

Guidelines for conducting cost–benefit analysis of household energy and health interventions



World Health
Organization

Guidelines
for conducting
cost–benefit analysis
of household energy and
health interventions

Guy Hutton

Swiss Tropical Institute

with

Eva Rehfues

World Health Organization



**World Health
Organization**

WHO Library Cataloguing-in-Publication Data

World Health Organization.

Guidelines for conducting cost-benefit analysis of household energy and health interventions /
Guy Hutton with Eva Rehfuess.

1.Air pollution, Indoor. 2.Fuels. 3.Environmental health. 4.Cost-benefit analysis. 5.Guidelines.
6.Developing countries. I.Hutton, Guy. II.Rehfuess, Eva. III.Title.

ISBN 92 4 159481 0

(NLM classification: WA 754)

ISBN 978 92 4 159481 3

© World Health Organization 2006

All rights reserved. Publications of the World Health Organization can be obtained from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int). Requests for permission to reproduce or translate WHO publications – whether for sale or for noncommercial distribution – should be addressed to WHO Press, at the above address (fax: +41 22 791 4806; e-mail: permissions@who.int).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

The named authors alone are responsible for the views expressed in this publication.

Designed by minimum graphics.

Printed in Switzerland.

Contents

Acknowledgements	v
Abbreviations	vi
Foreword	vii
1. Introduction	1
1.1 Indoor air pollution in the world today	1
1.2 Why economic analysis?	2
1.3 Types of economic analysis	4
1.4 Outputs of cost–benefit analysis	5
1.5 Economic versus financial analysis	6
1.6 Constraints on and opportunities for economic analysis	6
1.7 Overview of the guidelines	7
2. Cost–benefit framework	8
3. Choosing interventions	14
3.1 Policy-relevant alternatives	14
3.2 Description of interventions	15
4. Boundaries	17
4.1 Viewpoint or perspective	17
4.2 Directness of association	19
4.3 Time horizon of analysis	20
4.3.1 Time period of intervention	20
4.3.2 Time period of impact	20
5. Cost estimation	22
5.1 Cost identification and inclusion	22
5.2 Sources of data on costs	25
5.2.1 Overview	25
5.2.2 Routine information sources	25
5.2.3 Periodic information sources	26
5.2.4 Special surveys or studies	26
5.3 Cost quantification	26
5.4 Cost valuation	28
5.4.1 Overview	28
5.4.2 Traded goods	30
5.4.3 Non-traded goods	31

5.4.4	Unit of presentation	33
5.4.5	Differential timing of costs	33
6.	Impact estimation	35
6.1	Impact identification and inclusion	35
6.2	Sources of data on impact	39
6.2.1	Overview	39
6.2.2	Routine information sources	41
6.2.3	Periodic information sources	41
6.2.4	Special surveys or studies	41
6.3	Impact quantification	42
6.3.1	Overview	42
6.3.2	Health benefits and health service use	42
6.3.3	Time use	44
6.3.4	Household environment	44
6.3.4	Fuel savings	44
6.3.5	Environmental impacts	45
6.4	Impact valuation	45
6.4.1	Overview	45
6.4.2	Human capital approach	47
6.4.3	Revealed preferences	48
6.4.4	Contingent valuation method	49
6.4.5	Differential timing of impacts	50
7.	Dealing with uncertainty	52
7.1	Types of uncertainty	52
7.2	Choosing the type of uncertainty analysis	53
7.3	Choosing which parameters to vary	54
7.4	Choosing the ranges and distribution of uncertain parameters	55
8.	Presentation and interpretation of results	56
8.1	Who can use the results of an economic evaluation?	56
8.2	Presentation of results	57
8.2.1	Basic presentation	57
8.2.2	Viewpoint	59
8.2.3	Currency	59
8.2.4	Capacity level	59
8.3	Interpretation of results in a decision-making context	59
8.3.1	Efficiency considerations highlighted by cost–benefit analysis	59
8.3.2	Other considerations	60
8.4	Constraints to using the results of economic evaluation in decision-making	61
9.	Conclusions	63
	References	64

Acknowledgements

The authors are grateful to the following people for their review of these guidelines and their helpful, constructive comments:

- Kalpana Balakrishnan (Sri Ramachandra Medical College, India)
- Douglas Barnes (World Bank, Washington, DC, United States)
- Liz Bates (Intermediate Technology Development Group/Practical Action, England)
- Adam Biran (London School of Hygiene and Tropical Medicine, England)
- Robert Bos (Public Health and Environment, World Health Organization)
- Nigel Bruce (University of Liverpool, England)
- Diarmid Campbell-Lendrum (Public Health and Environment, World Health Organization)
- Daniel Chisholm (Health Systems Financing, World Health Organization)
- Supriya Lahiri (University of Massachusetts at Lowell, United States)
- Sumi Mehta (The Health Effects Institute, United States)
- Kirk Smith (University of California at Berkeley, United States)
- Tessa Tan-Torres (Health Systems Financing, World Health Organization)

In addition, we are grateful to the many individuals around the world who reviewed the global cost-benefit analysis (Hutton et al., 2006), whose real-life application of the methodology has informed these guidelines.

