH_4 value ERU	US$ 13.2 (3.2 more potent than CO_2)	US$ 30.4 (7.6 more potent than CO_2)	US$ 90.4 (22.6 more potent than CO_2)
GENERAL				
Sensitivity analysis 11	Discount rate	5%	3%	0%
Sensitivity analysis 12	Biofuel used	—	Ethanol	Methanol at US$ 0.25 per litre

LPG, liquefied petroleum gas; COPD, chronic obstructive pulmonary disease; GNI, gross national income; CO_2, carbon dioxide; CH_4, methane; ERU, "for Kyoto" Emission Reduction Unit.

[a] Note, in the optimistic scenario the LPG emission factors are lower than in the base case, whereas in the optimistic scenario for biomass fuels the emission factors are higher than in the base case. The converse is true for the pessimistic scenario.

exact information on the proportion of domestically-used biomass that is renewably harvested, it is likely that a large proportion of wood cut down is not replaced. For example, Kammen & Lew (2005) state that a significant proportion of wood used in charcoal production is unsustainably harvested. Garzuglia & Saket (2003) summarized the net losses in global woody biomass between the years 1990 and 2000. Their results show a loss of 3.26% or 18 million tones of woody biomass, from 554 to 536 million tonnes (see Annex Table A10.2). Europe is the only continent with a net gain over this period, with the majority of the loss arising in Africa and South America (a loss of roughly 8.5 million tonnes each). However, these figures do not give an exact picture of the proportion of domestically-used biomass that is harvested renewably. Therefore, given the high rate of clearance in Africa and Latin America, the proportion of renewably-harvested wood is assumed to be 10% on these two continents; for Europe it is set to 100%, and for the other subregions to 50%.

2.11 Sensitivity analysis

To examine the impact of uncertainty in the variables, one-way and two-way sensitivity analyses were performed, where optimistic and pessimistic values for selected variables were substituted in the model and benefit–cost ratios (BCR) re-estimated. Variables that were included in the sensitivity analysis are presented, with their ranges, in Table 5. In cases where the most conservative estimates (in the extreme analysis) give a BCR of close to 1 or less than 1, a probabilistic sensitivity analysis would need to be conducted to understand the distribution of the ratio. This will be the subject of future examination.

3. Results

3.1 Overall cost–benefit results

Tables 6–10 present the overall results of the study for scenarios I, III, and IV: total economic benefits, net costs, benefit–cost ratios, and net present values. Annex Tables B present the same results for the other five scenarios modelled. Economic figures are rounded to the nearest US$ 10 million value, and are presented for urban and rural populations separately.

Total economic benefits (for urban and rural populations combined), presented in Table 6, amount to roughly US$ 90 billion per year for providing 50% of households with access to LPG. A pro-poor approach to promote LPG access is associated with US$ 12 billion more economic benefits, at US$ 102 billion, due to greater fuel-collection time savings. The 50% improved-stove scenario generates US$ 105 billion economic benefits. Annex Table B7.1 shows that the economic benefits for ethanol are the same as for LPG, and that the 100% coverage scenarios lead to twice the economic benefits of the 50% coverage. In all three scenarios, a high proportion of the urban benefits accrue to WPR-B, while the rural benefits are more evenly distributed between subregions, in particular AFR, AMR-B and SEAR.

The annual net intervention costs are presented in Table 7, calculated as intervention costs minus cost savings from switching fuel or from using less of the same fuel. Negative figures therefore indicate a net saving. The global annual cost of scenario I is US$ 13 billion, compared with US$ 15 billion for scenario IV and a net saving of over US$ 34 billion for scenario III. The net costs vary significantly between urban and rural settings. In urban settings the net intervention costs are proportionately lower than in rural settings, as the urban population are already purchasing a higher proportion of their fuel. Over half the urban costs in scenario I are accounted for by WPR-B, while for rural costs a significant proportion is accounted for by SEAR-B. In some regions there is a cost saving in urban areas in scenario I (AFR-E, AMR-D, EMR-D, EUR and SEAR-B). For the improved-stove scenario, there are net savings in all regions except EMR-B.

The resulting BCRs are presented in Table 8. The BCR is calculated by dividing the economic benefit (see Table 6) by the economic cost (see Table 7). When the value is greater than 1.0, the economic benefits are greater than the costs (i.e. they give a return on investment). When the value is less than zero (i.e. a negative number), there is both a net intervention cost saving *and* an economic benefit. The only benefit–cost value for which a scenario is not profitable is between zero and 1.0.

Table 8 bears witness to considerable variations in BCRs between scenarios and world subregions, ranging from −51 for SEAR-D (improved stove in rural setting) to +136 for EMR-B (improved stove in urban setting). The majority of the results, however, lie somewhere between −20 and +10, and only two results, the LPG pro-poor approach in urban populations of AMR-D and SEAR-D, appear to be non cost-beneficial. Annex Table B7.2 shows that the results for ethanol are generally cost-beneficial, although for some regions the ratio is between 0 and 1 (AMR-D, EMR-D and SEAR-D), presumably because the intervention costs for ethanol are higher than for LPG.

These diverging results between subregions, between interventions and between the rural and urban settings can be explained by the data inputs. It is important to note that a higher BCR can be explained both by a smaller denominator (net cost) and a larger numerator (benefit), where the former has a relatively greater impact on the BCR than has the latter. Consequently, the divergence in BCRs can be largely attributed to the different

Table 6. Total annual economic benefits (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	2 540	3 080	2 500	3 080	1 910	2 070
AFR-E	2 420	5 450	2 690	7 210	2 480	3 850
AMR-B	610	5 980	620	6 250	9 600	7 510
AMR-D	220	440	120	830	790	480
EMR-B	1 330	2 080	1 350	2 130	4 980	2 910
EMR-D	470	1 620	460	1 670	1 300	1 890
EUR-B	410	1 030	420	1 030	2 130	410
EUR-C	500	410	530	430	910	70
SEAR-B	310	4 030	40	4 930	1 040	3 580
SEAR-D	2 610	5 440	2 440	6 690	5 600	4 130
WPR-B	45 180	4 240	50 200	7 010	42 970	3 910
World (non-A)	**56 600**	**33 800**	**61 370**	**41 260**	**73 710**	**30 810**
World (non-A)	**90 400**		**101 630**		**104 520**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 7. Annual net intervention costs (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	100	840	760	950	-1 090	-100
AFR-E	-230	880	220	1 050	-2 100	-410
AMR-B	50	1 570	90	1 680	-3 430	-400
AMR-D	-60	260	130	240	-1 220	-50
EMR-B	270	500	270	500	40	30
EMR-D	-30	750	30	800	-1 810	-270
EUR-B	-60	340	-30	350	-1 830	-40
EUR-C	-90	120	-100	140	-790	-10
SEAR-B	-70	1 520	190	1 460	-1 220	-270
SEAR-D	1 000	3 610	1 790	3 640	-4 750	-80
WPR-B	1 670	200	730	490	-13 630	-940
World (non-A)	**2 550**	**10 590**	**4 080**	**11 300**	**-31 830**	**-2 540**
World (non-A)	**13 140**		**15 380**		**-34 370**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 8. Benefit–cost ratios (US$ return per US$ 1 invested)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	26.5	3.7	3.3	3.2	Neg	Neg
AFR-E	Neg	6.2	12.7	6.9	Neg	Neg
AMR-B	14.3	3.8	6.9	3.7	Neg	Neg
AMR-D	Neg	1.8	0.9	3.6	Neg	Neg
EMR-B	4.9	4.2	4.9	4.3	136.1	89.9
EMR-D	Neg	2.2	16.1	2.1	Neg	Neg
EUR-B	Neg	3.0	Neg	2.9	Neg	Neg
EUR-C	Neg	3.4	Neg	3.1	Neg	Neg
SEAR-B	Neg	2.7	0.2	3.4	Neg	Neg
SEAR-D	2.6	1.5	1.4	1.8	Neg	Neg
WPR-B	27.0	21.2	68.5	14.6	Neg	Neg
World (non-A)	**22.3**	**3.2**	**15.1**	**3.7**	**Neg**	**Neg**
World (non-A)	**6.9**		**6.7**		**Neg**	

Neg: a negative ratio means that intervention cost savings exceed intervention costs.

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 9. Benefit–cost ratios with intervention cost savings included with economic benefits (US$ return per US$ 1 invested)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	3.8	3.3	3.0	3.2	34.2	29.0
AFR-E	4.3	4.7	4.1	6.0	42.2	44.0
AMR-B	4.0	3.4	3.8	3.4	52.2	50.5
AMR-D	2.5	1.7	1.0	3.1	63.7	38.3
EMR-B	4.9	4.2	4.9	4.3	76.2	77.3
EMR-D	2.6	2.0	2.4	2.0	41.1	28.3
EUR-B	3.7	2.6	3.6	2.5	107.5	87.9
EUR-C	3.6	2.7	3.8	2.7	79.4	87.7
SEAR-B	3.1	2.4	0.2	2.9	63.6	45.8
SEAR-D	1.8	1.5	1.3	1.8	32.1	28.3
WPR-B	8.8	6.7	9.9	10.2	110.7	164.1
World (non-A)	**6.0**	**2.8**	**6.2**	**3.4**	**68.0**	**45.9**
World (non-A)	**4.3**		**4.7**		**60.9**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

way in which fuel-cost savings and time savings influence the cost–benefit calculation. Fuel savings are subtracted from the intervention cost in the denominator, whereas time savings are added to the economic benefits in the numerator.

First, urban areas have greater BCRs than do rural areas, due to the effect of subtracting fuel savings from the intervention costs in the denominator. Second, the LPG pro-poor scenario appears to be less cost-beneficial than the LPG scenario because few among the poorer households were purchasing their fuel prior to the intervention. Third, the large variation in results between world subregions is explained by several differences in data inputs, such as type of solid fuel used, economic value of time and assumptions regarding the cost of intervention.

Table 9 presents BCRs under a different algorithm for calculating the BCR: by adding intervention cost savings as an economic benefit to the numerator, instead of subtracting them from intervention costs in the denominator. This reduces the apparent efficiency of the interventions, given the relatively greater influence of the denominator in the calculation. In scenario I the global BCR is 4.3 instead of 6.9, with a significantly greater effect for urban areas, given that the intervention cost savings are greater in urban than in rural contexts. For the improved-stove intervention in scenario III, the BCR becomes positive, at a value of 60.9, which shows a highly cost-beneficial intervention. The BCR of the biofuel intervention in scenario II, on the other hand, also decreases from 2.1 to 1.9 under the alternative methodology (Annex Tables B7.2 and B7.3). Hence, a comparison of the cost–benefit results in Tables 8 and 9 and in the Annex Tables illustrates the important impact of algorithm choices on the overall results and conclusions. It is clear, however, that both algorithms produce results that are highly favourable for the selected interventions.

The net present value (NPV) presented in Table 10 is the estimated annual economic surplus, calculated by subtracting net costs from economic benefits. The average annual value of the NPV at global level is US$ 77 billion for scenario I, US$ 97 billion for scenario IV, and US$ 139 billion for scenario III. The intervention with the least benefit is scenario II (biofuels) at US$ 47 billion (see Annex Table B7.4). A large proportion of the economic surplus for all

Table 10. Net present value (average annual value; US$ million)[a]

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	2 440	2 240	1 740	2 120	3 000	2 180
AFR-E	2 660	4 570	2 480	6 160	4 580	4 260
AMR-B	560	4 410	530	4 580	13 030	7 920
AMR-D	270	190	–10	600	2 010	520
EMR-B	1 060	1 590	1 070	1 630	4 940	2 880
EMR-D	500	870	430	870	3 110	2 150
EUR-B	470	690	450	680	3 960	450
EUR-C	580	290	630	290	1 690	80
SEAR-B	380	2 510	–140	3 460	2 260	3 850
SEAR-D	1 620	1 830	640	3 050	10 340	4 210
WPR-B	43 510	4 040	49 460	6 530	56 610	4 850
World (non-A)	**54 050**	**23 230**	**57 290**	**29 970**	**105 540**	**33 350**
World (non-A)	**77 490**		**97 430**		**138 920**	

[a] A negative net present value represents the value that is likely to be lost over the lifetime of an intervention. A negative value in the table reflects the average annual loss.

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

scenarios, especially in urban areas, is estimated to occur in one subregion, WPR-B.

3.2 Population targeted

Tables 11 and 12 show the populations that are estimated to benefit from fuel and stove improvements. Table 11 is a summary of Annex Tables B1.1–B1.4, which show the populations switching from each type of solid fuel. Note that the predicted global population in 2015 is 7.2 billion. A total of 1.4 billion people are predicted to benefit from the 50% fuel-improvement scenarios, divided equally between urban and rural areas. This equals 19.5% of the world's population in 2015. The subregions that benefit most include (in order of importance):

Table 11. Population (million) targeted for 50% fuel-change interventions

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	91	94	184	28	47	53	57
AFR-E	63	108	171	27	45	50	49
AMR-B	7	64	71	6	12	18	35
AMR-D	8	10	18	2	4	5	7
EMR-B	11	18	29	3	5	8	13
EMR-D	27	70	97	12	22	28	36
EUR-B	5	12	17	1	2	4	9
EUR-C	4	3	7	0	1	1	5
SEAR-B	13	105	117	9	19	28	60
SEAR-D	144	234	379	36	72	103	168
WPR-B	284	34	317	22	42	74	180
World (non-A)	**657**	**752**	**1 409**	**147**	**271**	**372**	**619**

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 12. Population (million) targeted for 50% stove-improvement intervention

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	53	49	102	15	26	29	31
AFR-E	52	59	110	17	29	32	32
AMR-B	65	46	112	10	19	28	55
AMR-D	16	7	22	2	5	6	9
EMR-B	25	16	41	4	7	11	18
EMR-D	57	58	116	15	26	33	42
EUR-B	15	2	18	1	3	4	10
EUR-C	4	0	5	0	0	1	3
SEAR-B	23	55	78	6	13	19	40
SEAR-D	242	123	365	35	68	99	163
WPR-B	393	25	418	29	54	96	238
World (non-A)	**947**	**439**	**1 386**	**134**	**251**	**359**	**642**

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

SEAR-D, WPR-D, AFR-D, AFR-E and SEAR-B. The population groups that benefit most are the age groups > 30 years (44%), 15–29 years (26%), 5–14 years (19%) and 0–4 years (11%).

A total of 1.4 billion people are predicted to benefit from the 50% stove improvement, roughly two thirds of whom live in urban areas. This equals 39% of the world's population in 2015. The subregions that benefit most include (in order of importance): WPR-D, SEAR-D, EMR-D, AMR-B, AFR-E, AFR-D and SEAR-B.

3.3 Intervention costs

While Table 7 presents the net intervention costs, Tables 13 and 14 show the two main components of the net cost calculation, namely intervention costs and cost savings. The switch to LPG in scenario I carries a cost of US$ 24 billion globally, whereas the switch to ethanol in scenario II costs US$ 53 billion (Annex Table B2.1). The pro-poor approaches in scenarios IV and V bear the same cost as scenarios I and II, as the fuel cost is independent of whether households are collecting or purchasing their fuel prior to the intervention. Scenario III, to promote improved stoves, is considerably cheaper, at US$ 2 billion globally. These major cost differences between fuel and stove improvements exist because fuel-change interventions involve both a more expensive stove and regular expenditure on a new type of fuel (LPG or ethanol).

By switching to LPG or ethanol in scenarios I and II, a higher fuel efficiency generates around US$ 10 billion in fuel savings globally (see Table 14 and Annex Table B2.2). Scenario III, to promote improved stoves, leads to considerably greater fuel savings, at roughly US$ 37 billion globally. The pro-poor approaches in scenarios IV and V lead to lower financial savings, at US$ 8 billion, as fewer households pay for their fuel prior to the intervention. At least 80% of the fuel-cost savings occur in urban areas, as opposed to rural areas. Almost half of the fuel-cost savings in urban areas (scenarios I and III) are accounted for by WPR-B, increasing to over two thirds for scenario IV. Fuel-change interventions also lead to important fuel savings in other regions, such as SEAR and AFR; for the improved-stove intervention, AMR is also a significant contributor.

Table 13. Annual intervention cost (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	866	972	866	972	90	78
AFR-E	797	1 236	797	1 236	111	99
AMR-B	187	1 871	187	1 871	255	160
AMR-D	180	285	180	285	32	14
EMR-B	275	497	275	497	66	38
EMR-D	313	911	313	911	77	79
EUR-B	173	438	173	438	37	5
EUR-C	222	176	222	176	22	1
SEAR-B	185	1 779	185	1 779	36	86
SEAR-D	2 151	3 777	2 151	3 777	333	154
WPR-B	5 565	706	5 565	706	516	30
World (non-A)	**10 914**	**12 649**	**10 914**	**12 649**	**1 575**	**744**
World (non-A)	**23 563**		**23 563**		**2 319**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 14. Annual fuel-cost savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	770	134	106	21	1 184	183
AFR-E	1 030	358	584	188	2 213	511
AMR-B	145	299	97	192	3 681	564
AMR-D	236	34	50	52	1 247	57
EMR-B	5	2	0	0	29	5
EMR-D	345	158	285	109	1 887	346
EUR-B	228	95	203	87	1 865	50
EUR-C	307	56	321	36	805	9
SEAR-B	260	257	0	316	1 257	356
SEAR-D	1 153	171	359	140	5 078	234
WPR-B	3 892	506	4 832	225	14 153	971
World (non-A)	**8 372**	**2 070**	**6 837**	**1 365**	**33 399**	**3 287**
World (non-A)	**10 442**		**8 202**		**36 686**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 15. Annual value of health-system cost savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	9	9	9	9	1	1
AFR-E	10	16	10	16	1	2
AMR-B	0	4	0	4	0	1
AMR-D	2	2	2	2	0	0
EMR-B	0	0	0	0	0	0
EMR-D	6	16	6	16	1	2
EUR-B	0	0	0	0	0	0
EUR-C	0	0	0	0	0	0
SEAR-B	1	7	1	7	0	2
SEAR-D	17	29	17	29	3	5
WPR-B	31	3	31	3	8	1
World (non-A)	**77**	**88**	**77**	**88**	**16**	**15**
World (non-A)	**165**		**165**		**31**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

3.4 Health-care cost savings

Health-care cost savings include those savings that occur within the health system (i.e. on outpatient consultations and associated medical treatment, and inpatient consultations and associated medical treatment) and those that occur outside the health system that are borne directly by the patient (i.e. transport, food and non-medical supplies for the duration of health care).

Health-system cost savings are presented in Table 15, and amount to US$ 165 million annually for 50% of solid-fuel users gaining access to cleaner fuels, and US$ 31 million for 50% of solid-fuel users gaining access to an improved stove. Urban and rural areas share these benefits roughly equally. The distribution of health-system cost savings between subregions and the urban versus rural setting reflects differences in population characteristics and fuel use. For example, SEAR-D is characterized by a large rural population using solid fuels, while WPR-B has a relatively larger urban population using solid fuels. Five regions account for approximately 90% of these benefits: WPR-B, SEAR-D, AFR-E, AFR-D and EMR-D.

The patient-cost savings associated with transport and food in relation to modern as well as traditional health care are presented in Table 16. The results show considerably lower potential savings from improved health, at around US$ 10 million annually when 50% of the population gain access to cleaner fuels, and US$ 1 million annually when 50% of the population gain access to improved stoves.

Table 17 presents the annual total value of health-care cost savings, which sums Tables 15 and 16. At 50% coverage, the LPG option results in health-care cost savings of US$ 174 million annually, and the improved stoves option in savings of US$ 32 million.