This publication was copy-edited by Susan Kaplan. The cover photographs were kindly provided by Nigel Bruce/Practical Action.

The preparation and publication of these guidelines for conducting cost-benefit analysis of household energy and health interventions were made possible by the generous support of the United States Agency for International Development.

Abbreviations

AE	avertive expenditure	I\$	international dollar
ALRI	acute lower respiratory infection	IAP	indoor air pollution
BCR	benefit–cost ratio (economic return per unit of currency spent)	kg	kilogram
CBA	cost–benefit analysis	LPG	liquefied petroleum gas
CEA	cost–effectiveness analysis	MDG	Millennium Development Goal
CH ₄	methane	MJ	megajoules
c.i.f.	cost, insurance and freight (price of traded goods after import)	NGO	nongovernmental organization
CMA	cost-minimization analysis	NPV	net present value (present value of economic benefits minus costs)
CO	carbon monoxide	OECD	Organisation for Economic Co-operation and Development
CO ₂	carbon dioxide	PIC	products of incomplete combustion
COPD	chronic obstructive pulmonary disease	PM	particulate matter
CUA	cost–utility analysis	PPP	purchasing power parity
CVM	contingent valuation method	QALY	quality-adjusted life-year
DALY	disability-adjusted life-year	R & D	research and development
EIRR	economic internal rate of return	RAD	restricted activity day
f.o.b.	free on board (price of traded goods before import)	US\$	United States dollar
g/l	grams per litre	VOSL	value of statistical life
GHG	greenhouse gas	WHO	World Health Organization
GNI	gross national income	WLD	work loss day
		WTP	willingness to pay
		WTA	willingness to accept

Foreword

Worldwide, more than 3 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 (CBA) 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. WHO has conducted a global CBA 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.

The publications mentioned above are both based on the *Guidelines for conducting cost–benefit analysis of household energy and health interventions*. These guidelines introduce the cost–benefit framework and outline the different steps in the process of analysis: choosing interventions, defining boundaries, estimating costs and impacts, carrying out sensitivity analysis and presenting the results and their implications. The present technical publication is intended for economists and professionals interested in conducting CBA at the national and subnational levels.

1. Introduction

1.1 Indoor air pollution in the world today

In the year 2003, around half the world's population – more than 3 billion people – still used solid fuel to meet their energy needs. The percentages ranged from under 20 per cent in Europe and Central Asia to 80 per cent and more in sub-Saharan Africa and Asia (Bruce et al., 2000; Smith et al., 2004; Rehfuess et al., 2006).

The inefficient burning of solid fuels, such as dung, wood, charcoal and coal, combined with poor ventilation, produces high levels of hundreds of pollutants (Ezzati et al., 2002).¹ Exposure to indoor air pollution (IAP) from the combustion of solid fuels has been implicated, with varying degrees of evidence, as a risk factor for several diseases in developing countries, including acute lower respiratory infections (ALRI) and otitis media (middle ear infection), chronic obstructive pulmonary disease (COPD), lung cancer (from coal smoke), asthma, cancer of the nasopharynx and larynx, tuberculosis, perinatal conditions and low birth weight, and diseases of the eye, such as cataract and blindness (Bruce et al., 2006; Ezzati & Kammen, 2002).²

Indoor air pollution is estimated to cause 3.7% of the overall disability adjusted life-years (DALYs) in high-mortality developing countries, falling to around 1.9% in low-mortality developing countries, as classified by the World Health Organization (WHO) (WHO, 2000a). Conservative

estimates of global mortality due to IAP from solid fuels show that in 2002, approximately 1.5 million deaths were attributable to exposure to IAP (WHO, 2006). These estimates only include death and disability from ALRI, COPD and lung cancer (from coal smoke), i.e. those health outcomes for which the evidence for a link with IAP is considered conclusive.

In addition to direct health effects resulting from exposure to IAP, other health effects include burns and scalds from open fires and unsafe cooking arrangements and the risks from collecting firewood, such as the risks of carrying heavy loads and dangers from mines, snakebites and violence (Bruce et al., 2006).

As an indication of the extent of exposure to IAP in the world today, Table 1 shows the percentage of households using solid fuels and traditional stoves in 2003. Solid fuel use is high in all developing WHO subregions, with firewood being the most commonly used cooking fuel worldwide. Table 1 also illustrates the differences between rural and urban areas, showing the significantly higher rates of solid fuel use in rural areas.

Women, young children and the elderly are particularly affected by IAP, as not only are they more exposed to it but they are also more vulnerable to its effects (Smith et al., 2000). WHO's most recent estimates suggest that nearly 800 000 child deaths are attributable to this environmental risk factor. Moreover, IAP is responsible for an estimated 511 000 deaths among women compared to only 173 000 among men (WHO, 2006). Figures 1 and 2 show the global distribution of these deaths, highlighting the high burden of mortality in sub-Saharan Africa, South-East Asia and the Western Pacific region.

Diseases caused by exposure to IAP are labelled diseases of poverty, because as people become

¹ Pollutants in biomass and coal smoke include particulate matter, carbon monoxide, nitrogen dioxide, sulfur oxides (mainly from coal), formaldehyde, and polycyclic organic matter, including carcinogens. Small particles are considered the most serious and widespread health hazards of IAP from solid fuel use.

² Evidence is strongest for ALRI in children younger than 5 years, COPD in adults, and lung cancer from coal exposure in adults; at present the evidence base is not strong enough to include other diseases in calculations of the burden of disease from exposure to IAP.

Table 1. Percentage of households using different types of solid fuels

WHO subregion	Solid fuel							
	Coal/lignite		Charcoal		Firewood		Dung and agricultural residues	
	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
AFR-E	8.8	1.6	15.1	15.0	24.6	57.9	4.4	12.1
AMR-B	0.7	3.2	0.5	2.1	3.0	46.5	0.6	0.8
AMR-D	9.6	0.1	11.7	2.2	0.7	66.8	2.8	6.2
EMR-B	0.7	0.7	0.0	0.0	0.1	0.1	18.6	51.1
EMR-D	0.4	0.5	0.5	1.1	20.8	47.8	1.2	8.8
EUR-B	0.4	0.4	0.1	0.1	4.6	31.7	0.7	1.7
EUR-C	0.9	1.1	0.2	0.4	4.9	6.0	0.2	0.0
SEAR-B	0.4	0.0	25.7	0.3	0.0	85.4	0.0	0.0
SEAR-D	3.5	1.2	7.2	1.3	16.2	71.1	1.4	16.1
WPR-B	7.1	3.3	12.4	14.3	14.6	44.5	1.2	4.6

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 – World Health Survey 2003; for 33 countries – other available sources; for remaining 36 developing and middle-income countries – estimates based on modelled data.

more prosperous they tend to move up the energy ladder from dung, wood and charcoal towards liquefied petroleum gas (LPG), gas and electricity. The users of these cleaner, more efficient and more convenient energy sources are less prone to IAP-related diseases (WHO, 2002).

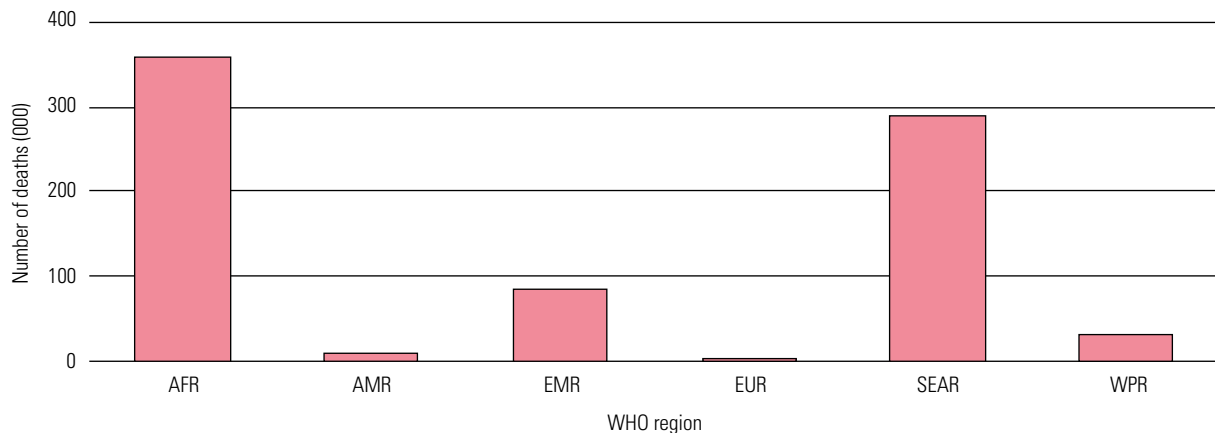
Considering the important disease burden associated with IAP, and the low socioeconomic status of the vulnerable population groups who bear most of this burden, it is crucial to address the disease and economic burden linked to the health impacts of exposure to IAP. Reducing exposure to IAP and improvements in household energy practices are expected to make important contributions to meeting several of the Millennium Development Goals – food security and poverty reduction (Goal 1), gender equality and women's empowerment (Goal 3), reduced child mortality (Goal 4), improved maternal health (Goal 5), a reduction in infectious diseases including tuberculosis (Goal 6) and sustainable development (Goal 7).