3.5 Time savings

Tables 18 and 19 present the annual savings in fuel-collection time, Table 18 in units of million hours and Table 19 in units of million US$. Scenario I generates a benefit of 3.7 billion hours, or the equivalent of US$ 21 billion. The benefit of the LPG pro-poor approach in scenario IV is even greater, at 5.5 billion hours, or the equivalent of US$ 31 billion. The pro-poor option saves more time because it targets first those collecting and preparing dung or crop residues, and second those collecting wood, and finally those purchasing fuels, such as charcoal or coal. The improved-stove intervention (sce-

Table 16. Annual value of patient-cost savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1.5	1.7	1.5	1.7	0.2	0.2
AFR-E	0.8	1.3	0.8	1.3	0.1	0.2
AMR-B	0.0	0.1	0.0	0.1	0.0	0.0
AMR-D	0.1	0.1	0.1	0.1	0.0	0.0
EMR-B	0.0	0.0	0.0	0.0	0.0	0.0
EMR-D	0.2	0.5	0.2	0.5	0.0	0.1
EUR-B	0.0	0.0	0.0	0.0	0.0	0.0
EUR-C	0.0	0.0	0.0	0.0	0.0	0.0
SEAR-B	0.0	0.2	0.0	0.2	0.0	0.0
SEAR-D	1.0	1.6	1.0	1.6	0.1	0.2
WPR-B	0.7	0.1	0.7	0.1	0.1	0.0
World (non-A)	**4.3**	**5.6**	**4.3**	**5.6**	**0.5**	**0.7**
World (non-A)	**9.9**		**9.9**		**1.2**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 17. Annual value of total health-care cost savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	10	11	10	11	2	2
AFR-E	11	18	11	18	2	3
AMR-B	0	4	0	4	0	1
AMR-D	2	2	2	2	0	0
EMR-B	0	0	0	0	0	0
EMR-D	6	16	6	16	1	2
EUR-B	0	0	0	0	0	0
EUR-C	0	0	0	0	0	0
SEAR-B	1	7	1	7	0	2
SEAR-D	18	30	18	30	3	6
WPR-B	31	4	31	4	8	1
World (non-A)	**81**	**93**	**81**	**93**	**16**	**16**
World (non-A)	**174**		**174**		**32**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 18. Annual fuel-collection time savings (million hours)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	148	289	219	307	114	197
AFR-E	146	707	227	1 039	157	505
AMR-B	4	101	5	113	50	95
AMR-D	1	15	2	31	3	13
EMR-B	50	79	51	81	151	89
EMR-D	29	204	30	211	81	224
EUR-B	3	21	4	21	14	6
EUR-C	4	7	5	8	5	1
SEAR-B	0	189	0	235	0	131
SEAR-D	133	805	172	1 031	292	552
WPR-B	572	278	1 144	555	1 040	266
World (non-A)	**1 090**	**2 695**	**1 859**	**3 633**	**1 906**	**2 079**
World (non-A)	**3 785**		**5 492**		**3 985**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 19. Annual value of fuel-collection time savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	510	997	754	1 059	392	679
AFR-E	543	2 633	845	3 872	583	1 881
AMR-B	72	1 845	99	2 058	919	1 739
AMR-D	9	129	17	258	23	110
EMR-B	891	1 406	916	1 445	2 688	1 586
EMR-D	98	680	100	703	269	746
EUR-B	56	341	68	341	229	90
EUR-C	61	116	78	140	81	9
SEAR-B	0	1 245	0	1 549	0	861
SEAR-D	366	2 218	473	2 841	805	1 522
WPR-B	4 646	2 253	9 291	4 507	8 446	2 164
World (non-A)	**7 252**	**13 863**	**12 641**	**18 771**	**14 434**	**11 387**
World (non-A)	**21 115**		**31 412**		**25 821**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 20. Annual cooking-time savings (million hours)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	224	217	204	255	312	268
AFR-E	208	278	170	338	404	360
AMR-B	21	174	20	175	472	297
AMR-D	19	25	7	49	90	39
EMR-B	23	36	23	36	128	73
EMR-D	59	149	55	156	290	295
EUR-B	16	34	16	34	115	16
EUR-C	19	13	20	13	46	2
SEAR-B	35	292	0	363	154	366
SEAR-D	397	590	305	761	1 584	734
WPR-B	849	93	823	141	2 796	161
World (non-A)	**1 869**	**1 901**	**1 642**	**2 320**	**6 392**	**2 613**
World (non-A)	**3 770**		**3 962**		**9 005**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 21. Annual value of cooking-time savings (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	772	749	703	879	1 075	925
AFR-E	774	1 037	632	1 258	1 507	1 342
AMR-B	375	3 172	359	3 199	8 627	5 421
AMR-D	157	211	61	410	752	326
EMR-B	417	641	412	650	2”280	1”309
EMR-D	195	494	182	521	966	982
EUR-B	252	543	251	544	1”864	260
EUR-C	332	224	337	215	790	32
SEAR-B	231	1 923	0	2 385	1 010	2 410
SEAR-D	1 094	1 628	842	2 097	4 365	2 024
WPR-B	6 890	752	6 679	1 142	22 702	1 309
World (non-A)	**11 489**	**11 374**	**10 458**	**13 299**	**45 938**	**16 341**
World (non-A)	**22 863**		**23 757**		**62 279**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 22. Annual value of time savings (fuel collection and cooking) (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1 282	1 746	1 457	1 938	1 467	1 604
AFR-E	1 317	3 669	1 477	5 130	2 090	3 223
AMR-B	447	5 017	458	5 257	9 547	7 160
AMR-D	166	340	78	668	774	437
EMR-B	1 308	2 047	1 328	2 095	4 967	2 895
EMR-D	293	1 174	282	1 223	1 235	1 728
EUR-B	308	884	319	885	2 092	351
EUR-C	394	340	414	355	871	41
SEAR-B	231	3 168	0	3 933	1 010	3 270
SEAR-D	1 459	3 846	1 315	4 937	5 171	3 546
WPR-B	11 536	3 006	15 970	5 648	31 148	3 473
World (non-A)	**18 740**	**25 237**	**23 099**	**32 070**	**60 372**	**27 728**
World (non-A)	**43 977**		**55 169**		**88 100**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

nario III) results in benefits of 4 billion hours, or the equivalent of US$ 26 billion.

Tables 20 and 21 follow the same approach in presenting annual savings in cooking time. Scenario I leads to savings in cooking time worth 3.8 billion hours, or the equivalent of US$ 23 billion. The LPG pro-poor scenario generates similar benefits of 4.0 billion hours, or the equivalent of US$ 24 billion. At 9.0 billion hours, or the equivalent of US$ 62 billion, the improved-stove intervention (scenario III) results in considerably greater savings in cooking time than the two fuel-change interventions.

Table 22 presents the sum of Tables 19 and 21. The global annual economic benefit of reduced fuel-collection and cooking time is US$ 44 billion (scenario I), US$ 55 billion (scenario IV) and US$ 88 billion (scenario III). Globally, cooking-time savings contribute more than twice the fuel-collection time savings in the improved-stove scenario. However, for fuel-change scenario I (LPG), fuel-collection time savings are approximately equal to savings in cooking time.

3.6 Health-related productivity gains

Tables 23 and 24 present the annual sickness time avoided, Table 23 in units of million workdays gained and Table 24 in units of million US$. Scenarios I and IV give a benefit of 417 million workdays gained, or the equivalent of US$ 1.5 billion. Scenario III generates 146 million workdays through sickness time avoided, or the equivalent of US$ 510 million.

Tables 25 and 26 follow the same approach for the number of deaths averted annually. Scenarios I and IV result in 1.3 million deaths avoided, or the equivalent of US$ 39 billion. Scenario III averts 0.5 million deaths, thereby generating the equivalent of US$ 14 billion. The majority of these benefits are accounted for by WPR.

Table 27 presents health-related productivity gains as the sum of Tables 24 and 26. The global annual economic benefits are roughly US$ 40 billion for scenarios I and IV, and US$ 14 billion for scenario III. At the global level for both fuel-change and improved-stoves interventions, deaths averted account for the majority of the productivity gains from health improvements. While these interventions prevent fewer deaths than cases of disease, the economic value associated with an averted death is considerably greater than for a non-fatal case. This is especially true for ALRI and COPD, compared to lung cancer, due to the short survival time of patients with the latter.

Table 23. Annual sickness time avoided (million workdays)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	43	47	43	47	15	16
AFR-E	26	43	26	43	9	15
AMR-B	0	5	0	5	0	2
AMR-D	2	2	2	2	1	1
EMR-B	0	0	0	0	0	0
EMR-D	7	17	7	17	2	6
EUR-B	0	1	0	1	0	0
EUR-C	0	0	0	0	0	0
SEAR-B	2	17	2	17	1	6
SEAR-D	45	74	45	74	16	26
WPR-B	77	9	77	9	27	3
World (non-A)	**203**	**214**	**203**	**214**	**71**	**75**
World (non-A)	**417**		**417**		**146**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 24. Annual value of sickness time avoided (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	83	89	83	89	29	31
AFR-E	55	91	55	91	19	32
AMR-B	6	61	6	61	2	21
AMR-D	9	11	9	11	3	4
EMR-B	4	7	4	7	1	2
EMR-D	14	35	14	35	5	12
EUR-B	4	10	4	10	1	3
EUR-C	1	1	1	1	0	0
SEAR-B	11	92	11	92	4	32
SEAR-D	91	147	91	147	32	52
WPR-B	576	63	576	63	202	22
World (non-A)	**854**	**606**	**854**	**606**	**299**	**212**
World (non-A)	**1 460**		**1 460**		**511**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 25. Annual number of deaths averted (thousands)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	54	57	54	57	19	20
AFR-E	39	57	39	57	14	20
AMR-B	1	6	1	6	1	2
AMR-D	1	1	1	1	0	0
EMR-B	0	0	0	0	0	0
EMR-D	7	18	7	18	3	6
EUR-B	1	1	1	1	0	0
EUR-C	1	1	1	1	0	0
SEAR-B	1	9	1	9	0	3
SEAR-D	60	72	60	72	21	25
WPR-B	901	29	901	29	315	10
World (non-A)	**1 065**	**250**	**1 065**	**250**	**373**	**87**
World (non-A)	**1 315**		**1 315**		**460**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 26. Annual value of deaths averted (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	704	733	704	733	246	257
AFR-E	552	810	552	810	193	283
AMR-B	115	505	115	505	40	177
AMR-D	27	33	27	33	9	12
EMR-B	6	9	6	9	2	3
EMR-D	93	232	93	232	33	81
EUR-B	64	44	64	44	23	15
EUR-C	58	39	58	39	20	13
SEAR-B	30	244	30	244	10	85
SEAR-D	671	780	671	780	235	273
WPR-B	31 970	1 010	31 970	1 010	11 189	354
World (non-A)	**34 289**	**4 440**	**34 289**	**4 440**	**12 001**	**1 554**
World (non-A)	**38 729**		**38 729**		**13 555**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 27. Annual value of sickness time and deaths averted (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	787	822	787	822	275	288
AFR-E	607	901	607	901	212	315
AMR-B	121	566	121	566	42	198
AMR-D	36	45	36	45	13	16
EMR-B	10	16	10	16	3	5
EMR-D	107	267	107	267	37	94
EUR-B	68	54	68	54	24	19
EUR-C	58	39	58	39	20	14
SEAR-B	41	336	41	336	14	118
SEAR-D	762	927	762	927	267	324
WPR-B	32 546	1 073	32 546	1 073	11 391	376
World (non-A)	**35 143**	**5 046**	**35 143**	**5 046**	**12 300**	**1 766**
World (non-A)	**40 189**		**40 189**		**14 066**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

3.7 Environmental benefits

Tables 28–31 present the economic value associated with different types of environmental benefit. In Table 28, the local environmental benefits associated with less deforestation are presented; they are approximately US$ 5 billion for scenarios I and IV. The value to the local environment of 50% of solid-fuel users utilizing improved stoves is roughly US$ 2 billion annually.

Tables 29 and 30 present the estimated economic value of reducing emissions of CO_2 and CH_4, respectively, which have implications primarily for the global environment (greenhouse effect and global warming). For scenario I, the value of CO_2 reductions is approximately US$ 1 billion per year, compared with approximately US$ 2 billion for scenario IV (LPG pro-poor). The value is lower for improved stoves, at US$ 680 million annually. Negative values are recorded in the EUR region, because the increase in CO_2 emissions from switching to LPG outweighs the reduced emissions from less biomass use. For reduced CH_4 emissions, the economic values are considerably less, at under 5% of the value of CO_2 reductions.

When summated, the economic value of the local and global environmental benefits is approximately US$ 6 billion annually for scenarios I and II (see Table 31 and Annex Table B6.5), US$ 7 billion annually for scenario IV, and US$ 2 billion annually for scenario III.

3.8 Contribution to overall economic benefits

Tables 32–35 present the contribution of each category of economic benefit to overall economic benefits. As shown in Table 32, the contribution of health-care savings to overall economic benefits is insignificant, at less than 1% globally, and a maximum of 2% for individual subregions (e.g. SEAR-B urban).

Table 28. Annual value of local environmental benefits (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	285	299	76	89	98	103
AFR-E	347	616	420	808	119	212
AMR-B	28	317	29	345	10	109
AMR-D	8	46	4	91	3	16
EMR-B	0	0	0	0	0	0
EMR-D	57	130	51	117	20	45
EUR-B	38	98	36	94	13	34
EUR-C	48	33	58	39	17	11
SEAR-B	27	456	0	567	9	157
SEAR-D	328	522	293	604	113	179
WPR-B	914	136	1 413	244	314	47
World (non-A)	**2 080**	**2 652**	**2 380**	**2 998**	**715**	**912**
World (non-A)	**4 732**		**5 378**		**1 627**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 29. Annual value of global environmental benefits related to a reduction in CO_2 emissions (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	168	193	169	211	66	74
AFR-E	136	242	173	341	54	93
AMR-B	8	72	9	79	5	44
AMR-D	3	11	3	22	3	7
EMR-B	11	18	12	18	7	11
EMR-D	9	31	10	46	6	18
EUR-B	-1	-6	-1	-5	2	3
EUR-C	-1	-1	-3	-3	2	1
SEAR-B	6	65	0	80	4	37
SEAR-D	42	107	45	185	41	76
WPR-B	144	22	227	41	109	14
World (non-A)	**525**	**754**	**643**	**1 016**	**299**	**379**
World (non-A)	**1 279**		**1 659**		**678**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 30. Annual value of global environmental benefits related to a reduction in CH_4 emissions (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario IV (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	5	5	4	6	2	2
AFR-E	5	6	4	8	2	2
AMR-B	0	3	0	3	0	1
AMR-D	1	0	0	1	0	0
EMR-B	1	1	0	1	0	0
EMR-D	0	1	0	2	0	0
EUR-B	0	0	0	0	0	0
EUR-C	0	0	0	0	0	0
SEAR-B	0	3	0	3	0	1
SEAR-D	4	5	2	8	1	2
WPR-B	11	1	10	2	4	0
World (non-A)	**28**	**27**	**22**	**33**	**10**	**9**
World (non-A)	**55**		**55**		**19**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 31. Annual total value of local and global environmental benefits (million US$)

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario IV (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	458	496	250	306	166	179
AFR-E	488	864	597	1 158	175	307
AMR-B	36	393	39	427	15	154
AMR-D	11	57	7	114	6	23
EMR-B	12	19	12	19	7	11
EMR-D	66	163	61	165	26	63
EUR-B	37	92	36	89	15	36
EUR-C	48	33	54	37	19	13
SEAR-B	33	523	0	650	13	195
SEAR-D	374	634	341	797	155	257
WPR-B	1 070	159	1 650	286	427	61
World (non-A)	**2 633**	**3 433**	**3 046**	**4 047**	**1 024**	**1 300**
World (non-A)	**6 066**		**7 093**		**2 324**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 32. Health-care savings as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		Scenario II (LPG pro-poor)		Scenario III (improved stove)	
WHO subregion	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**
AFR-D	0.4	0.4	0.4	0.4	0.1	0.1
AFR-E	0.5	0.3	0.4	0.2	0.1	0.1
AMR-B	0.1	0.1	0.1	0.1	0.0	0.0
AMR-D	0.8	0.5	1.5	0.3	0.0	0.1
EMR-B	0.0	0.0	0.0	0.0	0.0	0.0
EMR-D	1.3	1.0	1.4	1.0	0.1	0.1
EUR-B	0.0	0.0	0.0	0.0	0.0	0.0
EUR-C	0.0	0.0	0.0	0.0	0.0	0.0
SEAR-B	0.3	0.2	2.1	0.1	0.0	0.0
SEAR-D	0.7	0.6	0.8	0.5	0.1	0.1
WPR-B	0.1	0.1	0.1	0.1	0.0	0.0
World (non-A)	**0.1**	**0.3**	**0.1**	**0.2**	**0.0**	**0.1**
World (non-A)	**0.2**		**0.2**		**0.0**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 33. *Time savings as a proportion of overall economic benefits*

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario II (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**
AFR-D	50.5	56.8	58.2	63.0	76.8	77.4
AFR-E	54.4	67.3	54.9	71.2	84.3	83.8
AMR-B	73.9	83.9	74.1	84.1	99.4	95.3
AMR-D	77.0	76.5	63.6	80.6	97.6	91.9
EMR-B	98.4	98.3	98.4	98.4	99.8	99.4
EMR-D	62.1	72.5	61.8	73.2	95.1	91.6
EUR-B	74.4	85.8	75.3	86.0	98.2	86.4
EUR-C	78.7	82.6	78.6	82.4	95.7	60.6
SEAR-B	75.6	78.5	0.0	79.8	97.3	91.2
SEAR-D	55.8	70.7	54.0	73.8	92.4	85.8
WPR-B	25.5	70.9	31.8	80.6	72.5	88.8
World (non-A)	**33.1**	**74.6**	**37.6**	**77.7**	**81.9**	**90.0**
World (non-A)	**48.6**		**53.8**		**84.3**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 34. *Workdays lost due to illness and deaths averted as a proportion of overall economic benefits*

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario II (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**
AFR-D	31.0	26.7	31.4	26.7	14.4	13.9
AFR-E	25.0	16.5	22.5	12.5	8.6	8.2
AMR-B	20.1	9.5	19.6	9.1	0.4	2.6
AMR-D	16.8	10.1	29.5	5.4	1.6	3.3
EMR-B	0.7	0.8	0.7	0.7	0.1	0.2
EMR-D	22.7	16.5	23.4	16.0	2.9	5.0
EUR-B	16.5	5.2	16.1	5.2	1.1	4.6
EUR-C	11.7	9.5	11.1	9.1	2.2	20.2
SEAR-B	13.3	8.3	97.9	6.8	1.4	3.3
SEAR-D	29.2	17.1	31.3	13.9	4.8	7.9
WPR-B	72.0	25.3	64.8	15.3	26.5	9.6
World (non-A)	**62.1**	**14.9**	**57.3**	**12.2**	**16.7**	**5.7**
World (non-A)	**44.5**		**39.2**		**13.5**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table 35. Environmental benefits as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to a cleaner fuel or an improved stove					
	Scenario I (LPG)		**Scenario II (LPG pro-poor)**		**Scenario III (improved stove)**	
WHO subregion	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**
AFR-D	18.1	16.1	10.0	9.9	8.7	8.6
AFR-E	20.1	15.9	22.2	16.1	7.1	8.0
AMR-B	6.0	6.6	6.3	6.8	0.2	2.1
AMR-D	5.3	12.9	5.4	13.7	0.8	4.7
EMR-B	0.9	0.9	0.9	0.9	0.1	0.4
EMR-D	14.0	10.0	13.4	9.8	2.0	3.3
EUR-B	9.0	8.9	8.5	8.7	0.7	9.0
EUR-C	9.6	7.9	10.3	8.5	2.1	19.2
SEAR-B	10.8	13.0	0.0	13.2	1.3	5.4
SEAR-D	14.3	11.7	14.0	11.9	2.8	6.2
WPR-B	2.4	3.8	3.3	4.1	1.0	1.6
World (non-A)	**4.7**	**10.2**	**5.0**	**9.8**	**1.4**	**4.2**
World (non-A)	**6.7**		**6.9**		**2.2**	

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

The value of time savings is, in most scenarios and regions, by far the most important economic benefit, although for fuel-change interventions the variation between urban and rural areas is noteworthy. For example, for scenario I, the contribution of time savings to overall economic benefit in urban WPR-B is only 26%, compared with 56% in urban SEAR-D, while for rural areas the proportion is at least 70% in almost all regions. This variation is largely due to the different assumed practices in purchasing or collecting firewood, and the use of dung and agricultural residues in rural areas. However, for improved stoves, the contributions of time savings to the overall economic benefits are more similar due to the higher importance of time savings from cooking.