1.2 Why economic analysis?

Economic analysis involves comparing the costs and consequences of different interventions, enabling conclusions to be drawn about their relative efficiency. Several types of economic analysis are possible, covering cost description and cost analysis, outcome description and outcome analysis, and economic evaluation (Drummond et al., 1997). Whereas cost studies examine the economic inputs to an intervention, and outcome studies examine the health or economic outcomes of an intervention, economic evaluation examines both the costs and the outcomes resulting from the same intervention. Only after a robust analysis of the costs and outcomes of a course of action can meaningful conclusions be drawn about economic efficiency.

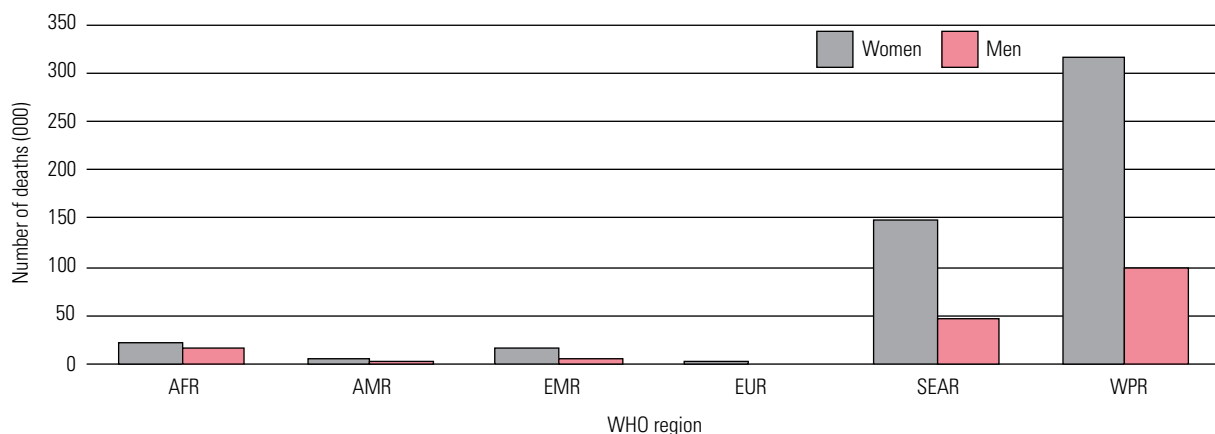
Therefore, economic evaluation enables explicit and quantitative comparisons of the efficiency of interventions using a simple-to-interpret summary efficiency measure – cost per impact achieved – as the common outcome measure. Assuming that different economic evaluation studies use the same

Figure 1. Acute lower respiratory infections in children under five years due to indoor air pollution, by WHO region (year 2002)



AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region.

Figure 2. Chronic obstructive pulmonary disease in adults due to indoor air pollution, by WHO region (year 2002)



AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region.

methods for quantifying the cost-effectiveness or cost-benefit of different interventions, the efficiency measure can be compared across analyses. This gives policy-makers in the public and private sectors a wealth of comparable data on which to base informed decisions. Also, equity and distributional issues can be explicitly considered in economic evaluation, as the beneficiaries of different interventions can be identified, and weights assigned to them depending on the equity objectives of society.

The results of economic evaluation can be used in a variety of ways:

- As a *project analysis tool*, to inform those choosing between alternatives under consideration for large-scale projects.
- As a government *policy-making tool*, incorporating new cost-effective or cost-beneficial interventions into public policy or into government planning (and hence public service provision), or discontinuing cost-ineffective interventions.
- As a tool for *assessing social impacts* of interventions, by specifically identifying the sub-populations that are gaining or losing, and shaping a policy or intervention to target identified groups.

- As a *decision tool* for use by an implementing agency, such as a hospital, company or non-governmental organization (NGO).

There are a range of players who are interested in using the results of economic evaluation. These include:

- *Government departments*, such as ministries, which are interested in using public money to provide free or subsidized services, or to promote private markets.
- *NGOs*, which largely exist to promote the social good, especially for members and population groups perceived as having unmet basic needs.
- *Individual or institutional decision-makers*, such as hospitals and other budget holders who wish to optimize resource allocation, or clinicians who are faced with various treatment options for a given disease.
- *Private enterprises*, which produce goods where there is demand and potential for profit.
- *Individuals or consumers*, who make purchase decisions based on their personal wealth (goods, money), their trading or purchase opportunities, and their perception of needs.
- *External donors*, which may include bilateral government agencies, multilateral agencies, and international NGOs.