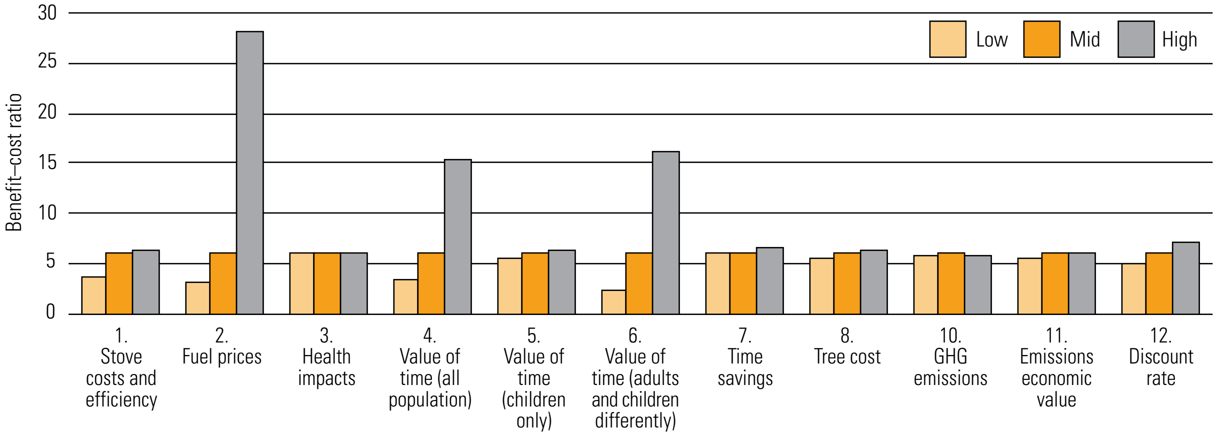
The value of workdays lost due to illness and deaths averted as a proportion of overall economic benefits is also important; as with time savings, significant variation is apparent between urban and rural areas and between regions. At the global level, gains in health-related productivity account for 62% of benefits in urban areas and 15% in rural areas for scenario I. For scenario IV, these proportions decrease to 57% and 12%, respectively. For scenario III, the contribution at global level is close to 17% and 6%, for urban and rural areas, respectively.

The value of environmental benefits as a proportion of overall economic benefits is also important, ranging between 1% and 10% of total benefits at the global level, with considerable variation between intervention scenarios and rural versus urban contexts. Globally, environmental benefits in scenarios I and IV account for roughly 5% of total economic benefits in urban areas and 10% in rural areas. For scenario III, the contribution to total economic benefits at the global level is 1% and 4% for urban and rural areas, respectively.

3.9 Sensitivity analysis

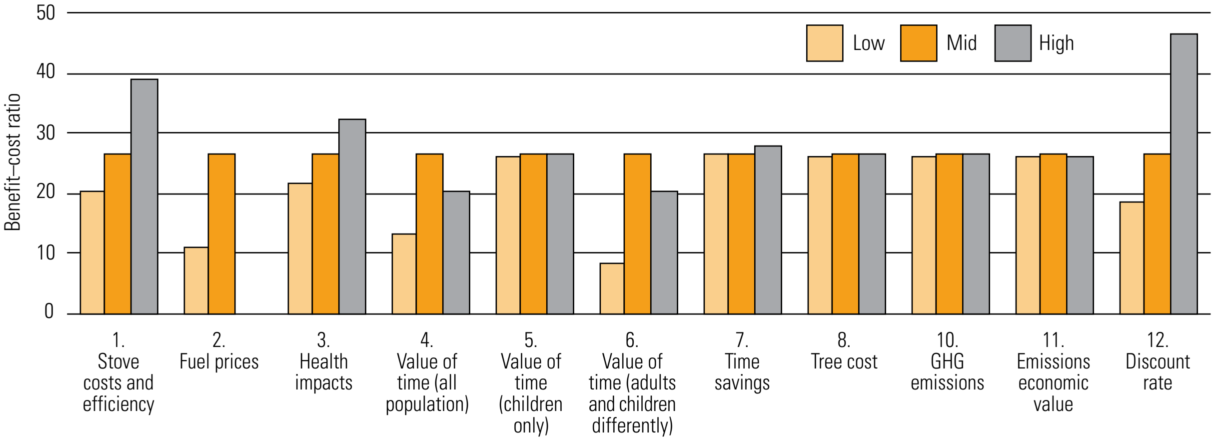
Twelve different sensitivity analyses were performed to evaluate the impact of changes in assumptions for selected variables on results and conclusions. Figures 1–4 present results for selected regions and for scenarios I and II, the latter to show the potential variability of results under an intervention promoting biofuels. Scenario III is not presented graphically, given the limited information conveyed by the negative benefit–cost ratios. All sensitivity-analysis results are presented for rural and urban areas combined. Annex Tables C present more complete results for all subregions for scenarios I and IV, and also the statistics for scenario III.

Figure 1. Variation in the benefit–cost ratios using low and high values for scenario I (liquefied petroleum gas) in AFR-D



AFR, WHO African Region; D (mortality stratum) high child, high adult; GHG, greenhouse gas.

Figure 2. Variation in the benefit–cost ratios using low and high values for scenario I (liquefied petroleum gas) in WPR-B[a]



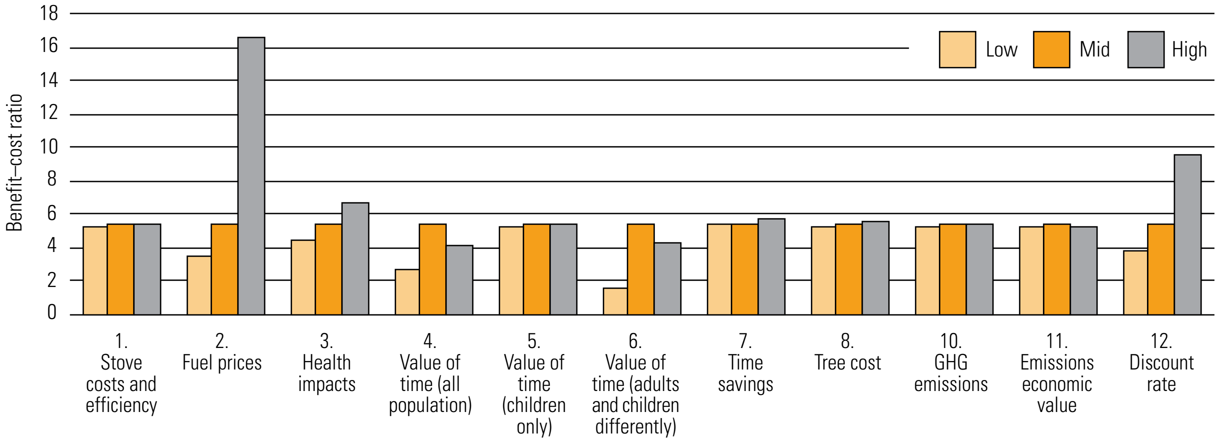
[a] A missing value for fuel prices indicates a negative BCR.

WPR, WHO Western Pacific Region; B (mortality stratum) low child, low adult; GHG, greenhouse gas.

The BCRs under different assumptions show high sensitivity, depending on the data assumptions. For scenario I (LPG), BCRs are considerably affected by changes in assumptions, especially in relation to stove costs and efficiency, fuel prices, and the value of time assigned to time savings. Globally, an alternative time value of 30% of gross national income per capita instead of the 100% GNI assumption in the base-case analysis reduces the BCR from 6.9 to 2.2. For the other variables tested in the one- and two-way sensitivity analyses, changes observed were not major, and even under pessimistic assumptions remained above a BCR of 5.0. In fact, within the range of all optimistic and pessimistic alternatives tested in one- and two-way sensitivity analyses, the BCR always remained above 2.0. It should be noted, however, that replacing all input variables with extreme values at the same time may lead to the BCR falling below 1.0. In fact, under certain optimistic assumptions, the BCR either increases to a very high number (e.g. fuel prices for AFR-D in Figure 1), or it turns negative (e.g. fuel prices for WPR-B in Figure 2), thus indicating negative net intervention costs.

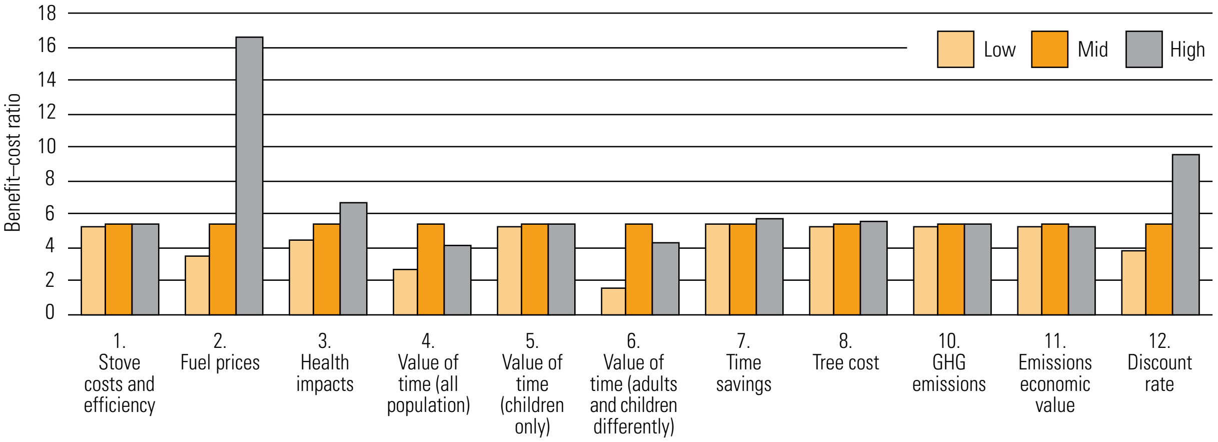
For scenario II (biofuel) the BCR stays above 1.0 under all pessimistic assumptions. Only under the low time-value assumptions and the high fuel-price assumption does the BCR fall close to 1.0

Figure 3. Variation in the benefit–cost ratios using low and high values for scenario II (biofuel) in AFR-D



AFR, WHO African Region; D (mortality stratum) high child, high adult; GHG, greenhouse gas.

Figure 4. Variation in the benefit–cost ratios using low and high values for scenario II (biofuel) in WPR-B



WPR, WHO Western Pacific Region; B (mortality stratum) low child, low adult; GHG, greenhouse gas.

for AFR-D (Figure 3). Under all other pessimistic assumptions, the one- and two-way sensitivity analysis results in a BCR above 1.5. Under optimistic scenarios, the BCR rises to over 4.0 under alternative time-value and fuel-price assumptions. For some subregions (e.g. WPR-B in Figure 4), where the minimum wage used is lower than the GNI per capita, the BCR for the "optimistic" scenario is in fact lower than the base-case result.

In conclusion, the study has shown a favourable BCR for modelled interventions, which is relatively robust to variation in the assumptions. While the base-case results reflect the best estimates or subregional averages for the input values, it is likely that the actual BCRs fall within a closer interval around the base-case value than the values suggested by the results of the sensitivity analysis. On the other hand, given that many variables are uncertain, only a sensitivity analysis which includes all types of uncertainty simultaneously will give a true indication of the extent of uncertainty in the results.

4. Discussion and conclusions

4.1 Interpretation of results

The CBA results presented in this publication demonstrate that household energy interventions are potentially highly efficient for society to undertake, when comparing the estimated intervention costs with a selection of major health and economic benefits. In terms of achieving the MDG target of halving the population without effective access to modern cooking fuels, the global economic benefits outweigh the costs approximately 7-fold. In other words, an annual net investment of US$ 13–US$ 15 billion to increase access to LPG generates economic benefits worth US$ 90–US$ 100 billion (range reflecting base-case and pro-poor approach). The actual up-front investment is roughly US$ 24 billion per year, with expected annual fuel savings of US$ 10 billion. When the intervention cost saving is added to the economic benefit instead of being subtracted from the intervention cost, the global benefit–cost ratio for Scenario I remains high at 4.3.

In terms of halving the population that does not use an improved cooking stove, the BCR is negative: in other words, the direct savings resulting from the intervention outweigh the intervention costs. The net intervention cost is *minus* US$ 34 billion annually. The actual up-front investment is roughly US$ 2 billion per year, with expected annual fuel savings of US$ 37 billion, and generates an economic benefit of US$ 105 billion. When the intervention cost saving is added to the economic benefit instead of being subtracted from the intervention cost, the global BCR for Scenario III is highly favourable at around 60.

The strength of the present CBA is that it attempts to be comprehensive by including the most important costs and benefits. It models 11 different developing and middle-income subregions separately, and presents disaggregated results for rural and urban populations in recognition of the major contextual differences. The study reveals time savings and productivity gains due to health impacts as the major components of the economic benefit estimates, and shows that environmental effects are also a significant contributor.

All costs and benefits are estimated on an annual basis, and relate to the achievement of the voluntary MDG target as well as universal coverage in 2015. Therefore, assuming a gradual scaling up of the interventions, the costs and benefits presented would not be realized in full until 2015. Also, given that the coverage data used for 2005 in fact reflect 2003 data, the findings may overestimate both costs and economic benefits in relation to the different scenarios.

As this is the first global CBA of household energy and health interventions, the results cannot be compared with or validated against the findings of other economic analyses. Only a few country studies have been conducted, such as those of Larson & Rosen (2002) in Guatemala and Kenya for reductions in mortality and in Pakistan for reductions in morbidity. These studies show that benefits outweigh costs by a factor of 10 or more (WHO, 2002).

A recent cost–effectiveness analysis of interventions to reduce indoor air pollution was conducted for a similar set of interventions (i.e. improved stoves, kerosene and LPG) in the same 11 WHO subregions, and results presented as cost per disability-adjusted life year (DALY) averted (Mehta & Shahpar, 2004). Cost-effectiveness varies greatly by subregion for the improved-stove intervention: from US$ 500–US$ 730 per DALY averted in Africa; US$ 610–US$ 1180 in South-East Asia; US$ 5880 in AMR-B; US$ 7800 in EMR-D; to as much as US$ 32 240 in WPR-B. Cost-effectiveness ratios were less favourable for LPG interventions, from US$ 1410 in WPR-B to more than US$ 6000 in all remaining subregions. Using a threshold of around US$ 500 as a benchmark for what ministries of health would be willing to spend to avert one DALY, interventions to reduce indoor air pollution do not appear to be cost-effective from a health perspective. In comparison, studies from India modelled the same interventions and found them to be cost-effective: the cost–effectiveness ratio of improved biomass stoves was estimated at US$ 50 to US$ 100 per DALY averted (Smith, 1998) while the use of kerosene and LPG stoves in rural areas in India varied from US$ 150 to US$ 200 per DALY averted (Hughes et al., 2001). Comparing the results of the global cost–effectiveness analysis by Mehta & Shahpar (2004) and the findings of the present CBA implies that cleaner-fuel and improved-stove programmes may not be justified from the health perspective alone. Yet, once wider benefits are included, household energy and health interventions generate an overall economic benefit for society.

4.2 Uncertainty and the need for further research

Given the global nature of the study, not all of the potential costs and benefits could be included, due to lack of scientific evidence or the context-specific nature of some costs and benefits. For many input variables, in the absence of data for many different countries or settings, findings from individual studies were chosen as representative at the subregional or global level.

Potential benefits of household energy and health interventions that were excluded comprise, for example, additional health effects for which the role of indoor air pollution as a risk factor remains inconclusive; potential improvements in food safety and nutrition due to the more efficient handling of available energy sources; economic benefits of switching fuel source associated with opportunities for education and income generation; the increased availability of fertilizer when switching away from use of dung and agricultural residues for cooking and heating; the exclusion of NO_2 and other gases that are potentially linked to global warming as well as the exclusion of any GHG emissions linked to charcoal manufacture.

On the other hand, some assumptions made in this study favour the interventions, such as the notion that any reduction in the burning of biomass for cooking purposes leads to an overall reduction in biomass burning, i.e. the biomass is not instead burned in the field (for example, crop residue burning or tree clearance). The assumptions in relation to health impacts are particularly questionable. First, it remains to be proven that improved stoves successfully reduce morbidity and mortality from ALRI and COPD, and, if so, by how much. Secondly, this study assumes the use of a good improved stove in good working condition with constant health impacts over time. However, it is more likely that stove performance declines over time due to little or no maintenance, which would also lead to lower health benefits over time. Finally, many households use more than one fuel or stove, while this study assumes a complete switch from traditional practices to modern practices. In reality, households almost never make a complete switch to modern fuels, given that biomass fuels are still easily available and free, and improved stoves do not always provide adequately for all household energy needs, such as space-heating.

Therefore, it is appropriate to question the validity of the results of the CBA. Uncertainty in some data and assumptions, such as those regarding fuel prices, value of time and discount rate were examined for their impact on the BCRs (see Table 5 and section 3.9). The sensitivity analyses show that the results are generally relatively robust with regard to the ranges tested. Only alternative assumptions about the value of time led to large variations in the BCR, which in some cases approached 1.0. A limitation of the sensitivity analysis is that only one-way and two-way sensitivity analyses were conducted. Consequently, the full range that the BCR could take when many or all variables are varied together in a multi-way sensitivity analysis was not examined. Furthermore, sensitivity analysis could not be undertaken for all variables, given the lack of information about the uncertainty range. However, those variables with the largest impact on overall conclusions were analysed, and the results for the base case as well as most sensitivity analyses were highly favourable. It is therefore unlikely that uncertainty in less significant variables would change the overall conclusion of the study.

Nevertheless, there is a considerable need for further research on the major determinants of the BCR, not only at the global level, where uncertainty remains high in using generalized data, but also at the country level, where types of cost and impact can vary significantly. Further applications of the model, using detailed country-level data, will therefore give a better indication of the cost–benefit implications of investing in modern fuels or improved stoves at the national or subnational levels.

4.3 Policy issues

The development impact of households moving up the energy ladder and using improved cooking stoves is clear, even in the absence of a global CBA. Yet, it is important to recognize that many barriers to successfully reducing indoor air pollution and improving household energy practices exist, including: the lack of national and state policies and leadership on household energy; apathy of governments and households and resistance to change; lack of inter-institutional coordination; lack of education and training; and household poverty and lack of access to resources (Ahmed et al., 2005). In addition to resource constraints at the household level, there are severe resource constraints at the national and international levels, given the large number of development priorities of donors and country governments. In other words, in expanding coverage of access to cleaner fuels and improved stoves, many issues must be dealt with beyond showing that household energy and health programmes are a good investment.

Although a largely academic exercise, CBA can contribute to the policy debate and help define implementation strategies. Most importantly, CBA shows not only the potential efficiency of the interventions, but also who is likely to incur the costs and who enjoys the benefits of the interventions.

Intervention costs are divided into costs related to distribution (programme costs), one-time purchase of stoves and related equipment or investments, and recurrent costs of fuel purchase and maintenance. In a pure market situation, the majority, if not all, of these costs fall on the household, and therefore the investment is a private decision. However, governments tend to intervene through initiating distribution programmes, subsidizing stoves, as in the case of many household energy projects worldwide (WHO, 2002) and running high-profile subsidy schemes such as the kerosene subsidization in India (Gangopadhyay et al., 2005). One essential function of governments in market economies is to provide enabling environments for the private sector to function. Also, nongovernmental organizations and international donors intervene regularly in the provision of essential goods where market distortions exist, or where the poor are disproportionately negatively affected by the operation of a market mechanism.

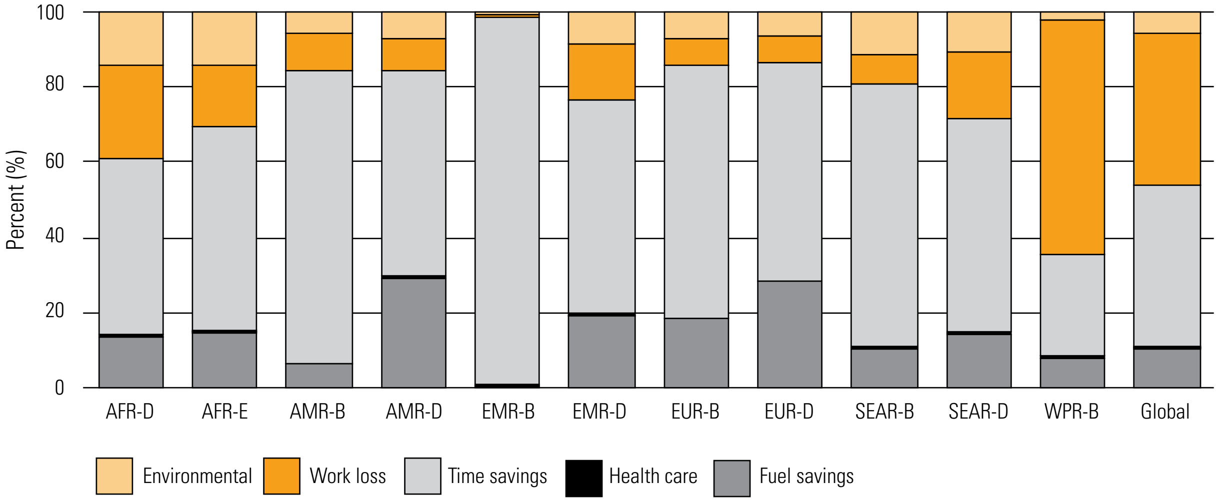
On the benefit side, Figures 5 and 6 show who enjoys the intervention benefits for Scenarios I and III, respectively. While not identical, the distribution of benefits is similar for LPG and for improved cooking stoves. Households benefit from immediate fuel savings, lower health-care expenditures, less morbidity and mortality, and time savings in relation to less illness, fuel collection and cooking. For most subregions, the most important of these is convenience-time savings, followed by fuel-cost savings and fewer workdays lost. The government also gains by averting health system costs, although the greater societal benefit is from positive impacts on the local and global environment. While the primary beneficiary is as identified above, it is expected that many benefits are shared by society more generally (e.g. subsequent community effects), and feedback to the government (e.g. in the form of more tax revenue through a more productive workforce).

The implication of private households receiving the majority of the benefits is that households should be willing to invest in fuel changes and improved stoves, once they are sufficiently aware of their positive impacts. Assuming that the results of the CBA are reliable, it follows that a good starting-point for action would be to make populations and their governments more aware of these.

However, as stated above, there are many constraints to implementing successful programmes or supporting markets to improve coverage of clean and efficient household energy solutions. In particular, global programmes such as the proposed Global Clean Cooking Fuel Initiative (Goldemberg et al., 2004) will need to develop local solutions that are appropriate to the needs and circumstances of each context. These solutions need to be tested under real-life conditions where technical performance and acceptability of interventions to the target audience can be fully assessed (WHO, 2002).

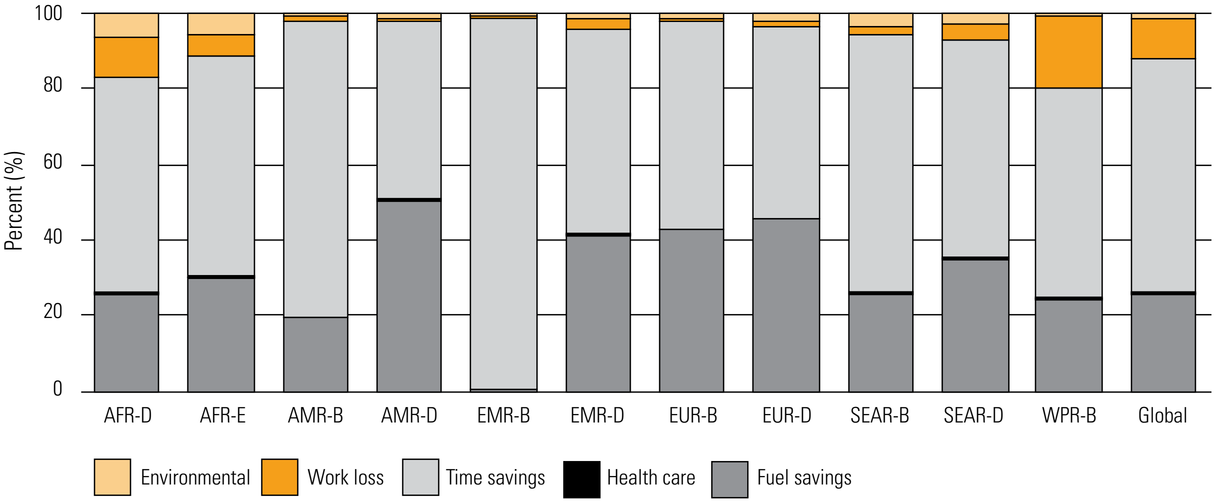
Not being able to make energy choices is associated with poverty as well as lack of physical access to interventions, and micro-credit schemes are one widely cited strategy to help poor households to purchase efficient appliances. The rationale is

Figure 5. Contribution to overall economic benefits for Scenario I



AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Figure 6. Contribution to overall economic benefits for Scenario III



AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

that credits can be paid back once the households have realized fuel cost savings, and benefited from improved health and the associated economic benefits. Given that the average household-budget share of cash energy ranges from around 2.4% in Nepal, to 4.7% in South Africa, to 5.0% in India, to 6.4% in Guatemala (Ahmed et al., 2005), these funds can contribute to adoption of more efficient fuel and stove options.

In summary, what is required to accelerate the pace of change in sustainable adoption of modern household energy practices? Critical ingredients will be a substantial increase in awareness of the problem at the international, national and local levels, inter-sectoral policies that bring together health and development efforts, and – last but not least – funding support from governments, donors and the private sector. With the new World Bank investment framework for clean energy and development[1] and the European Union Energy Facility making nearly € 200 million (approximately US$ 252 million) available for energy solutions in Africa, the Caribbean and the Pacific region,[2] funding sources that place emphasis on access to modern cooking energy are finally becoming available.

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[1] http://siteresources.worldbank.org/DEVCOMMINT/Documentation/20890696/DC2006–0002(E)-CleanEnergy.pdf

[2] http://www.euei.org/

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Annex tables

Annex Tables A. Data inputs[a]

Annex Tables A1. WHO-CHOICE data

Table A1.1 WHO Member States by WHO region and mortality stratum

WHO subregion	Mortality stratum	WHO Member States in reporting categories
AFR	D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo, Djibouti, Somalia, Sudan
AFR	E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of The Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMR	A	Canada, United States of America
AMR	B	Antigua And Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts And Nevis, Saint Lucia, Saint Vincent And The Grenadines, Suriname, Trinidad And Tobago, Uruguay, Venezuela
AMR	D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMR	B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMR	D	Afghanistan, Egypt, Iraq, Morocco, Pakistan, Yemen
EUR	A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
EUR	B	Albania, Armenia, Azerbaijan, Bosnia And Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, Turkmenistan, The Former Yugoslav Republic of Macedonia, Turkey, Uzbekistan, Yugoslavia
EUR	C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEAR	B	Democratic Republic of Timor-Leste, Indonesia, Réunion, Sri Lanka, Thailand
SEAR	D	Bangladesh, Bhutan, Democratic Peoples Republic of Korea, India, Maldives, Myanmar, Nepal,
WPR	A	Australia, Japan, New Zealand
WPR	B	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Micronesia (Federated States of), Mongolia, New Caledonia, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Vanuatu, Viet Nam,

[a] The following acronyms are used in the tables in the Annex: AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region. Mortality strata: A, very low child, very low adult; B, low child, low adult; C, low child, high adult; D, high child, high adult; E, high child, very high adult.

Table A1.2 Price multiplier[a] of medical goods imported, for different coverage levels (year 2003)

WHO subregion	Base CIF/FOB ratio[b]	50% coverage	80% coverage	95% coverage	100% coverage
AFR-D	1.44	1.451	1.455	1.459	1.463
AFR-E	1.43	1.445	1.450	1.455	1.460
AMR-B	1.27	1.277	1.277	1.280	1.284
AMR-D	1.35	1.354	1.360	1.365	1.371
EMR-B	1.29	1.291	1.293	1.298	1.307
EMR-D	1.37	1.380	1.386	1.169	1.173
EUR-B	1.22	1.224	1.226	1.228	1.230
EUR-C	1.24	1.251	1.252	1.261	1.271
SEAR-B	1.34	1.346	1.351	1.357	1.359
SEAR-D	1.25	1.250	1.253	1.255	1.257
WPR-B	1.30	1.301	1.303	1.305	1.307

Source: Johns et al. (2003).

[a] Calculated as the ratio of cost after import (c.i.f.) to cost before import (f.o.b.), taking into account the costs of transportation of traded good to the country of final destination.

[b] f.o.b., free on board – a trade term requiring the seller to deliver goods on board a vessel designated by the buyer. The seller fulfils his obligations to deliver when the goods have passed over the ship's rail.

c.i.f., cost, insurance and freight – a trade term requiring the seller to arrange for the transport of goods by sea to a port of destination, and provide the buyer with the documents necessary to obtain the goods from the carrier.

Annex Tables A2. Stove costs

Table A2.1 Improved stove costs (in US$, year 2005)

WHO subregion	World price	Price following importation	Annual price
AFR-D	6.00	8.71	3.08
AFR-E	6.00	8.67	3.07
AMR-B	6.00	7.66	2.71
AMR-D	6.00	8.12	2.87
EMR-B	6.00	7.75	2.74
EMR-D	6.00	8.28	2.93
EUR-B	6.00	7.34	2.60
EUR-C	6.00	7.51	2.65
SEAR-B	6.00	8.08	2.86
SEAR-D	6.00	7.50	2.65
WPR-B	6.00	7.81	2.76

Note: there is no distinction between urban and rural prices.

Table A2.2 Liquefied petroleum gas stove costs (stove plus cylinder) in selected countries (years 2004–2005)

WHO subregion	Country	Price (US$)
AFR-D	Cameroon	28.00
AFR-D	Ghana	70.00
AFR-D	Senegal	21.00
AFR-E	Côte d'Ivoire	37.00
AFR-E	South Africa	50.00
AMR-D	Guatemala	59.50
EMR-D	Sudan	58.00
SEAR-B	Indonesia	100.00
SEAR-B	Sri Lanka	46.00

Sources: World LP Gas Association (2004); Ahmed et al. (2005).

Table A2.3 Liquefied petroleum gas stove costs (stove plus cylinder) (in US$, year 2005)

WHO subregion	National or world price	Price following importation	Annual price
AFR-D	58.00	84.16	9.87
AFR-E	58.00	83.81	9.83
AMR-B	60.00	76.62	8.98
AMR-D	60.00	81.24	9.52
EMR-B	110.00	142.01	16.65
EMR-D	110.00	151.80	17.80
EUR-B	110.00	134.64	15.78
EUR-C	110.00	137.61	16.13
SEAR-B	100.00	134.60	15.78
SEAR-D	46.00	57.50	6.74
WPR-B	100.00	130.10	15.25

Note: there is no distinction between urban and rural prices.

Table A2.4 Biofuel stove costs (evaporative stove) (in US$, year 2005)

WHO subregion	National or world price	Price following importation	Annual price
AFR-D	35.00	50.79	5.95
AFR-E	35.00	50.58	5.93
AMR-B	35.00	44.70	5.24
AMR-D	35.00	47.39	5.56
EMR-B	35.00	45.19	5.30
EMR-D	35.00	48.30	5.66
EUR-B	35.00	42.84	5.02
EUR-C	35.00	43.79	5.13
SEAR-B	35.00	47.11	5.52
SEAR-D	35.00	43.75	5.13
WPR-B	35.00	45.54	5.34

Note: there is no distinction between urban and rural prices.

Table A2.5 Annualized programme costs per household (in US$, year 2005)

WHO subregion	Fuel change	Stove improvement
AFR-D	0.45	1.17
AFR-E	0.23	0.72
AMR-B	1.26	3.85
AMR-D	0.51	1.43
EMR-B	1.26	3.85
EMR-D	0.35	0.90
EUR-B	0.72	2.12
EUR-C	0.72	2.12
SEAR-B	0.22	0.65
SEAR-D	0.15	0.43
WPR-B	0.40	0.02

Annex Tables A3. Raw fuel-consumption data

Table A3.1 Coal consumption for selected countries

		Number of households			Fuel consumption		
WHO subregion	**Country**	**Urban**	**Rural**	**Total**	**Tonnes per year**	**Kg per household per year**	**Kg per household per day**
AFR-D	Ghana	24 636	5 227	29 864	4 000	134	0.37
AFR-E	Congo	85 057	7 318	92 375	90 000	974	2.67
AFR-E	Kenya	0	3 915	3 915	1 000	255	0.70
AFR-E	South Africa	134 868	195 878	330 746	2 516 000	7 607	20.84
EMR-D	Pakistan	39 205	167 695	206 900	1 000	5	0.01
EUR-B	Slovakia	5455	4 612	10 067	450 000	44 700	122.46
EUR-C	Estonia	0	837	837	47 000	56 134	153.79
EUR-C	Kazakhstan	27 786	203 952	231 738	7 000	30	0.08
EUR-C	Latvia	830	0	830	30 000	36 132	98.99
EUR-C	Russian Federation	259 463	0	259 463	13 054 000	50 312	137.84
EUR-C	Ukraine	107 839	82 154	189 992	2 826 000	14 874	40.75
WPR-B	China	96 432 978	0	96 432 978	69 217 000	718	1.97

Source: UN Statistics Division (2002).

Table A3.2 Charcoal consumption for selected countries

		Number of households			Fuel consumption		
WHO subregion	**Country**	**Urban**	**Rural**	**Total**	**Tonnes per year**	**Kg per household per year**	**Kg per household per day**
AFR-E	Kenya	575 412	364 131	939 543	647	689	1.89
AFR-E	Uganda	428 406	3 425 354	3 853 760	752	195	0.53
AMR-B	Brazil	13 994	573 362	587 356	674	1 148	3.14
AMR-B	Colombia	25 001	74 024	99 025	371	3 747	10.26
AMR-D	Nicaragua	6 968	41	7 009	5	713	1.95
WPR-B	Cambodia[a]	—	—	—	—	—	1.52

Source: UN Statistics Division (2002), except [a]Cambodia – National Institute of Statistics, Cambodia (1997).

Table A3.3 Firewood consumption for selected countries

WHO subregion	Country	Number of households			Fuel consumption		
		Urban	Rural	Total	Tonnes per year	Kg per household per year	Kg per household per day
AFR-D	Benin	329 939	22 335	352 273	5 975	10 601	29.04
AFR-D	Burkina Faso	979 102	1 231 514	2 210 617	15 730	4 447	12.18
AFR-D	Chad	194 292	1 026 190	1 220 482	8 414	4 309	11.80
AFR-D	Ghana	637 461	2 289 595	2 927 056	28 536	6 093	16.69
AFR-D	Mali	384 219	1 733 742	2 117 962	6 685	1 973	5.40
AFR-D	Mauritania	20 594	153 996	174 590	2 073	7 421	20.33
AFR-D	Mauritius	106	3 930	4 036	8	1 239	3.39
AFR-D	Senegal	96 357	907 861	1 004 218	4 245	2 642	7.24
AFR-E	Congo	132 542	349 651	482 194	1 636	2 121	5.81
AFR-E	Côte d'Ivoire	687 141	1 564 862	2 252 003	11 510	3 194	8.75
AFR-E	Ethiopia	1 793 377	1 0534 405	1 2327 783	90 150	4 570	12.52
AFR-E	Kenya	117 431	3 155 802	3 273 233	20 002	3 819	10.46
AFR-E	Malawi	1 751 748	196 033	1 947 781	6 940	2 227	6.10
AFR-E	Rwanda	116 398	1 552 386	1 668 784	10 350	3 876	10.62
AFR-E	Uganda	0	3 719	3 719	48 496	8 149 673	22 327.87
AFR-E	Zambia	173 140	1 204 989	1 378 130	7 219	3 274	8.97
AMR-B	Brazil	391 826	1 3078 115	1 3469 941	41 031	1 904	5.22
AMR-B	Colombia	175 005	1 327 814	1 502 819	7 597	3 159	8.66
AMR-B	Dom.Republic	32 781	165 516	198 297	556	1 752	4.80
AMR-B	Uruguay	783	26 533	27 317	2 370	54 225	148.56
AMR-D	Bolivia	23 178	894 057	917 234	2 184	1 488	4.08
AMR-D	Ecuador	1 182	89 586	90 769	4 674	32 184	88.17
AMR-D	Guatemala	711 393	5 144	716 537	14 437	12 593	34.50
AMR-D	Nicaragua	380 254	37 906	418 160	5 307	7 932	21.73
AMR-D	Peru	306 057	1 584 851	1 890 908	6 825	2 256	6.18
EMR-B	Tunisia	2 779	2 144	4 923	2 116	268 623	735.95
EMR-D	Morocco	3 417	211 067	21 4485	400	1 166	3.19
EMR-D	Pakistan	2 094 663	1 7335 436	19 430 099	30 670	987	2.70
SEAR-B	Sri Lanka	281 878	2 967 452	3249331	7 636	1 469	4.02
SEAR-D	Bangladesh	1 269 253	1 5535 376	16 804 629	27 763	1 033	2.83
SEAR-D	Myanmar	2 480 979	3 272 756	5 753 735	19 384	2 106	5.77
SEAR-D	Nepal	496 725	2 773 430	3 270 155	17 100	3 268	8.95
WPR-B	Malaysia	1 832	61 482	63 314	4 454	43 968	120.46
WPR-B	Cambodia[a]	—	—	—	—	—	1.77

Source: UN Statistics Division (2002), except [a]Cambodia – National Institute of Statistics, Cambodia (1997).