An economic analysis of the problem of household energy, IAP and health can be applied to address some of the following issues. As governments seek areas of intervention where the social rates of return are high, economic evaluation can be used to justify the introduction of efficient new interventions, or the withdrawal of inefficient current interventions. This type of analysis is supported by most of the existing economic evaluation guidelines, and is termed “incremental analysis” (Drummond & Jefferson, 1996; Weinstein et al., 1996). On the one hand, there may be a new intervention, such as a modern processed biomass fuel (e.g. ethanol or plant oils), which promises great benefit at a low cost. Economic evaluation potentially acts as a promotional tool for getting new interventions accepted and into policy. On the other hand, there may be a government subsidy supporting an intervention that is known to be very costly but with limited benefits to society or specific segments of society. For example, the Government of India

invests heavily in subsidizing LPG, a policy that has failed to reach the poor for whom it was introduced (Gangopadhyay et al., 2005). Economic evaluation potentially helps to quantify the inefficiency of such government subsidies, and contributes to policy change.

A different type of economic analysis evaluates all potential interventions in terms of their economic efficiency, compared with a baseline of *no intervention*. The resulting benefit–cost ratios inform the analyst as to which mix of interventions is optimal. Assuming resources currently employed for the existing set of interventions can be reallocated, this type of analysis maximizes the benefit to society with a given level of resource input. While such reallocations are rarely possible in the short run, government policy and resource allocation decisions could be defined so as to move towards this mix of interventions. The name commonly given to this type of analysis is “average analysis”, and it has been described by WHO as “sectoral analysis” in its generalized guidelines on cost–effectiveness analysis (Murray et al., 2000; Baltussen, 2002; Tan-Torres Edejer et al., 2003). As argued by WHO, it is important to understand not only the efficiency of new options, but also that of the current options, in order to choose (or move towards) the optimal mix of interventions. Furthermore, evaluating intervention efficiency against a “do nothing” alternative increases the transferability of results. However, there are various methodological and data challenges to sectoral analysis. One disadvantage is that decision-makers faced with resource allocation decisions are more interested in the incremental impact of discrete changes in budget allocations, given that they are rarely in a position to reallocate all current resource uses.

1.3 Types of economic analysis

There are two principal types of economic evaluation: cost–benefit analysis (CBA) and cost–effectiveness analysis (CEA) (Drummond et al., 1997). 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. Cost–utility analysis (CUA) represents a subtype of CEA that measures health outcomes in generic terms to allow comparability between health interventions addressing different health outcomes.

Cost–benefit analysis, on the other hand, values all the outcomes of interventions in monetary terms. This gives three types of ratio:

- Cost–effectiveness ratio: health effect (lives saved or cases averted) per currency unit spent.
- Cost–utility ratio: health effect (healthy life-years gained, DALYs averted, quality-adjusted life-years gained) per currency unit spent.
- Benefit–cost ratio: monetary or welfare benefit per currency unit spent.

CEA and CUA are concerned mainly with the health sector perspective and therefore include only benefits directly linked to health improvements (Gold et al., 1996). The narrowly construed cost–effectiveness framework is suitable, for example, when evaluating the efficiency of programmes of vaccination against measles or antibiotic-treatment of pneumonia. Yet, for interventions that have many different health and non-health impacts, such as household energy and health interventions, the cost–effectiveness framework is not appropriate as it risks excluding some important benefits. For example, a cost–benefit study on interventions to improve water supply and sanitation quantified and valued selected non-health benefits, and compared these with intervention costs (Hutton & Haller, 2004). One important conclusion of the study was that non-health related benefits, such as time savings, make a substantial contribution to the overall economic benefits, thus justifying a broader cross-sectoral analysis. Moreover, household energy and health interventions are rarely financed and realized by the health sector and their implementation may primarily be motivated by the concerns of sectors other than health, such as deforestation (environment sector), soil erosion (agricultural sector) and poverty eradication (economic sector). Hence, when considering household energy and health interventions, it is relevant to evaluate the costs and benefits comprehensively in a social CBA framework (Layard, 1972). Alternatively, for decision-making within the health sector, CEA is more straightforward and less controversial in terms of measuring health impacts in health units rather than in monetary units.

1.4 Outputs of cost–benefit analysis

The goal of CBA is to identify whether the benefits of an intervention exceed its costs. A positive

net social benefit indicates that an intervention is worthwhile from an economic perspective. However, as public funds are limited, some ranking of the alternatives is necessary to enable decision-makers to choose the interventions that have the highest return on investment and/or bring the greatest benefit to target populations. Therefore, the primary output of a CBA is:

- The *benefit–cost ratio* (BCR), which shows the factor by which economic benefits exceed the economic costs.

However, the ratio itself is not the only information of interest to decision-makers, who may also wish to know how quickly the investment will be paid back, the attractiveness of the investment compared to placing the funds in a bank and earning interest, and so on. Therefore, the following summary measures are important additional outputs of a CBA, and can help make the case for investment in interventions to reduce population exposure to IAP (see also chapter 8):

- The *economic internal rate of return* (EIRR) shows the return on investment of the intervention, which is the discount rate at which the future expected stream of benefits equals the future expected stream of costs.
- The *net present value* (NPV) shows the net monetary or welfare gain that can be expected from the intervention in currency units of the base period (start of project).
- The *break-even point* shows the time period after which the economic benefits from an intervention will equal the resources invested in the intervention.