Annex Tables A4. Consolidated fuel-consumption data

Table A4.1 Coal consumption for WHO subregions based on country data (see Table A3.1)

WHO subregion	Kg per household per day	Source/assumption
AFR-D	2.67	Congo data is most reliable for AFR.
AFR-E	2.67	
AMR-B	5.00	No data available from UN Statistics Division, assumed to be between AFR/SEAR/WPR and EUR averages.
AMR-D	5.00	
EMR-B	5.00	
EMR-D	5.00	
EUR-B	10.00	EUR is large coal consumer.
EUR-C	10.00	
SEAR-B	1.97	China data is most reliable for SEAR and WPR.
SEAR-D	1.97	
WPR-B	1.97	

Table A4.2 Charcoal consumption for WHO subregions based on country data (see Table A3.2)

WHO subregion	Kg per household per day	Source/assumption
AFR-D	1.89	Kenya data is most reliable for AFR.
AFR-E	1.89	
AMR-B	3.14	Brazil is the only country with reliable data for middle-income countries.
AMR-D	3.14	
EMR-B	3.14	
EMR-D	3.14	
EUR-B	3.14	
EUR-C	3.14	
SEAR-B	1.89	Kenya data are the most appropriate for use in SEAR and WPR, and similar to data for Cambodia (1.52).
SEAR-D	1.89	
WPR-B	1.89	

Table A4.3 Firewood consumption for WHO subregions based on country data (see Table A3.3)

WHO subregion	Kg per household per day	Source/assumption
AFR-D	8.00	Although consumption per household is above 10 kg per day for several African countries, a conservative value of 8 kg per day is used.
AFR-E	8.00	
AMR-B	5.22	Large variations are recorded between AMR countries; being the largest wood-using population the value for Brazil is used.
AMR-D	5.22	
EMR-B	3.19	The value for Tunisia is unrealistic; instead the value for Morocco is used.
EMR-D	2.70	The value for Pakistan is used.
EUR-B	8.00	Being more economically advanced, per capita firewood consumption is likely to be higher for those households using firewood. A conservative estimate from AFR is used.
EUR-C	8.00	
SEAR-B	4.02	The value from Sri Lanka is used.
SEAR-D	2.83	Being the largest wood-using population, the value for Bangladesh is used; this is likely to reflect the situation in India better than values for Nepal or Myanmar.
WPR-B	5.00	Being relatively abundant in wood and more economically advanced than SEAR, a higher average of 5 kg per day is used.

Table A4.4 LPG consumption for WHO subregions based on Smith et al. (2005)

WHO subregion	Country representing subregion	Litres consumed in 2001 (million)	Population (million)	Percentage population using LPG for cooking	Consumption per person per year	Average household size	Consumption per household per day
WPR-B	China	18 527	1285.2	31.9	45.2	4.41	0.545
SEAR-D	India	11 173	1033.3	26.9	40.2	4.81	0.530
SEAR-B	Indonesia	1 610	214.4	23.0	32.6	4.53	0.405
AMR-B & AMR-D	Brazil	10 510	174.0	90.7	66.6	4.82	0.880
EMR-D	Pakistan	657	146.3	19.0	23.7	5.94	0.385
None	Bangladesh	37	140.9	13.6	1.9	4.81	0.025
None	Nigeria	24	117.8	13.4	1.5	4.83	0.020
AFR-D & AFR-E	Viet Nam[a]	354	79.2	18.9	23.6	4.41	0.285
WPR-B	Philippines	1 133	77.2	31.3	46.9	4.41	0.566
EMR-B & EUR-B & EUR-C	Egypt	4 017	69.1	90.6	64.2	6.19	1.087

[a] As no data are available from AFR-D and AFR-E, a country at similar level of development – Viet Nam – was chosen to represent this region.

Annex Tables A5. Fuel prices

Table A5.1 Liquefied petroleum gas prices used in the study (US$ per kg; year 2005)

WHO subregion	World price	Urban price	Rural price
AFR-D	0.255	0.370	0.444
AFR-E	0.255	0.368	0.442
AMR-B	0.255	0.326	0.391
AMR-D	0.255	0.345	0.414
EMR-B	0.255	0.329	0.395
EMR-D	0.255	0.352	0.422
EUR-B	0.255	0.312	0.375
EUR-C	0.255	0.319	0.383
SEAR-B	0.255	0.343	0.412
SEAR-D	0.255	0.319	0.383
WPR-B	0.255	0.332	0.398

Table A5.2 Ethanol prices used in the study (US$ per kg; year 2005)

WHO subregion	World price	Urban price	Rural price
AFR-D	0.360	0.522	0.627
AFR-E	0.360	0.520	0.624
AMR-B	0.360	0.460	0.552
AMR-D	0.360	0.487	0.585
EMR-B	0.360	0.465	0.558
EMR-D	0.360	0.497	0.596
EUR-B	0.360	0.441	0.529
EUR-C	0.360	0.450	0.540
SEAR-B	0.360	0.485	0.581
SEAR-D	0.360	0.450	0.540
WPR-B	0.360	0.468	0.562

Table A5.3 Methanol prices used in the study (US$ per kg; year 2005)

WHO subregion	World price	Urban price	Rural price
AFR-D	0.250	0.363	0.435
AFR-E	0.250	0.361	0.434
AMR-B	0.250	0.319	0.383
AMR-D	0.250	0.339	0.406
EMR-B	0.250	0.323	0.387
EMR-D	0.250	0.345	0.414
EUR-B	0.250	0.306	0.367
EUR-C	0.250	0.313	0.375
SEAR-B	0.250	0.337	0.404
SEAR-D	0.250	0.313	0.375
WPR-B	0.250	0.325	0.390

Table A5.4 Coal prices used in the study (US$ per kg; year 2005)

WHO subregion	World price	Urban price	Rural price
AFR-D	0.051	0.074	0.074
AFR-E	0.051	0.074	0.074
AMR-B	0.051	0.065	0.065
AMR-D	0.051	0.069	0.069
EMR-B	0.051	0.066	0.066
EMR-D	0.051	0.070	0.070
EUR-B	0.051	0.062	0.062
EUR-C	0.051	0.064	0.064
SEAR-B	0.051	0.069	0.069
SEAR-D	0.051	0.064	0.064
WPR-B	0.051	0.066	0.066

Table A5.5 Charcoal and wood prices for selected countries (US$ per kg; year 2005)

		Charcoal		**Firewood**	
WHO subregion	**Country**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	Burkina Faso	0.200	0.100	0.500	0.250
AFR-D	Niger	0.260	0.110	0.090	0.460
AFR-E	Rwanda	0.600	0.240	0.020	0.010
AFR-E	Uganda	0.110	–	0.040	–
AFR-E	Zambia	0.060	–	–	–
AMR-B	Argentina	0.770	–	0.440	–
AMR-B	Venezuela	0.590	–	–	–
SEAR-D	Bangladesh (source 1)	0.083	0.065	0.033	0.030
SEAR-D	Bangladesh (source 2)	0.140	–	0.044	0.025
SEAR-D	India	0.260	–	–	–
WPR-B	Philippines	0.100	0.050	0.120	0.060
WPR-B	China	1.750	–	–	–

Table A5.6 Charcoal prices used in the study (US$ per kg; year 2005)

WHO subregion	**Urban price**	**Rural price**
AFR-D	0.300	0.240
AFR-E	0.300	0.150
AMR-B	0.770	0.385
AMR-D	0.770	0.385
EMR-B	0.770	0.385
EMR-D	0.770	0.385
EUR-B	0.770	0.385
EUR-C	0.770	0.385
SEAR-B	0.260	0.130
SEAR-D	0.260	0.150
WPR-B	0.150	0.750

Table A5.7 Firewood prices used in the study (US$ per kg; year 2005)

WHO subregion	**Urban price**	**Rural price**
AFR-D	0.05	0.03
AFR-E	0.05	0.03
AMR-B	0.12	0.06
AMR-D	0.12	0.06
EMR-B	0.20	0.10
EMR-D	0.20	0.10
EUR-B	0.20	0.10
EUR-C	0.20	0.10
SEAR-B	0.12	0.06
SEAR-D	0.04	0.03
WPR-B	0.12	0.06

Annex Tables A6. Disease cases and deaths attributable to indoor air pollution

Table A6.1 ALRI cases and deaths attributable to indoor air pollution (year 2005)

	Incidence (under 5 years)		**Deaths (under 5 years)**	
WHO subregion	**Male**	**Female**	**Male**	**Female**
AFR-D	7 699 438	7 332 375	118 700	86 476
AFR-E	7 513 278	6 557 503	130 903	75 826
AMR-B	1 205 478	1 097 607	1 656	1 427
AMR-D	642 458	697 166	3 429	3 466
EMR-B	115 605	101 452	372	300
EMR-D	4 341 147	4 028 930	44 602	44 136
EUR-B	403 599	435 325	2 887	2 245
EUR-C	27 220	25 285	77	40
SEAR-B	602 113	1 359 413	1 663	3 668
SEAR-D	13 344 493	13 884 818	145 701	157 232
WPR-B	2 255 892	4 551 723	10 003	24 147
World (non-A)	**38 150 720**	**40 071 596**	**459 992**	**398 963**

ALRI, acute lower respiratory infection.
Source: WHO (2006) and unpublished data.

Table A6.2 COPD cases and deaths attributable to indoor air pollution (year 2005)

	Incidence		**Deaths**	
WHO subregion	**Male (over 30 years)**	**Female (over 30 years)**	**Male (over 30 years)**	**Female (over 30 years)**
AFR-D	18 363	17 456	8 289	10 694
AFR-E	15 856	30 642	10 004	13 446
AMR-B	8 072	17 933	2 367	5 360
AMR-D	4 001	4 039	1 085	2 069
EMR-B	1 150	2 449	148	511
EMR-D	12 662	24 677	6 577	18 737
EUR-B	1 628	12 036	777	2 845
EUR-C	310	3 965	170	730
SEAR-B	18 971	41 260	7 973	25 913
SEAR-D	77 512	275 494	49 655	154 514
WPR-B	188 964	486 519	119 546	365 812
World (non-A)	**347 489**	**916 469**	**206 590**	**600 631**

Source: WHO (2006) and unpublished data.

Table A6.3 Lung cancer cases and deaths attributable to indoor air pollution (year 2005)

WHO subregion	Incidence Male (over 30 years)	Incidence Female (over 30 years)	Deaths Male (over 30 years)	Deaths Female (over 30 years)
AFR-D	34	21	31	18
AFR-E	39	138	37	67
AMR-B	45	84	51	109
AMR-D	0	0	0	0
EMR-B	0	0	0	0
EMR-D	11	10	12	12
EUR-B	7	30	8	18
EUR-C	8	63	9	27
SEAR-B	0	0	0	0
SEAR-D	149	344	164	306
WPR-B	8 486	19 592	8 914	12 525
World (non-A)	**8 778**	**20 282**	**9 225**	**13 082**

Source: WHO (2006) and unpublished data.

Annex Tables A7. Health economic and health system variables

Table A7.1 Unit costs of outpatient and inpatient costs, excluding drugs, materials and additional procedures (US$, year 2005)

WHO subregion	Health centre Low	Health centre Mid	Health centre High	Hospital Low	Hospital Mid	Hospital High
AFR-D	0.71	1.53	4.73	2.07	6.65	45.06
AFR-E	0.91	1.95	6.04	2.64	8.49	57.49
AMR-B	2.33	4.39	8.61	8.43	34.83	63.72
AMR-D	2.78	5.23	10.26	10.05	41.51	75.94
EMR-B	1.17	3.83	13.12	3.43	25.56	73.28
EMR-D	1.10	3.60	12.34	3.23	24.04	68.93
EUR-B	0.59	2.01	4.32	2.93	15.88	36.09
EUR-C	1.00	3.40	7.30	4.95	26.84	60.99
SEAR-B	0.76	1.47	2.41	2.71	6.69	14.93
SEAR-D	0.85	1.63	2.67	3.02	7.44	16.60
WPR-B	0.75	1.29	4.07	3.04	8.40	48.36

Table A7.2 Average length of inpatient stay in hospital

	ALRI (days per case)		COPD (days per year)		Cancer (days per case)
WHO subregion	**Severe**	**Very severe**	**Moderate**	**Severe**	**All**
AFR-D	3	5	8	10	60
AFR-E	3	5	8	10	60
AMR-B	3	5	8	10	60
AMR-D	3	5	8	10	60
EMR-B	3	5	8	10	60
EMR-D	3	5	8	10	60
EUR-B	3	5	8	10	60
EUR-C	3	5	8	10	60
SEAR-B	3	5	8	10	60
SEAR-D	3	5	8	10	60
WPR-B	3	5	8	10	60

ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease.

Table A7.3 Severity and recovery time of diseases related to exposure to IAP

Variable	ALRI	COPD	Lung cancer
Severity[a] (% of patients with disease)			
1	86%	60%	
2	12%	30%	
3	2%	10%	100%
Days sick (if treated)			
1	5	25	
2	10	100	
3	15	200	125
Days sick (if not treated)			
1	10	75	
2	20	150	
3	30	250	125

IAP, indoor air pollution; ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease.

[a] 1 refers to moderate ALRI and mild COPD; 2 refers to severe ALRI and moderate COPD; 3 refers to very severe ALRI and severe COPD.

Table A7.4 Percentage of cases seeking modern health care,[a] by disease

WHO subregion	ALRI (%)	COPD (%)	Cancer (%)
AFR-D	32.99	30	20
AFR-E	55.73	30	20
AMR-B	50.30	30	20
AMR-D	43.83	30	20
EMR-B	76.80	30	20
EMR-D	59.38	30	20
EUR-B	52.53	30	20
EUR-C	47.70	30	20
SEAR-B	71.60	30	20
SEAR-D	62.03	30	20
WPR-B	64.48	30	20

ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease.

[a] These data refer equally to the percentage of people with mild cases who seek outpatient care and the percentage of patients with moderate or severe cases who are hospitalized.

Table A7.5 WHO recommendations for drugs and commodities to treat ALRI in children younger than 5 years old[a]

Inputs per delivery level	Facility level	First referral level
Pneumonia Low HIV burden	– oral amoxicillin (25 mg/kg) twice daily for 3 days – 6 doses of paracetamol (100-mg tablet) – 3 days salbutamol for 10% of cases (one 2-mg tablet, 3 times a day).	
Pneumonia High HIV burden	– oral amoxicillin (25 mg/kg) twice daily for 5 days – 6 doses of paracetamol (100-mg tablet) – 4 days salbutamol for 10% of cases (one 2-mg tablet, 3 times a day).	
Severe pneumonia	– oral antibiotic – referral	– 3 days inpatient – 3 days injectable antibiotics – 2 days oral amoxicillin – 4 days salbutamol (50% of cases) – chest X-ray (20% of cases) – oxygen (20% of cases) – IV kit, syringe, needle, cotton, oxygen tubing and nasal aspirator – 1 outpatient follow-up visit
Very severe pneumonia	– oral antibiotic – referral	– 5 days inpatient – 5 days injectable antibiotics – 5 days oral amoxicillin – 4 days salbutamol (50% of cases) – chest X-ray – oxygen (50% of cases) – 10 days injectable gentamicin – steroids (5% of cases) – IV kit, syringe, needle, cotton, oxygen tubing and nasal aspirator – 5 outpatient follow-up visits

ALRI, acute lower respiratory infection.

[a] WHO recommends different dosages depending on age and weight. The dosages in the table are based on an average weight of 10 kg.

Table A7.6 Drug and procedure costs per case (US$, year 2005)

	ALRI				COPD			Cancer	
	Moderate (OP)		Severe (IP)	Very severe (IP)	Mild (OP)	Moderate (IP)	Severe (IP)	IP	OP
WHO subregion	**Low HIV**	**High HIV**							
AFR-D	0.17	0.27	7.61	14.86	3.58	168.2	181.7	44.3	5.3
AFR-E	0.17	0.27	7.60	14.80	3.07	167.0	180.4	44.0	5.3
AMR-B	0.15	0.24	16.32	22.71	64.90	148.3	160.2	39.1	4.7
AMR-D	0.16	0.25	16.45	23.24	68.99	157.7	170.3	41.5	5.0
EMR-B	0.15	0.24	13.12	19.62	65.92	150.7	162.7	39.7	4.8
EMR-D	0.16	0.26	13.25	20.15	70.01	160.0	172.8	42.1	5.1
EUR-B	0.14	0.23	15.87	22.01	62.34	142.5	153.9	37.5	4.5
EUR-C	0.14	0.23	15.90	22.14	63.36	144.8	156.4	38.1	4.6
SEAR-B	0.16	0.25	11.80	18.55	68.47	156.5	169.1	41.2	4.9
SEAR-D	0.15	0.24	8.61	14.90	63.88	146.0	157.7	38.4	4.6
WPR-B	0.15	0.24	11.74	18.28	66.43	151.8	164.0	40.0	4.8

ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease; OP, outpatient; IP, inpatient.

Annex Tables A8. Productivity gain data

Table A8.1 Workdays lost due to illness

Disease	Severity	Treated or untreated	Time incapacitated
ALRI	Non-severe	Treated	5 days
		Untreated (or mistreated)	10 days
	Severe	Treated	10 days
		Untreated (or mistreated)	20 days
	Very severe	Treated	15 days
		Untreated (or mistreated)	30 days
COPD	Stage I	Treated	10% of time
		Untreated (or mistreated)	30% of time
	Stage II	Treated	40% of time
		Untreated (or mistreated)	60% of time
	Stage III	Treated	80% of time
		Untreated (or mistreated)	100% of time
Lung cancer	Final year	Treated or untreated	100% of time

ALRI, acute lower respiratory infection; COPD, chronic obstructive pulmonary disease.

Table A8.2 Value of time (US$, year 2005)

	Annual value		Daily value[a]	
WHO subregion	**GNI**	**Minimum wage**	**GNI**	**Minimum wage**
AFR-D	792	2 329	3.45	10.13
AFR-E	857	4 295	3.73	18.67
AMR-B	4 201	2 227	18.27	9.68
AMR-D	1 928	1 603	8.38	6.97
EMR-B	4 107	2 334	17.86	10.15
EMR-D	765	876	3.33	3.81
EUR-B	3 722	6 342	16.18	27.58
EUR-C	3 919	1 113	17.04	4.84
SEAR-B	1 513	647	6.58	2.81
SEAR-D	634	331	2.76	1.44
WPR-B	1 867	1 438	8.12	6.25

[a] The daily value is calculated by dividing the annual value by the number of working days (i.e. 230 days per year based on 5 working days a week minus 30 days holiday).

Annex Tables A9. Firewood-collection times

Table A9.1 Firewood-collection times for selected countries (hours per day per household)

WHO subregion	Country	Low	Mean	High
AFR-D	Burkina Faso	0.10	2.40	4.50
AFR-D	Ghana	0.20	0.70	1.40
AFR-D	Niger	2.00	4.00	6.00
AFR-D	Nigeria	0.10	0.30	0.60
AFR-E	Botswana	0.30	0.60	1.20
AFR-E	Ethiopia	0.90	3.30	6.30
AFR-E	Kenya	0.10	0.80	1.90
AFR-E	Malawi	0.57	1.07	2.14
AFR-E	Namibia	1.00	1.50	2.00
AFR-E	South Africa	0.90	1.30	2.60
AFR-E	Uganda	1.00	2.00	4.00
AFR-E	Tanzania	0.30	0.60	1.10
AFR-E	Zambia	0.35	0.70	1.90
AFR-E	Zimbabwe	0.25	0.50	0.64
EMR-D	Sudan	0.85	1.70	3.40
SEAR-B	Indonesia	0.15	0.30	0.60
SEAR-D	India	0.33	0.67	1.00
SEAR-D	Nepal	0.83	1.66	3.20
WPR-B	China	0.23	1.94	2.09

Source: Dutta S (2005). Energy as a key variable in eradicating extreme poverty and hunger: A gender and energy perspective on empirical evidence on MDG #1. Report to United Kingdom Department for International Development (DfID)/ENERGIA International Network on Gender and Sustainable Energy. Project on gender as a key variable in energy interventions. Draft version, September 2005 and further Internet and literature searches.