In addition to these summary outputs of CBA, the component parts themselves, such as cost or outcome data, can be used for decision-making. For example, a comparative cost analysis of a stove manufacture and distribution programme in several regions of a country would enable conclusions to be drawn about which ones perform better and why. An economic costing also contributes to price/tariff setting for public services, and to allocation of government budgets. Furthermore, the financial viewpoint can be presented by disaggregating cost and outcome data into financial impact versus purely economic impact. The next section elaborates on the distinction between economic and financial analysis.

1.5 Economic versus financial analysis

As alluded to above, the distinction between economic and financial analysis is important. The major differences are summarized in Table 2.

Financial analysis is generally the assessment of income, expenditure, cash flows, profit and end-of-period balance (balance sheet). Financial analysis of an intervention therefore estimates the financial impact of the intervention on the implementing agency, or those financially affected. Economic analysis, on the other hand, ultimately measures the impact of an intervention on the country’s economy, and considers overall resource uses and consequences, based on the premise that resources are scarce.

In economics, a resource is defined as being an object that has economic value. Economic value is understood as the opportunity cost of a resource – “opportunity” in the sense that if a resource is not employed for one use, it has an alternative use which also brings welfare gains. These welfare gains are not necessarily financial returns in the narrow sense – they may be health gains, a reduction in pollution, or higher standards of living, for which appropriate valuation methods must be chosen. Taxes, subsidies, penalties and financial sanctions have no economic value, given that they

only reflect transfer, not use, of resources. For this reason, they are excluded from the analysis. However, in a distributional assessment of an intervention, the losses and gains by different groups should appear, in order to address equity issues.

1.6 Constraints on and opportunities for economic analysis

Indoor air pollution has received relatively little attention from researchers examining the economic efficiency of household energy, public health or lifestyle change interventions. One possible explanation is that changing exposure to IAP is an intervention that spans several sectors, and is on the fringe of health sector activities. Also, IAP and its negative health effects is a problem that mainly affects the developing world. Given the 90/10 gap described by the Global Forum for Health Research (i.e. globally 90% of research resources are spent on the health problems of 10% of the world’s population), it is hardly surprising that this area is severely under-researched (Global Forum for Health Research, 1999).

Furthermore, although the health sector has a responsibility for raising awareness about the health impacts of IAP and for promoting interventions to reduce exposure, the main economic

Table 2. Differences between financial and economic analysis

Variable	Financial analysis	Economic analysis
Outputs of interest	Income; expenditure; cash flow; profit; end-of-period balance; internal financial rate of return; net present financial value.	Benefit–cost ratio; internal economic rate of return; net present value.
Costs	All financial outlays, present or future, which have a monetary cost.	All uses of resources, present or future, which have an economic (“opportunity”) cost.
	Examples include actual monetary payments for human resources, materials, or infrastructure.	Examples include the use of scarce human resources, infrastructure that has alternative uses, and donated goods.
	Valuation of future expenditures is at present value using market interest rates.	Valuation of future expenditures is at present value using a discount rate that reflects social time preference. ^a
Consequences or outcomes	All financial consequences of a given intervention, including further associated expenditures, cost savings or revenues.	All resource consequences associated with a given intervention, including the freeing up of spare capacity for alternative uses, improvements in qualitative indicators, and economic value of resource savings.

^a Social time preference is defined as the value society attaches to present, as opposed to future, consumption. The social time preference rate (STPR) is used for discounting future benefits and costs, and is based on comparisons of utility across different points in time or different generations.

evaluation tool of choice of health policy-makers is CEA as their objective is to maximize the population's health for a given budget. The question of broader economic efficiency, as addressed through CBA, is not a central concern of health policy-makers (Hutton, 2000).

The number of published economic studies on household energy and health is very small (Habermehl, 1999; Larson & Rosen, 2002; Dhanapala, 2003; Larsen, 2004; Tse et al. 2004; Wyon, 2004). One study, conducted as part of WHO's work on generalized CEA, examines the health benefits of interventions to reduce IAP from solid fuel use. It presents cost per healthy year gained for improving access to cleaner fuels alone (propane/LPG, paraffin/kerosene), improved stoves alone, and cleaner fuels and improved stoves combined (Mehta & Shahpar, 2004). However, as noted by various reviewers, assessment of environmental health interventions with broader effects needs to incorporate benefits beyond the direct health improvement into standard economic evaluations,

including time savings, reduction of pressure on natural resources, and convenience (Hutton, 2000; Smith, 2002; Hutton et al., 2006; WHO, 2006). In its publication *Fuel for life: household energy and health* (WHO, 2006), WHO draws on a global cost-benefit study on household energy and health interventions (Hutton et al., 2006) to conclude that investing in household energy pays off.