Table A9.2 Firewood-collection times, by WHO subregion (hours per day per household)

WHO subregion	**Low**	**Mean**	**High**	**Comment**
AFR-D	0.26	0.79	1.40	An average of sample countries is used.
AFR-E	0.58	1.54	3.02	An average of sample countries is used.
AMR-B	0.15	0.30	0.60	AMR being timber-rich, SEAR-B estimates are applied (Indonesia).
AMR-D	0.15	0.30	0.60	
EMR-B	0.58	1.54	3.02	Given the extremely low use of firewood and its inaccessibility, AFR-E estimates are applied.
EMR-D	0.35	0.69	1.05	As the main wood-using country in EMR-D is Pakistan, the average for SEAR-D is applied.
EUR-B	0.15	0.30	0.60	EUR being timber-rich, SEAR-B estimates are applied (Indonesia).
EUR-C	0.15	0.30	0.60	
SEAR-B	0.15	0.30	0.60	The only sample country is Indonesia.
SEAR-D	0.35	0.69	1.05	A weighted average of data from India and Nepal is used.
WPR-B	0.23	1.94	2.09	The only sample country is China.

Annex Tables A10. Environmental variables

Table A10.1 Kilograms of CO_2 and CH_4 emissions per kg of fuel burnt

	CO_2		**CH_4**	
Fuel type	**Mean**	**Range**	**Mean**	**Range**
LPG	3085 (LPG)[a]	3190 (LPG)[b] 2993 (liquid gas)[c] 2950 (LPG)[d]	0.054	
Ethanol	2900 (ethane)[d]		0.054*	
Coal	2031	1840[d] 952–3110[c]	12*	
Charcoal	2411[a]	2570[e] 2155–2567[e] 1350–3300[f]	7.906[a]	6.7–7.8[e] 18–270[f]
Non-renewably harvested wood	1688[a]	1590[e] 1560–1620[e] 1397–1980[a]	8[e] 8.5[a]	6–10[e] 4–13[a]
Renewably-harvested wood	200*		1*	
Dung	1005	974–1063[a]	10.53	3–18[a]
Agricultural residues	1005*		10.53*	
Kerosene	2575 turbin kerosene	2333–3119	0.64	0.3–1[a]

CO_2, carbon dioxide; CH_4, methane.

* Indicates the assumption used due to lack of data sources; [a] Smith et al. (2000a); [b] Smith et al. (2000b); [c] Web site: http://www.umwelt-bundesamt.de/uba-info-daten-e/daten-e/carbon-dioxide-emissions.htm; [d] Thomas C, Tennant T, Rolls J (2000). *The GHG Indicator: UNEP Guidelines for Calculating Greenhouse Gas Emissions for Businesses and Non-Commercial Organisations*. Paris, United Nations Environment Programme (http://www.uneptie.org/energy/publications/files/ghgind.htm); [e] http://listserv.repp.org/pipermail/gasification/2004-May/001048.html; [f] Kammen DM, Lew DJ (2005). *Review of technologies for the production and use of charcoal*. Colorado, National Renewable Energy Laboratory.

Table A10.2 Woody biomass cover and change from 1990 to 2000 (million tonnes)

	Woody biomass		**Change from 1990 to 2000**	
World region	**1990**	**2000**	**Amount**	**Percentage**
Africa	115.80	107.20	-8.600	-7.43
Asia	91.74	91.12	-0.620	-0.68
Oceania	16.39	16.08	-0.306	-1.87
Europe	58.44	58.96	0.516	0.88
North and Central America	59.55	58.96	-0.591	-0.99
South America	212.16	203.68	-8.477	-4.00
World	**554.08**	**536.00**	**-18.078**	**-3.26**

Source: Garzuglia M, Saket M (2003). *Wood volume and woody biomass. Review of FRA 2000 estimates*. Rome, Forestry Department. Food and Agriculture Organization.Working Paper 68. Forestry Resources Assessment Programme.

Annex Tables B. Detailed results of interventions II, V, VI, VII, VIII

Annex Tables B1. Population targeted

Table B1.1 Population (million) targeted for 50% fuel-change interventions – moving from coal

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	3.22	0.58	3.80	0.56	0.95	1.09	1.20
AFR-E	10.47	2.00	12.47	2.02	3.30	3.63	3.52
AMR-B	0.97	3.90	4.88	0.42	0.84	1.22	2.40
AMR-D	3.04	0.01	3.05	0.34	0.65	0.85	1.20
EMR-B	0.40	0.25	0.64	0.06	0.12	0.18	0.29
EMR-D	0.48	0.65	1.13	0.14	0.25	0.32	0.41
EUR-B	0.37	0.13	0.50	0.04	0.07	0.12	0.27
EUR-C	0.64	0.44	1.09	0.06	0.12	0.21	0.70
SEAR-B	0.19	0.00	0.19	0.02	0.03	0.05	0.10
SEAR-D	17.85	3.14	20.99	1.98	3.91	5.67	9.43
WPR-B	57.10	1.66	58.76	4.00	7.61	13.53	33.63
World (non-A)	**94.73**	**12.76**	**107.49**	**9.63**	**17.85**	**26.86**	**53.14**

Table B1.2 Population (million) targeted for 50% fuel-change interventions – moving from charcoal

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	18.71	3.91	22.61	3.35	5.67	6.49	7.11
AFR-E	17.96	18.75	36.72	5.82	9.64	10.76	10.50
AMR-B	0.64	2.53	3.17	0.27	0.55	0.79	1.56
AMR-D	3.70	0.30	4.00	0.45	0.85	1.12	1.59
EMR-B	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EMR-D	0.59	1.35	1.94	0.25	0.44	0.55	0.71
EUR-B	0.10	0.05	0.16	0.01	0.02	0.04	0.08
EUR-C	0.14	0.16	0.30	0.02	0.03	0.06	0.19
SEAR-B	12.41	0.37	12.78	1.00	2.10	3.08	6.60
SEAR-D	36.72	3.40	40.12	3.78	7.45	10.83	18.06
WPR-B	99.72	7.20	106.92	7.33	13.95	24.70	60.94
World (non-A)	**190.71**	**38.01**	**228.72**	**22.27**	**40.70**	**58.41**	**107.34**

Table B1.3 Population (million) targeted for 50% fuel-change interventions – moving from fuel wood

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	32.36	40.40	72.76	11.02	18.54	20.93	22.27
AFR-E	29.27	72.39	101.65	15.95	26.54	29.90	29.27
AMR-B	4.26	57.04	61.30	5.22	10.63	15.32	30.14
AMR-D	0.22	9.05	9.27	0.95	1.84	2.54	3.95
EMR-B	0.06	0.04	0.09	0.01	0.02	0.03	0.04
EMR-D	25.00	57.32	82.32	10.45	18.59	23.26	30.03
EUR-B	3.85	11.39	15.23	1.11	2.18	3.65	8.29
EUR-C	3.51	2.40	5.91	0.32	0.63	1.17	3.80
SEAR-B	0.00	104.17	104.17	8.12	17.11	25.21	53.72
SEAR-D	82.62	185.81	268.43	25.95	50.91	72.98	118.59
WPR-B	117.41	22.39	139.81	9.74	18.60	32.55	78.92
World (non-A)	**298.55**	**562.40**	**860.95**	**88.82**	**165.60**	**227.52**	**379.02**

Table B1.4 Population (million) targeted for 50% fuel-change interventions – moving from dung and agricultural residues

				By age group			
WHO subregion	**Urban**	**Rural**	**Total**	**0–4 years**	**5–14 years**	**15–29 years**	**30+ years**
AFR-D	36.28	48.79	85.07	12.89	21.70	24.47	26.01
AFR-E	5.23	15.13	20.36	3.19	5.31	5.99	5.87
AMR-B	0.89	0.95	1.83	0.16	0.32	0.46	0.90
AMR-D	0.89	0.84	1.73	0.19	0.36	0.48	0.71
EMR-B	10.55	17.90	28.45	2.80	5.11	7.84	12.71
EMR-D	1.39	10.59	11.99	1.53	2.70	3.40	4.36
EUR-B	0.60	0.61	1.21	0.09	0.18	0.29	0.66
EUR-C	0.14	0.00	0.14	0.01	0.01	0.03	0.09
SEAR-B	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEAR-D	7.14	42.08	49.22	4.79	9.39	13.41	21.63
WPR-B	9.65	2.31	11.97	0.84	1.60	2.79	6.73
World (non-A)	**72.77**	**139.20**	**211.97**	**26.48**	**46.67**	**59.15**	**79.67**

Annex Tables B2. Intervention costs

Table B2.1 Annual intervention cost (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1 870	2 150	1 870	2 150	1 730	1 940	3 740	4 300	180	160
AFR-E	1 720	2 740	1 720	2 740	1 590	2 470	3 440	5 480	220	200
AMR-B	450	4 520	450	4 520	370	3 740	890	9 050	510	320
AMR-D	430	690	430	690	360	570	860	1 390	60	30
EMR-B	630	1 160	630	1 160	550	990	1 270	2 330	130	80
EMR-D	620	1 860	620	1 860	630	1 820	1 230	3 730	150	160
EUR-B	400	1 030	400	1 030	350	880	800	2 060	70	10
EUR-C	510	410	510	410	440	350	1 020	830	40	0
SEAR-B	380	3 750	380	3 750	370	3 560	760	7 500	70	170
SEAR-D	5 130	9 120	5 130	9 120	4 300	7 550	10 270	18 240	670	310
WPR-B	11 980	1 560	11 980	1 560	11 130	1 410	23 970	3 120	1 030	60
World (non-A)	**24 120**	**28 990**	**24 120**	**28 990**	**21 820**	**25 280**	**48 250**	**58 030**	**3 130**	**1 500**
World (non-A)	**53 110**		**53 110**		**47 100**		**106 280**		**4 630**	

Table B2.2 Annual fuel-cost savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	770	130	110	20	3 080	540	3 080	540	2 370	370
AFR-E	1 030	360	580	190	4 120	1 430	4 120	1 430	4 430	1 020
AMR-B	140	300	100	190	580	1 200	580	1 200	7 360	1 130
AMR-D	240	30	50	50	940	130	940	130	2 490	110
EMR-B	0	0	0	0	20	10	20	10	60	10
EMR-D	340	160	280	110	1 380	630	1 380	630	3 770	690
EUR-B	230	100	200	90	910	380	910	380	3 730	100
EUR-C	310	60	320	40	1 230	220	1 230	220	1 610	20
SEAR-B	260	260	0	320	1 040	1 030	1 040	1 030	2 510	710
SEAR-D	1 150	170	360	140	4 610	680	4 610	680	10 160	470
WPR-B	3 890	510	4 830	220	15 570	2 020	15 570	2 020	28 310	1 940
World (non-A)	**8 360**	**2 080**	**6 830**	**1 370**	**33 480**	**8 270**	**33 480**	**8 270**	**66 800**	**6 570**
World (non-A)	**10 440**		**8 200**		**41 750**		**41 750**		**73 370**	

Table B2.3 Annual net intervention costs (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1 100	2 020	1 760	2 130	-1 350	1 400	660	3 760	-2 190	-210
AFR-E	690	2 380	1 140	2 550	-2 530	1 040	-680	4 050	-4 210	-820
AMR-B	310	4 220	350	4 330	-210	2 540	310	7 850	-6 850	-810
AMR-D	190	660	380	640	-580	440	-80	1 260	-2 430	-80
EMR-B	630	1 160	630	1 160	530	980	1 250	2 320	70	70
EMR-D	280	1 700	340	1 750	-750	1 190	-150	3 100	-3 620	-530
EUR-B	170	930	200	940	-560	500	-110	1 680	-3 660	-90
EUR-C	200	350	190	370	-790	130	-210	610	-1 570	-20
SEAR-B	120	3 490	380	3 430	-670	2 530	-280	6 470	-2 440	-540
SEAR-D	3 980	8 950	4 770	8 980	-310	6 870	5 660	17 560	-9 490	-160
WPR-B	8 090	1 050	7 150	1 340	-4 440	-610	8 400	1 100	-27 280	-1 880
World (non-A)	**15 760**	**26 910**	**17 290**	**27 620**	**-11 660**	**17 010**	**14 770**	**49 760**	**-63 670**	**-5 070**
World (non-A)	**42 670**		**44 910**		**5 350**		**64 530**		**-68 740**	

Annex Tables B3. Health-care cost savings

Table B3.1 Annual value of health-system cost savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	9	9	9	9	18	18	18	18	3	3
AFR-E	10	16	10	16	20	33	20	33	3	5
AMR-B	0	4	0	4	1	9	1	9	0	2
AMR-D	2	2	2	2	3	4	3	4	1	1
EMR-B	0	0	0	0	1	1	1	1	0	0
EMR-D	6	16	6	16	12	31	12	31	2	5
EUR-B	0	0	0	0	0	1	0	1	0	0
EUR-C	0	0	0	0	0	0	0	0	0	0
SEAR-B	1	7	1	7	2	14	2	14	0	3
SEAR-D	17	29	17	29	35	57	35	57	7	11
WPR-B	31	3	31	3	62	7	62	7	16	2
World (non-A)	**77**	**88**	**77**	**88**	**153**	**175**	**153**	**175**	**31**	**30**
World (non-A)	**165**		**165**		**328**		**328**		**61**	

Table B3.2 Annual value of patient-cost savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1.5	1.7	1.5	1.7	3.0	3.3	3.0	3.3	0.4	0.4
AFR-E	0.8	1.3	0.8	1.3	1.6	2.7	1.6	2.7	0.2	0.3
AMR-B	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0
AMR-D	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
EMR-B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMR-D	0.2	0.5	0.2	0.5	0.4	1.0	0.4	1.0	0.0	0.1
EUR-B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUR-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEAR-B	0.0	0.2	0.0	0.2	0.1	0.5	0.1	0.5	0.0	0.1
SEAR-D	1.0	1.6	1.0	1.6	1.9	3.2	1.9	3.2	0.2	0.4
WPR-B	0.7	0.1	0.7	0.1	1.3	0.2	1.3	0.2	0.2	0.0
World (non-A)	**4.3**	**5.6**	**4.3**	**5.6**	**8.5**	**11.3**	**8.5**	**11.3**	**1.0**	**1.4**
World (non-A)	**9.9**		**9.9**		**19.8**		**19.8**		**2.4**	

Table B3.3 Annual value of total health-care cost savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	10	11	10	11	21	22	21	22	3	3
AFR-E	11	18	11	18	22	36	22	36	3	5
AMR-B	0	4	0	4	1	9	1	9	0	2
AMR-D	2	2	2	2	4	4	4	4	1	1
EMR-B	0	0	0	0	1	1	1	1	0	0
EMR-D	6	16	6	16	12	32	12	32	2	5
EUR-B	0	0	0	0	0	1	0	1	0	0
EUR-C	0	0	0	0	0	0	0	0	0	0
SEAR-B	1	7	1	7	2	14	2	14	0	3
SEAR-D	18	30	18	30	37	61	37	61	7	11
WPR-B	31	4	31	4	63	7	63	7	16	2
World (non-A)	**81**	**93**	**81**	**93**	**162**	**186**	**162**	**186**	**32**	**32**
World (non-A)	**174**		**174**		**348**		**348**		**64**	

Annex Tables B4. Time savings

Table B4.1 Annual fuel-collection time savings (million hours)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	148	289	219	307	296	579	296	579	228	394
AFR-E	146	707	227	1 039	292	1 413	292	1 413	313	1 010
AMR-B	4	101	5	113	8	202	8	202	101	190
AMR-D	1	15	2	31	2	31	2	31	5	26
EMR-B	50	79	51	81	100	157	100	157	301	178
EMR-D	29	204	30	211	59	409	59	409	161	448
EUR-B	3	21	4	21	7	42	7	42	28	11
EUR-C	4	7	5	8	7	14	7	14	9	1
SEAR-B	0	189	0	235	0	379	0	379	0	262
SEAR-D	133	805	172	1 031	265	1 609	265	1 609	584	1 104
WPR-B	572	278	1 144	555	1 144	555	1 144	555	2 080	533
World (non-A)	**1 090**	**2 695**	**1 859**	**3 633**	**2 180**	**5 390**	**2 180**	**5 390**	**3 812**	**4 158**
World (non-A)	**3 785**		**5 492**		**7 570**		**7 570**		**7 970**	

Table B4.2 Annual value of fuel-collection time savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	510	997	754	1 059	1”020	1 994	1 020	1 994	784	1 359
AFR-E	543	2 633	845	3 872	1 086	5 265	1 086	5 265	1 167	3 762
AMR-B	72	1 845	99	2 058	145	3 689	145	3 689	1 839	3 478
AMR-D	9	129	17	258	17	258	17	258	46	220
EMR-B	891	1 406	916	1 445	1 782	2 812	1 782	2 812	5 376	3 171
EMR-D	98	680	100	703	196	1 360	196	1 360	537	1 491
EUR-B	56	341	68	341	112	683	112	683	457	181
EUR-C	61	116	78	140	123	233	123	233	161	18
SEAR-B	0	1 245	0	1 549	0	2 489	0	2 489	0	1 721
SEAR-D	366	2 218	473	2 841	731	4 436	731	4 436	1 611	3 044
WPR-B	4 646	2 253	9 291	4 507	9 291	4 507	9 291	4 507	16 891	4 327
World (non-A)	**7 252**	**13 863**	**12 641**	**18 771**	**14 503**	**27 726**	**14 503**	**27 726**	**28 868**	**22 774**
World (non-A)	**21 115**		**31 412**		**42 229**		**42 229**		**51 642**	

Table B4.3 Annual cooking-time savings (million hours)

	By 2015, reduce by 50% population without access to biofuels				**By 2015, 100% access to a cleaner fuel or an improved stove**					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	224	217	204	255	448	435	448	435	624	537
AFR-E	208	278	170	338	416	557	416	557	809	721
AMR-B	21	174	20	175	41	347	41	347	945	594
AMR-D	19	25	7	49	37	50	37	50	179	78
EMR-B	23	36	23	36	47	72	47	72	255	147
EMR-D	59	149	55	156	117	297	117	297	581	591
EUR-B	16	34	16	34	31	67	31	67	230	32
EUR-C	19	13	20	13	39	26	39	26	93	4
SEAR-B	35	292	0	363	70	585	70	585	307	733
SEAR-D	397	590	305	761	793	1 181	793	1 181	3 168	1 469
WPR-B	849	93	823	141	1 697	185	1 697	185	5 592	322
World (non-A)	**1 869**	**1 901**	**1 642**	**2 320**	**3 737**	**3 802**	**3 737**	**3 802**	**12 783**	**5 226**
World (non-A)	**3 770**		**3 962**		**7 539**		**7 539**		**18 009**	

Table B4.4 Annual value of cooking-time savings (million US$)

	By 2015, reduce by 50% population without access to biofuels				**By 2015, 100% access to a cleaner fuel or an improved stove**					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	772	749	703	879	1 544	1 498	1 544	1 498	2 151	1 850
AFR-E	774	1 037	632	1 258	1 548	2 073	1 548	2 073	3 014	2 685
AMR-B	375	3 172	359	3 199	749	6 345	749	6 345	17 254	10 842
AMR-D	157	211	61	410	314	422	314	422	1 503	653
EMR-B	417	641	412	650	834	1 281	834	1 281	4 559	2 619
EMR-D	195	494	182	521	390	989	390	989	1 932	1 965
EUR-B	252	543	251	544	504	1 086	504	1 086	3 728	521
EUR-C	332	224	337	215	664	448	664	448	1 580	64
SEAR-B	231	1 923	0	2 385	462	3 846	462	3 846	2 020	4 820
SEAR-D	1 094	1 628	842	2 097	2 187	3 255	2 187	3 255	8 731	4 048
WPR-B	6 890	752	6 679	1 142	13 781	1 505	13 781	1 505	45 404	2 618
World (non-A)	**11 489**	**11 374**	**10 458**	**13 299**	**22 977**	**22 747**	**22 977**	**22 747**	**91 876**	**32 683**
World (non-A)	**22 863**		**23 757**		**45 724**		**45 724**		**124 559**	

Table B4.5 Annual value of time savings (fuel collection and cooking) (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1 282	1 746	1 457	1 938	2 564	3 492	2 564	3 492	2 934	3 209
AFR-E	1 317	3 669	1 477	5 130	2 634	7 338	2 634	7 338	4 181	6 447
AMR-B	447	5 017	458	5 257	894	10 034	894	10 034	19 093	14 320
AMR-D	166	340	78	668	331	680	331	680	1 549	873
EMR-B	1 308	2 047	1 328	2 095	2 616	4 093	2 616	4 093	9 935	5 790
EMR-D	293	1 174	282	1 223	586	2 349	586	2 349	2 470	3 456
EUR-B	308	884	319	885	616	1 769	616	1 769	4 185	701
EUR-C	394	340	414	355	787	681	787	681	1 741	82
SEAR-B	231	3 168	0	3 933	462	6 336	462	6 336	2 020	6 541
SEAR-D	1 459	3 846	1 315	4 937	2 918	7 691	2 918	7 691	10 341	7 092
WPR-B	11 536	3 006	15 970	5 648	23 072	6 011	23 072	6 011	62 295	6 945
World (non-A)	**18 740**	**25 237**	**23 099**	**32 070**	**37 480**	**50 473**	**37 480**	**50 473**	**120 744**	**55 457**
World (non-A)	**43 977**		**55 169**		**87 953**		**87 953**		**17 6201**	

Annex Tables B5. Health-related productivity gains

Table B5.1 Annual sickness time avoided (million workdays)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	43	47	43	47	86	93	86	93	30	33
AFR-E	26	43	26	43	52	85	52	85	18	30
AMR-B	0	5	0	5	1	9	1	9	0	3
AMR-D	2	2	2	2	3	4	3	4	1	1
EMR-B	0	0	0	0	1	1	1	1	0	0
EMR-D	7	17	7	17	13	35	13	35	5	12
EUR-B	0	1	0	1	1	2	1	2	0	1
EUR-C	0	0	0	0	0	0	0	0	0	0
SEAR-B	2	17	2	17	4	33	4	33	1	12
SEAR-D	45	74	45	74	91	149	91	149	32	52
WPR-B	77	9	77	9	153	17	153	17	54	6
World (non-A)	**203**	**214**	**203**	**214**	**405**	**428**	**405**	**428**	**142**	**150**
World (non-A)	**417**		**417**		**833**		**833**		**292**	

Table B5.2 Annual value of sickness time avoided (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	83	89	83	89	166	177	166	177	58	62
AFR-E	55	91	55	91	110	183	110	183	38	64
AMR-B	6	61	6	61	13	122	13	122	4	43
AMR-D	9	11	9	11	18	23	18	23	6	8
EMR-B	4	7	4	7	8	13	8	13	3	5
EMR-D	14	35	14	35	27	70	27	70	10	24
EUR-B	4	10	4	10	8	20	8	20	3	7
EUR-C	1	1	1	1	2	1	2	1	1	0
SEAR-B	11	92	11	92	22	183	22	183	8	64
SEAR-D	91	147	91	147	182	294	182	294	64	103
WPR-B	576	63	576	63	1 151	125	1 151	125	403	44
World (non-A)	**854**	**606**	**854**	**606**	**1 707**	**1 212**	**1 707**	**1 212**	**597**	**424**
World (non-A)	**1 460**		**1 460**		**2 919**		**2 919**		**1 021**	

Table B5.3 Annual number of deaths averted (thousands)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	54	57	54	57	108	113	108	113	38	40
AFR-E	39	57	39	57	77	115	77	115	27	40
AMR-B	1	6	1	6	3	13	3	13	1	4
AMR-D	1	1	1	1	2	2	2	2	1	1
EMR-B	0	0	0	0	0	0	0	0	0	0
EMR-D	7	18	7	18	14	36	14	36	5	13
EUR-B	1	1	1	1	2	1	2	1	1	0
EUR-C	1	1	1	1	2	1	2	1	1	0
SEAR-B	1	9	1	9	2	17	2	17	1	6
SEAR-D	60	72	60	72	120	143	120	143	42	50
WPR-B	901	29	901	29	1 801	57	1 801	57	630	20
World (non-A)	**1 065**	**250**	**1 065**	**250**	**2 130**	**499**	**2 130**	**499**	**746**	**175**
World (non-A)	**1 315**		**1 315**		**2 629**		**2 629**		**921**	

Table B5.4 Annual value of deaths averted (million US$)

	By 2015, reduce by 50% population without access to biofuels				**By 2015, 100% access to a cleaner fuel or an improved stove**					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	704	733	704	733	1 407	1 467	1 407	1 467	493	513
AFR-E	552	810	552	810	1 104	1 619	1 104	1 619	386	567
AMR-B	115	505	115	505	230	1 010	230	1 010	80	354
AMR-D	27	33	27	33	54	67	54	67	19	23
EMR-B	6	9	6	9	11	18	11	18	4	6
EMR-D	93	232	93	232	187	465	187	465	65	163
EUR-B	64	44	64	44	129	88	129	88	45	31
EUR-C	58	39	58	39	115	77	115	77	40	27
SEAR-B	30	244	30	244	59	489	59	489	21	171
SEAR-D	671	780	671	780	1 343	1 560	1 343	1 560	470	546
WPR-B	31 970	1 010	31 970	1 010	63 940	2 021	63 940	2 021	22 379	707
World (non-A)	**34 289**	**4 440**	**34 289**	**4 440**	**68 578**	**8 880**	**68 578**	**8 880**	**24 002**	**3 108**
World (non-A)	**38 729**		**38 729**		**77 458**		**77 458**		**27 110**	

Table B5.5 Annual value of sickness time and deaths averted (million US$)

	By 2015, reduce by 50% population without access to biofuels				**By 2015, 100% access to a cleaner fuel or an improved stove**					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	787	822	787	822	1 573	1 644	1 573	1 644	551	575
AFR-E	607	901	607	901	1 213	1 802	1 213	1 802	425	631
AMR-B	121	566	121	566	243	1 132	243	1 132	85	396
AMR-D	36	45	36	45	72	90	72	90	25	31
EMR-B	10	16	10	16	19	31	19	31	7	11
EMR-D	107	267	107	267	214	535	214	535	75	187
EUR-B	68	54	68	54	137	108	137	108	48	38
EUR-C	58	39	58	39	117	78	117	78	41	27
SEAR-B	41	336	41	336	81	672	81	672	28	235
SEAR-D	762	927	762	927	1 524	1 854	1 524	1 854	534	649
WPR-B	32 546	1 073	32 546	1 073	65 091	2 146	65 091	2 146	22 782	751
World (non-A)	**35 143**	**5 046**	**35 143**	**5 046**	**70 285**	**10 092**	**70 285**	**10 092**	**24 600**	**3 532**
World (non-A)	**40 189**		**40 189**		**80 377**		**80 377**		**28 132**	

Annex Tables B6. Environmental benefits

Table B6.1 Annual value of local environmental benefits (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	285	299	76	89	570	597	570	595	335	350
AFR-E	347	616	420	808	693	1 232	693	1 221	408	718
AMR-B	28	317	29	345	55	635	55	632	33	372
AMR-D	8	46	4	91	16	92	16	91	9	54
EMR-B	0	0	0	0	0	0	0	0	0	0
EMR-D	57	130	51	117	114	260	114	259	67	153
EUR-B	38	98	36	94	76	195	76	195	45	115
EUR-C	48	33	58	39	97	66	97	66	57	39
SEAR-B	27	456	0	567	54	912	54	912	32	536
SEAR-D	328	522	293	604	657	1 043	657	1 040	657	1 040
WPR-B	914	136	1 413	244	1 828	271	1 828	263	1 828	263
World (non-A)	**2 080**	**2 652**	**2 380**	**2 998**	**4 160**	**5 305**	**4 160**	**5 276**	**3 470**	**3 640**
World (non-A)	**4 732**		**5 378**		**9 465**		**9 436**		**7 110**	

Table B6.2 Annual value of global environmental benefits related to a reduction in CO_2 emissions (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	153	178	155	193	337	386	306	356	132	148
AFR-E	122	223	161	318	273	484	244	445	109	186
AMR-B	4	35	5	43	16	145	7	71	10	88
AMR-D	-1	6	1	12	6	22	-2	12	6	13
EMR-B	5	8	5	9	23	35	10	17	14	22
EMR-D	3	17	8	38	17	62	6	35	12	36
EUR-B	-5	-14	-5	-14	-2	-11	-10	-29	4	5
EUR-C	-6	-4	-9	-6	-2	-2	-12	-9	5	3
SEAR-B	2	36	0	62	11	129	4	72	7	74
SEAR-D	-9	31	22	121	83	213	-18	62	82	153
WPR-B	30	10	141	26	288	45	61	20	218	28
World (non-A)	**298**	**526**	**486**	**802**	**1 050**	**1 508**	**597**	**1 052**	**599**	**758**
World (non-A)	**824**		**1 288**		**2 558**		**1 649**		**1 357**	

CO_2, carbon dioxide.

Table B6.3 Annual value of global environmental benefits related to a reduction in CH_4 emissions (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	5	5	4	6	9	10	9	10	3	3
AFR-E	5	6	4	8	9	13	9	13	3	4
AMR-B	0	3	0	3	1	7	1	7	0	2
AMR-D	1	0	0	1	1	1	1	1	0	0
EMR-B	1	1	0	1	1	2	1	2	0	1
EMR-D	0	1	1	2	1	3	1	3	0	1
EUR-B	0	0	0	0	1	1	1	1	0	0
EUR-C	0	0	0	0	1	1	1	1	0	0
SEAR-B	0	3	0	4	1	5	1	5	0	2
SEAR-D	4	5	3	9	8	11	8	11	3	4
WPR-B	11	1	11	2	23	2	23	2	8	1
World (non-A)	**28**	**27**	**24**	**35**	**56**	**54**	**56**	**53**	**19**	**18**
World (non-A)	**55**		**59**		**110**		**109**		**37**	

CH_4, methane.

Table B6.4 Annual total value of global environmental benefits (reductions in CO_2 and CH_4 emissions) (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	158	183	159	199	346	396	316	366	135	152
AFR-E	127	229	165	326	282	496	253	458	112	191
AMR-B	4	39	6	46	17	151	8	77	10	91
AMR-D	0	6	1	13	7	23	-1	12	7	14
EMR-B	6	9	6	9	24	37	11	18	15	23
EMR-D	4	19	8	40	18	65	7	37	12	37
EUR-B	-5	-14	-5	-13	-1	-11	-9	-28	4	6
EUR-C	-6	-4	-8	-6	-1	-1	-12	-8	5	3
SEAR-B	3	39	0	65	12	135	5	77	8	76
SEAR-D	-5	37	25	130	91	224	-10	73	85	156
WPR-B	42	11	151	28	311	47	84	22	226	29
World (non-A)	**326**	**553**	**510**	**838**	**1 106**	**1 562**	**652**	**1 106**	**618**	**777**
World (non-A)	**879**		**1 348**		**2 668**		**1 758**		**1 395**	

CO_2, carbon dioxide; CH_4, methane.

Table B6.5 Annual total value of local and global environmental benefits (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	443	481	236	288	917	993	886	961	471	502
AFR-E	473	845	585	1 135	975	1 728	946	1 679	520	909
AMR-B	32	356	35	391	72	786	64	710	43	462
AMR-D	7	52	5	104	23	115	15	104	16	67
EMR-B	6	9	6	9	24	37	12	18	15	23
EMR-D	61	149	59	157	132	325	121	297	79	189
EUR-B	33	83	32	81	75	185	67	167	49	120
EUR-C	43	29	49	33	95	65	85	58	62	42
SEAR-B	30	495	0	632	66	1 047	59	989	39	613
SEAR-D	323	558	318	734	748	1 267	647	1 114	741	1 197
WPR-B	956	147	1 565	272	2 139	318	1 912	286	2 054	292
World (non-A)	**2 406**	**3 205**	**2 890**	**3 836**	**5 266**	**6 867**	**4 813**	**6 382**	**4 088**	**4 416**
World (non-A)	**5 611**		**6 726**		**12 133**		**11 195**		**8 504**	

Annex Tables B7. Overall cost–benefit results

Table B7.1 Total annual economic benefits (million US$)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	2 520	3 060	2 490	3 060	5 070	6 150	5 040	6 120	3 960	4 290
AFR-E	2 410	5 430	2 680	7 180	4 840	10 900	4 820	10 860	5 130	7 990
AMR-B	600	5 940	610	6 220	1 210	11 960	1 200	11 880	19 220	15 180
AMR-D	210	440	120	820	430	890	420	880	1 590	970
EMR-B	1 320	2 070	1 340	2 120	2 660	4 160	2 650	4 140	9 960	5 820
EMR-D	470	1 610	450	1 660	940	3 240	930	3 210	2 630	3 840
EUR-B	410	1 020	420	1 020	830	2 060	820	2 040	4 280	860
EUR-C	490	410	520	430	1 000	820	990	820	1 840	150
SEAR-B	300	4 010	40	4 910	610	8 070	600	8 010	2 090	7 390
SEAR-D	2 560	5 360	2 410	6 630	5 230	10 870	5 130	10 720	11 620	8 950
WPR-B	45 070	4 230	50 110	7 000	90 370	8 480	90 140	8 450	87 150	7 990
World (non-A)	**56 360**	**33 580**	**61 190**	**41 050**	**113 190**	**67 600**	**112 740**	**67 130**	**149 470**	**63 430**
World (non-A)	**89 940**		**102 240**		**180 790**		**179 870**		**212 900**	

Table B7.2 Benefit–cost ratios (US$ return per US$ 1 invested)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	2.3	1.5	1.4	1.4	Neg	4.4	7.6	1.6	Neg	Neg
AFR-E	3.5	2.3	2.4	2.8	Neg	10.5	Neg	2.7	Neg	Neg
AMR-B	1.9	1.4	1.7	1.4	Neg	4.7	3.9	1.5	Neg	Neg
AMR-D	1.1	0.7	0.3	1.3	Neg	2.0	Neg	0.7	Neg	Neg
EMR-B	2.1	1.8	2.1	1.8	5.0	4.2	2.1	1.8	142.3	83.1
EMR-D	1.7	0.9	1.3	0.9	Neg	2.7	Neg	1.0	Neg	Neg
EUR-B	2.4	1.1	2.1	1.1	Neg	4.1	Neg	1.2	Neg	Neg
EUR-C	2.5	1.2	2.7	1.2	Neg	6.3	Neg	1.3	Neg	Neg
SEAR-B	2.5	1.1	0.1	1.4	Neg	3.2	Neg	1.2	Neg	Neg
SEAR-D	0.6	0.6	0.5	0.7	Neg	1.6	0.9	0.6	Neg	Neg
WPR-B	5.6	4.0	7.0	5.2	Neg	Neg	10.7	7.7	Neg	Neg
World (non-A)	**3.6**	**1.2**	**3.5**	**1.5**	**Neg**	**4.0**	**7.6**	**1.3**	**Neg**	**Neg**
World (non-A)	**2.1**		**2.3**		**33.7**		**2.8**		**Neg**	

Neg: A negative ratio means that intervention cost savings exceed intervention costs.

Table B7.3 Benefit–cost ratios with intervention cost savings included with economic benefits (US$ return per US$ 1 invested)

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1.8	1.5	1.4	1.4	4.7	3.4	2.2	1.5	35.0	29.9
AFR-E	2.0	2.1	1.9	2.7	5.6	5.0	2.6	2.2	42.9	45.5
AMR-B	1.7	1.4	1.6	1.4	4.8	3.5	2.0	1.4	52.2	51.0
AMR-D	1.0	0.7	0.4	1.3	3.8	1.8	1.6	0.7	63.7	39.1
EMR-B	2.1	1.8	2.1	1.8	4.9	4.2	2.1	1.8	76.2	77.3
EMR-D	1.3	0.9	1.2	1.0	3.7	2.1	1.9	1.0	41.3	28.7
EUR-B	1.6	1.1	1.6	1.1	5.0	2.8	2.2	1.2	107.7	92.5
EUR-C	1.6	1.1	1.6	1.1	5.0	3.0	2.2	1.3	80.0	96.8
SEAR-B	1.5	1.1	0.1	1.4	4.5	2.6	2.2	1.2	63.8	47.1
SEAR-D	0.7	0.6	0.5	0.7	2.3	1.5	0.9	0.6	32.7	30.5
WPR-B	4.1	3.0	4.6	4.6	9.5	7.4	4.4	3.4	111.9	166.9
World (non-A)	**2.7**	**1.2**	**2.8**	**1.5**	**6.7**	**3.0**	**3.0**	**1.3**	**68.6**	**47.1**
World (non-A)	**1.9**		**2.1**		**4.7**		**2.1**		**61.7**	

Table B7.4 Net present value (average annual value)[a]

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	1 420	1 040	730	930	6 420	4 750	4 380	2 360	6 150	4 500
AFR-E	1 720	3 050	1 540	4 630	7 370	9 860	5 500	6 810	9 340	8 810
AMR-B	290	1 720	260	1 890	1 420	9 420	890	4 030	26 070	15 990
AMR-D	20	-220	-260	180	1 010	450	500	-380	4 020	1 050
EMR-B	690	910	710	960	2 130	3 180	1 400	1 820	9 890	5 750
EMR-D	190	-90	110	-90	1 690	2 050	1 080	110	6 250	4 370
EUR-B	240	90	220	80	1 390	1 560	930	360	7 940	950
EUR-C	290	60	330	60	1 790	690	1 200	210	3 410	170
SEAR-B	180	520	-340	1 480	1 280	5 540	880	1 540	4 530	7 930
SEAR-D	-1 420	-3 590	-2 360	-2 350	5 540	4 000	-530	-6 840	21 110	9 110
WPR-B	36 980	3 180	42 960	5 660	94 810	9 090	81 740	7 350	114 430	9 870
World (non-A)	**40 600**	**6 670**	**43 900**	**13 430**	**124 850**	**50 590**	**97 970**	**17 370**	**213 140**	**68 500**
World (non-A)	**47 270**		**57 330**		**175 440**		**115 340**		**281”640**	

[a] A negative net present value represents the value that is likely to be lost over the lifetime of an intervention. A negative value in the table reflects the average annual loss

Annex Tables B8. Contribution to overall economic benefits

Table B8.1 Health-care savings as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		Scenario V (biofuel pro-poor)		Scenario VI (LPG)		Scenario VII (biofuel)		Scenario VIII (improved stove)	
WHO subregion	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**	**Urban (%)**	**Rural (%)**
AFR-D	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1	0.1
AFR-E	0.5	0.3	0.4	0.2	0.5	0.3	0.5	0.3	0.1	0.1
AMR-B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
AMR-D	0.9	0.5	1.5	0.3	0.8	0.5	0.9	0.5	0.0	0.1
EMR-B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMR-D	1.3	1.0	1.4	1.0	1.3	1.0	1.3	1.0	0.1	0.1
EUR-B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUR-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEAR-B	0.3	0.2	2.1	0.1	0.3	0.2	0.3	0.2	0.0	0.0
SEAR-D	0.7	0.6	0.8	0.5	0.7	0.6	0.7	0.6	0.1	0.1
WPR-B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
World (non-A)	**0.1**	**0.3**	**0.2**	**0.0**	**0.1**	**0.0**	**0.1**	**0.2**	**0.2**	**0.1**
World (non-A)	**0.2**		**0.2**		**0.2**		**0.2**		**0.0**	