1.7 Overview of the guidelines

Chapter 2 introduces the framework and main stages for conducting a CBA. Chapter 3 provides guidance on how to select the household energy and health interventions to be evaluated. Chapter 4 details how to choose the boundaries for the analysis. Chapter 5 describes the approach to cost estimation and chapter 6 the approach to impact estimation.¹ Chapter 7 explores how to deal with uncertainty. Chapter 8 advises which results are most useful in a presentation, and chapter 9 concludes.

¹ The term "impact" is used instead of "benefit" because some of the effects of the intervention may be negative or have associated costs requiring calculation of net impact.

2. Cost–benefit framework

Guidelines on economic evaluation have been available since the late 1960s, when CBA became a routine part of development project appraisal by the World Bank and bilateral government donors with the publication of two major reference guidelines for the economic appraisal of development projects (Little & Mirrlees, 1968; United Nations Industrial Development Organization, 1972). Since then, other reference works have become available which further develop and clarify the basic economic evaluation framework (Little & Mirrlees, 1968; Dasgupta, 1970; Layard, 1972; United Nations Industrial Development Organization, 1972; Little & Mirrlees, 1974; Mishan, 1975; Sugden & Williams, 1978; Pearce & Nash, 1981; Asian Development Bank, 1997; MacArthur, 1997). Guidelines on economic evaluation have also been produced for specific sectors, covering health (Levin, 1983; Philips et al., 1993; Rovira, 1994; Gold et al., 1996; McGuire et al., 1989; Johansson, 1996; Drummond et al., 1997; Preker et al., 1997; Drummond & McGuire, 2001; Tan-Torres Edejer et al., 2003), water supply (Asian Development Bank, 1999), agriculture (Gittinger, 1984) and the environment (Hanley & Spash, 1993; Field, 1997; Organisation for Economic Cooperation and Development, 1995; Postle, 1997). In addition, there is an increasing number of costing guidelines which detail specific applications of costing, especially in the field of health care (WHO, 1979; WHO, 1988; Creese & Parker, 1994; Pepperall et al., 1994; Baladi, 1996; Luce et al., 1996; Sawert, 1996; WHO, 1998; Kumaranayake et al., 2000; Johns et al., 2002; Hutton & Baltussen, 2005).

The health sector is one sector where economic evaluation has been widely applied, with a large increase in published studies occurring in the late 1980s and early 1990s (Elixhauser et al., 1993). Following the publication in 1987 of a textbook by Drummond et al. entitled *Economic evaluation of health care programmes* (Drummond et al., 1987;

Drummond et al., 1997) there was already a commonly agreed economic evaluation framework. The publication of the textbook *Cost–effectiveness analysis in health and medicine* by Gold et al. in 1996 was another important contribution to the application of economic evaluation in the field of health. In the mid-1990s two important sets of journal publications appeared, based on the two above-mentioned textbooks, whose aim was to set norms and standards for economic submissions to academic journals (Drummond & Jefferson, 1996; Weinstein et al., 1996). More recently, WHO has published its own guidelines, which describe what is termed “generalized CEA” – a common approach for the global application of CEA to health interventions (Tan-Torres Edejer et al., 2003).

The general framework of economic evaluation, with a specific application to health interventions, is best summarized by the 10-point checklist proposed by Drummond et al. (Figure 3). The checklist contains the 10 essential questions that should be answered by an economic evaluation study in the health domain. The checklist reflects the general consensus of the health economics community at the time of publication.

Given the wide applicability of this economic evaluation checklist, the text below describes some of the main points to be considered under each question with reference to the chapter or section in which each point is further addressed in the present guidelines.

Question 1. Was a well-defined question posed in answerable form?

- The economic importance of the research question should be outlined.
- The hypothesis being tested, or question being addressed, in the economic evaluation should be clearly stated and justified.

Figure 3. The economic evaluation framework – a 10-point checklist

1. Was a well-defined question posed in answerable form?
2. Was a comprehensive description of the competing alternatives given?
3. Was the effectiveness of the programmes or services established?
4. Were all the important and relevant costs and consequences for each alternative identified?
5. Were costs and consequences measured accurately in appropriate physical units?
6. Were costs and consequences valued credibly?
7. Were costs and consequences adjusted for differential timing?
8. Was an incremental analysis of costs and consequences of alternatives performed?
9. Was allowance made for uncertainty in the estimates of costs and consequences?
10. Did the presentation and discussion of study results include all issues of concern to users?

Source: Drummond et al. (1997).

- The viewpoint(s) – for example, health system, patient, consumer, society – used for the analysis should be clearly stated and justified.
- The form(s) of evaluation used – for example, cost–minimization analysis (CMA), CBA, CEA or cost–utility analysis (CUA) – should be stated and justified.