Table B8.2 Time savings as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	50.9	57.1	58.5	63.3	50.6	56.8	50.9	57.1	74.1	74.8
AFR-E	54.7	67.6	55.1	71.4	54.4	67.3	54.7	67.6	81.5	80.7
AMR-B	74.5	84.5	75.1	84.5	73.9	83.9	74.5	84.5	99.3	94.3
AMR-D	78.9	77.2	64.9	81.5	77.1	76.4	78.9	77.2	97.4	90.0
EMR-B	99.1	98.9	99.1	98.8	98.3	98.4	98.7	98.9	99.7	99.5
EMR-D	62.3	72.9	62.8	73.7	62.3	72.5	63.0	73.2	93.9	90.0
EUR-B	75.1	86.7	76.0	86.8	74.2	85.9	75.1	86.7	97.8	81.6
EUR-C	80.3	83.0	79.7	82.6	78.7	83.0	79.5	83.0	94.6	54.8
SEAR-B	77.0	79.0	0.0	80.1	75.7	78.5	77.0	79.1	96.6	88.5
SEAR-D	57.0	71.7	54.6	74.5	55.8	70.8	56.9	71.7	89.0	79.2
WPR-B	25.6	71.1	31.9	80.7	25.5	70.9	25.6	71.1	71.5	86.9
World (non-A)	**33.3**	**75.2**	**37.7**	**78.1**	**33.1**	**74.7**	**33.2**	**75.2**	**80.8**	**87.4**
World (non-A)	**48.9**		**54.0**		**48.6**		**48.9**		**82.8**	

Table B8.3 Workdays lost due to illness and deaths averted as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to biofuels				By 2015, 100% access to a cleaner fuel or an improved stove					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	31.2	26.9	31.6	26.9	31.0	26.7	31.2	26.9	13.9	13.4
AFR-E	25.2	16.6	22.6	12.5	25.1	16.5	25.2	16.6	8.3	7.9
AMR-B	20.2	9.5	19.9	9.1	20.1	9.5	20.2	9.5	0.4	2.6
AMR-D	17.2	10.2	30.1	5.5	16.8	10.1	17.2	10.2	1.6	3.2
EMR-B	0.7	0.8	0.7	0.7	0.7	0.8	0.7	0.8	0.1	0.2
EMR-D	22.7	16.6	23.8	16.1	22.7	16.5	23.0	16.7	2.8	4.9
EUR-B	16.7	5.3	16.3	5.3	16.5	5.2	16.7	5.3	1.1	4.4
EUR-C	11.9	9.5	11.2	9.1	11.7	9.5	11.8	9.5	2.2	18.2
SEAR-B	13.5	8.4	101.5	6.8	13.3	8.3	13.5	8.4	1.4	3.2
SEAR-D	29.8	17.3	31.6	14.0	29.1	17.1	29.7	17.3	4.6	7.3
WPR-B	72.2	25.4	64.9	15.3	72.0	25.3	72.2	25.4	26.1	9.4
World (non-A)	**62.4**	**15.0**	**57.4**	**12.3**	**62.1**	**14.9**	**62.3**	**15.0**	**16.5**	**5.6**
World (non-A)	**44.7**		**39.3**		**44.5**		**44.7**		**13.2**	

Table B8.4 Environmental benefits as a proportion of overall economic benefits

	By 2015, reduce by 50% population without access to biofuels				**By 2015, 100% access to a cleaner fuel or an improved stove**					
	Scenario II (biofuel)		**Scenario V (biofuel pro-poor)**		**Scenario VI (LPG)**		**Scenario VII (biofuel)**		**Scenario VIII (improved stove)**	
WHO subregion	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
AFR-D	17.6	15.7	9.5	9.4	18.1	16.1	17.6	15.7	11.9	11.7
AFR-E	19.6	15.6	21.8	15.8	20.1	15.9	19.6	15.5	10.1	11.4
AMR-B	5.3	6.0	5.7	6.3	6.0	6.6	5.3	6.0	0.2	3.0
AMR-D	3.6	11.8	4.3	12.6	5.3	12.9	3.6	11.8	1.0	6.9
EMR-B	0.4	0.4	0.4	0.4	0.9	0.9	0.4	0.4	0.1	0.4
EMR-D	12.9	9.2	13.2	9.5	14.0	10.0	13.0	9.2	3.0	4.9
EUR-B	8.1	8.2	7.6	7.9	9.0	9.0	8.1	8.2	1.1	14.0
EUR-C	8.7	7.1	9.5	7.8	9.5	7.9	8.6	7.1	3.4	28.0
SEAR-B	9.8	12.3	0.0	12.9	10.8	13.0	9.8	12.4	1.9	8.3
SEAR-D	12.6	10.4	13.2	11.1	14.3	11.7	12.6	10.4	6.4	13.4
WPR-B	2.1	3.5	3.1	3.9	2.4	3.8	2.1	3.4	2.4	3.7
World (non-A)	**4.3**	**9.5**	**4.7**	**9.3**	**4.7**	**10.2**	**4.3**	**9.5**	**2.7**	**7.0**
World (non-A)	**6.2**		**6.6**		**6.7**		**6.2**		**4.0**	

Annex Tables C. Sensitivity analysis results at 50% coverage of intervention

For Tables C1 to C12, the results are presented for rural and urban areas combined. In all tables, “Neg” – a negative ratio – means that intervention cost savings exceed intervention costs.

Table C1. Benefit–cost ratios under low and high stove costs and stove efficiency assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	3.6	6.0	6.3	1.7	1.8	1.8	Neg	Neg	Neg
AFR-E	6.0	12.2	13.3	2.3	2.6	2.5	Neg	Neg	Neg
AMR-B	3.5	4.1	4.1	1.4	1.4	1.4	Neg	Neg	Neg
AMR-D	2.6	3.4	3.4	0.7	0.8	0.7	Neg	Neg	Neg
EMR-B	4.3	4.5	4.8	1.9	1.9	1.9	17.7	114.4	146.5
EMR-D	2.4	2.9	3.6	1.0	1.0	1.0	Neg	Neg	Neg
EUR-B	4.4	5.0	5.4	1.2	1.3	1.2	Neg	Neg	Neg
EUR-C	17.8	25.5	91.2	1.5	1.6	1.6	Neg	Neg	Neg
SEAR-B	2.5	3.0	3.3	1.1	1.2	1.1	Neg	Neg	Neg
SEAR-D	1.3	1.7	1.7	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	20.1	26.4	38.9	5.2	5.4	5.4	Neg	Neg	Neg
World (non-A)	**5.3**	**6.9**	**7.5**	**2.0**	**2.1**	**2.1**	**Neg**	**Neg**	**Neg**

Table C2. Benefit–cost ratios under low and high fuel price assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	3.2	6.0	28.2	1.2	1.8	4.1	Neg	Neg	Neg
AFR-E	5.1	12.2	Neg	1.6	2.6	6.9	Neg	Neg	Neg
AMR-B	2.5	4.1	9.8	1.0	1.4	2.9	Neg	Neg	Neg
AMR-D	1.6	3.4	Neg	0.5	0.8	1.9	Neg	Neg	Neg
EMR-B	3.1	4.5	8.2	1.4	1.9	3.6	147.5	114.4	147.5
EMR-D	1.7	2.9	7.8	0.7	1.0	2.3	Neg	Neg	Neg
EUR-B	2.4	5.0	108.2	0.8	1.3	3.1	Neg	Neg	Neg
EUR-C	4.2	25.5	Neg	0.9	1.6	6.6	Neg	Neg	Neg
SEAR-B	1.8	3.0	6.1	0.8	1.2	2.3	Neg	Neg	Neg
SEAR-D	1.1	1.7	4.0	0.4	0.6	1.2	Neg	Neg	Neg
WPR-B	11.1	26.4	Neg	3.4	5.4	16.6	Neg	Neg	Neg
World (non-A)	**3.8**	**6.9**	**28.9**	**1.4**	**2.1**	**4.8**	**Neg**	**Neg**	**Neg**

Table C3. Benefit–cost ratios under low and high health benefit assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	6.0	6.0	6.1	1.8	1.8	1.8	Neg	Neg	Neg
AFR-E	12.2	12.2	12.4	2.6	2.6	2.6	Neg	Neg	Neg
AMR-B	4.0	4.1	4.2	1.4	1.4	1.5	Neg	Neg	Neg
AMR-D	3.3	3.4	3.4	0.8	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	4.5	1.9	1.9	1.9	114.3	114.4	114.6
EMR-D	2.9	2.9	3.0	1.0	1.0	1.1	Neg	Neg	Neg
EUR-B	4.9	5.0	5.1	1.3	1.3	1.3	Neg	Neg	Neg
EUR-C	24.8	25.5	26.5	1.6	1.6	1.7	Neg	Neg	Neg
SEAR-B	2.9	3.0	3.1	1.2	1.2	1.2	Neg	Neg	Neg
SEAR-D	1.7	1.7	1.8	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	21.8	26.4	32.5	4.5	5.4	6.6	Neg	Neg	Neg
World (non-A)	**6.2**	**6.9**	**7.8**	**1.2**	**2.1**	**2.4**	**Neg**	**Neg**	**Neg**

Table C4. Benefit–cost ratios under low and high time value assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	3.3	6.0	15.4	1.0	1.8	4.6	Neg	Neg	Neg
AFR-E	6.6	12.2	52.3	1.4	2.6	10.9	Neg	Neg	Neg
AMR-B	2.1	4.1	2.2	0.7	1.4	0.8	Neg	Neg	Neg
AMR-D	1.8	3.4	2.8	0.4	0.8	0.6	Neg	Neg	Neg
EMR-B	2.3	4.5	2.6	1.0	1.9	1.1	74.0	114.4	84.0
EMR-D	1.5	2.9	3.2	0.5	1.0	1.1	Neg	Neg	Neg
EUR-B	2.5	5.0	8.0	0.6	1.3	2.1	Neg	Neg	Neg
EUR-C	13.5	25.5	8.2	0.8	1.6	0.5	Neg	Neg	Neg
SEAR-B	1.5	3.0	1.3	0.6	1.2	0.5	Neg	Neg	Neg
SEAR-D	0.9	1.7	0.9	0.3	0.6	0.3	Neg	Neg	Neg
WPR-B	13.3	26.4	20.3	2.7	5.4	4.1	Neg	Neg	Neg
World (non-A)	**3.5**	**6.9**	**7.8**	**1.1**	**2.1**	**2.4**	**Neg**	**Neg**	**Neg**

Table C5. Benefit–cost ratios under low and high children's time value assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	5.6	6.0	6.2	1.7	1.8	1.8	Neg	Neg	Neg
AFR-E	11.5	12.2	12.5	2.4	2.6	2.6	Neg	Neg	Neg
AMR-B	4.0	4.1	4.1	1.4	1.4	1.5	Neg	Neg	Neg
AMR-D	3.2	3.4	3.4	0.7	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	4.5	1.9	1.9	1.9	147.5	114.4	114.4
EMR-D	2.7	2.9	3.0	1.0	1.0	1.1	Neg	Neg	Neg
EUR-B	4.8	5.0	5.1	1.2	1.3	1.3	Neg	Neg	Neg
EUR-C	25.8	25.5	25.5	1.5	1.6	1.6	Neg	Neg	Neg
SEAR-B	2.8	3.0	3.0	1.1	1.2	1.2	Neg	Neg	Neg
SEAR-D	1.7	1.7	1.8	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	26.1	26.4	26.4	5.3	5.4	5.4	Neg	Neg	Neg
World (non-A)	**6.7**	**6.9**	**6.9**	**2.0**	**2.1**	**2.1**	**Neg**	**Neg**	**Neg**

Table C6. Benefit–cost ratios under low and high adult time value assumptions with low and high children's time value assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	2.2	6.0	16.1	0.6	1.8	4.8	Neg	Neg	Neg
AFR-E	4.3	12.2	53.4	0.9	2.6	11.2	Neg	Neg	Neg
AMR-B	1.3	4.1	2.3	0.4	1.4	0.8	Neg	Neg	Neg
AMR-D	1.1	3.4	2.9	0.2	0.8	0.7	Neg	Neg	Neg
EMR-B	1.4	4.5	2.6	0.6	1.9	1.1	44.5	114.4	65.1
EMR-D	1.0	2.9	3.3	0.3	1.0	1.2	Neg	Neg	Neg
EUR-B	1.6	5.0	8.3	0.4	1.3	2.1	Neg	Neg	Neg
EUR-C	8.4	25.5	8.9	0.5	1.6	0.5	Neg	Neg	Neg
SEAR-B	1.0	3.0	1.5	0.4	1.2	0.6	Neg	Neg	Neg
SEAR-D	0.6	1.7	1.0	0.2	0.6	0.4	Neg	Neg	Neg
WPR-B	8.1	26.4	20.5	1.6	5.4	4.2	Neg	Neg	Neg
World (non-A)	**2.2**	**6.9**	**8.1**	**0.7**	**2.1**	**2.5**	**Neg**	**Neg**	**Neg**

Table C7. Benefit–cost ratios under low and high assumptions for time savings due to fuel collection and cooking

	LPG			**Ethanol**			**Improved stove**		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	6.0	6.0	6.6	1.8	1.8	2.0	Neg	Neg	Neg
AFR-E	12.2	12.2	14.1	2.6	2.6	2.9	Neg	Neg	Neg
AMR-B	4.1	4.1	4.6	1.4	1.4	1.6	Neg	Neg	Neg
AMR-D	3.4	3.4	3.6	0.8	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	6.0	1.9	1.9	2.5	114.4	114.4	187.5
EMR-D	2.9	2.9	3.3	1.0	1.0	1.2	Neg	Neg	Neg
EUR-B	5.0	5.0	5.5	1.3	1.3	1.4	Neg	Neg	Neg
EUR-C	25.5	25.5	28.4	1.6	1.6	1.7	Neg	Neg	Neg
SEAR-B	3.0	3.0	3.3	1.2	1.2	1.3	Neg	Neg	Neg
SEAR-D	1.7	1.7	2.0	0.6	0.6	0.7	Neg	Neg	Neg
WPR-B	26.4	26.4	28.0	5.4	5.4	5.7	Neg	Neg	Neg
World (non-A)	**6.9**	**6.9**	**7.6**	**2.1**	**2.1**	**2.3**	**Neg**	**Neg**	**Neg**

Table C8. Benefit–cost ratios under low and high assumptions about tree replacement unit cost

	LPG			**Ethanol**			**Improved stove**		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	5.6	6.0	6.4	1.7	1.8	1.9	Neg	Neg	Neg
AFR-E	11.2	12.2	13.2	2.3	2.6	2.7	Neg	Neg	Neg
AMR-B	3.9	4.1	4.2	1.4	1.4	1.5	Neg	Neg	Neg
AMR-D	3.2	3.4	3.6	0.7	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	4.5	1.9	1.9	1.9	147.5	114.4	147.5
EMR-D	2.7	2.9	3.0	1.0	1.0	1.1	Neg	Neg	Neg
EUR-B	4.6	5.0	5.2	1.2	1.3	1.4	Neg	Neg	Neg
EUR-C	25.1	25.5	28.2	1.5	1.6	1.7	Neg	Neg	Neg
SEAR-B	2.7	3.0	3.2	1.1	1.2	1.3	Neg	Neg	Neg
SEAR-D	1.6	1.7	1.9	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	26.0	26.4	26.7	5.3	5.4	5.5	Neg	Neg	Neg
World (non-A)	**6.6**	**6.9**	**7.1**	**2.0**	**2.1**	**2.2**	**Neg**	**Neg**	**Neg**

Table C9. Benefit–cost ratios under low and high assumptions about greenhouse gas emissions per kg fuel burned

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	5.7	6.0	5.9	1.7	1.8	1.8	Neg	Neg	Neg
AFR-E	11.5	12.2	11.9	2.4	2.6	2.5	Neg	Neg	Neg
AMR-B	4.0	4.1	4.0	1.4	1.4	1.4	Neg	Neg	Neg
AMR-D	3.2	3.4	3.4	0.7	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	4.5	1.9	1.9	1.9	147.5	114.4	147.6
EMR-D	2.8	2.9	2.8	1.0	1.0	1.0	Neg	Neg	Neg
EUR-B	4.8	5.0	4.8	1.2	1.3	1.2	Neg	Neg	Neg
EUR-C	25.6	25.5	26.0	1.5	1.6	1.6	Neg	Neg	Neg
SEAR-B	2.8	3.0	2.9	1.1	1.2	1.1	Neg	Neg	Neg
SEAR-D	1.6	1.7	1.7	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	26.1	26.4	26.3	5.3	5.4	5.4	Neg	Neg	Neg
World (non-A)	**6.7**	**6.9**	**6.8**	**2.0**	**2.1**	**2.1**	**Neg**	**Neg**	**Neg**

Table C10. Benefit–cost ratios under low and high assumptions about the value of reductions in greenhouse gas emissions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	5.4	6.0	6.0	1.6	1.8	1.8	Neg	Neg	Neg
AFR-E	11.0	12.2	12.0	2.3	2.6	2.5	Neg	Neg	Neg
AMR-B	3.9	4.1	4.0	1.4	1.4	1.4	Neg	Neg	Neg
AMR-D	3.2	3.4	3.3	0.7	0.8	0.7	Neg	Neg	Neg
EMR-B	4.4	4.5	4.5	1.9	1.9	1.9	147.2	114.4	147.8
EMR-D	2.7	2.9	2.8	1.0	1.0	1.0	Neg	Neg	Neg
EUR-B	4.8	5.0	4.8	1.2	1.3	1.2	Neg	Neg	Neg
EUR-C	25.6	25.5	25.6	1.5	1.6	1.5	Neg	Neg	Neg
SEAR-B	2.8	3.0	2.9	1.1	1.2	1.1	Neg	Neg	Neg
SEAR-D	1.6	1.7	1.7	0.6	0.6	0.6	Neg	Neg	Neg
WPR-B	26.0	26.4	26.2	5.3	5.4	5.3	Neg	Neg	Neg
World (non-A)	**6.6**	**6.9**	**6.8**	**2.0**	**2.1**	**2.1**	**Neg**	**Neg**	**Neg**

Table C11. Benefit–cost ratios under low and high discount rate assumptions

	LPG			Ethanol			Improved stove		
WHO subregion	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
AFR-D	5.0	6.0	7.0	1.5	1.8	2.1	Neg	Neg	Neg
AFR-E	10.6	12.2	13.3	2.2	2.6	2.8	Neg	Neg	Neg
AMR-B	3.8	4.1	4.4	1.3	1.4	1.6	Neg	Neg	Neg
AMR-D	3.1	3.4	3.6	0.7	0.8	0.8	Neg	Neg	Neg
EMR-B	4.5	4.5	4.5	1.9	1.9	1.9	147.4	114.4	147.7
EMR-D	2.6	2.9	3.2	0.9	1.0	1.2	Neg	Neg	Neg
EUR-B	4.6	5.0	5.2	1.2	1.3	1.3	Neg	Neg	Neg
EUR-C	24.4	25.5	28.9	1.5	1.6	1.7	Neg	Neg	Neg
SEAR-B	2.7	3.0	3.1	1.1	1.2	1.2	Neg	Neg	Neg
SEAR-D	1.5	1.7	2.0	0.5	0.6	0.7	Neg	Neg	Neg
WPR-B	18.6	26.4	46.7	3.8	5.4	9.6	Neg	Neg	Neg
World (non-A)	**5.4**	**6.9**	**10.1**	**1.7**	**2.1**	**3.1**	**Neg**	**Neg**	**Neg**

Table C12. Benefit–cost ratios – methanol compared with ethanol

	Biofuel	
WHO subregion	**Ethanol**	**Methanol**
AFR-D	1.8	2.7
AFR-E	2.6	4.1
AMR-B	1.4	2.1
AMR-D	0.8	1.2
EMR-B	1.9	2.7
EMR-D	1.0	1.6
EUR-B	1.3	2.0
EUR-C	1.6	3.0
SEAR-B	1.2	1.7
SEAR-D	0.6	0.9
WPR-B	5.4	9.5
World (non-A)	**2.1**	**3.2**