It is crucial for a policy-relevant analysis to ask the right questions, as these set the framework for the entire analysis. This requires identification of the feasible alternatives in the policy context – including all those interventions that are affordable, technologically appropriate and culturally acceptable. Therefore, the analysis should ideally compare feasible policies and interventions that could be implemented in a timeframe of 5–10 years. Furthermore, the analysis should cover both the costs and impacts of the interventions, and place them in a specific decision-making context.

- This question is dealt with in chapter 3 “Choosing alternative interventions to evaluate”.

Question 2. Was a comprehensive description of the competing alternatives given?

- The alternative interventions should be described in sufficient detail to enable the reader to assess their relevance to a different setting or context – that is: who did what, to whom, where, and how often.

Once the interventions to be compared have been chosen, it is important to make available a full description of each technological solution and its

implementation. All relevant and feasible alternatives must be included and the option of the no-action alternative should not be overlooked. Knowledge of intervention design is important for policy-makers, researchers or implementers to assess the relevance and generalizability of the results of economic analysis to different settings. This will also enable them to adapt the intervention to different conditions.

- This question is also dealt with in chapter 3 “Choosing alternative interventions to evaluate”.

Question 3. Was the effectiveness of the programmes or services established?

- If the economic evaluation is based on a single effectiveness or impact study, such as a clinical trial, details of the design and results should be given – for example, selection of study population, method of allocation of subjects, analysis according to intention to treat, and effect size with confidence intervals.
- If the economic evaluation is based on an overview or meta-analysis of a number of effectiveness studies, details should be given of the method of synthesis or meta-analysis of the evidence – for example, search strategy and criteria for inclusion of studies.
- Justification should be given for the choice of the model and the key parameters.

The starting point for an economic evaluation study that measures intervention *efficiency* is to have available proof of the *effectiveness* of the cho-

sen interventions. If a new intervention option has no beneficial effect or impact, it does not make sense to conduct a study to assess its efficiency. If a new intervention option is known to have the same effectiveness as the currently employed strategy, a cost-comparison study may be relevant to investigate whether the new intervention is less costly, and justifies an economic evaluation study.

There are many challenges to establishing the effectiveness of health-related interventions. Controlled studies of adequate sample size are required to ensure that intervention benefits are related to the intervention itself and not the result of differences in contextual factors. Hence, the starting point of any economic evaluation should be “Is there adequate scientific evidence to indicate an intervention effect?” followed by “What is the magnitude of the effect?” Traditionally, the best source of information on intervention effectiveness is a randomized controlled trial (RCT), assuming it is a pragmatic trial reflecting real-world conditions. In the absence of an RCT, however, it is acceptable to draw on other types of study design, such as case–control or cohort studies. When doing so, scientific validity should be examined closely, and results interpreted accordingly. When a model is used to predict epidemiological outcomes beyond observed end-points, justification and references should be provided.

■ This question is dealt with in chapter 3 “Choosing alternative interventions to evaluate” and chapter 6 “Impact estimation”.

Question 4. Were all the important and relevant costs and consequences for each alternative identified?

- The full range of costs and consequences should be presented, before a justified choice is presented for the inclusion of the most relevant ones.
- Immediate or direct effects and secondary or indirect effects should be clearly distinguished. If changes in productivity (indirect benefits) are included they should be reported and discussed separately.
- Costs and consequences excluded from the base-case scenario could be included in the scenario analysis.

Once the effectiveness of the chosen interventions is established, the boundaries of the analysis must be defined. Depending on the nature of the intervention, there may be numerous different resource inputs, as well as a wide range of consequences or impacts. The intervention impacts can change in size and nature over time because there may be further knock-on or secondary effects associated with the intervention’s immediate effects. Therefore, it is crucial to determine at the start of the analysis what the likely inputs and impacts are, who they fall on, which of them should be measured, and over what time period. The choice of whether to include or exclude costs and benefits should take into account the requirement that little or no bias should be introduced. The boundaries should reflect the research question(s) and specific nature of the interventions. However, it should be recognized that there are (research) cost implications of carrying out the analysis with different boundaries.

■ This question is dealt with in chapter 4 “Boundaries of the cost–benefit analysis”, and chapter 5, section 5.1 and chapter 6, section 6.1 relating to costs and impacts, respectively.

Question 5. Were costs and consequences measured accurately in appropriate physical units?

- The primary outcome measure(s) for the economic evaluation should be clearly stated – for example, cases detected, life years, quality-adjusted life years (QALYs), DALYs, willingness to pay.
- Intervention impacts with economic consequences should be measured in appropriate physical units, in preparation for the valuation in monetary units.
- Methods for the estimation of quantities of unit costs should be given.

Once the exact items for measurement have been identified, the measurement process should be defined so as to capture the resource inputs and consequences appropriately. This is an important first step in estimating economic value, as these resource impacts form the basis for later valuation (see Question 6). Furthermore, the presentation of results in physical units enables simple recalculation based on different prices and input mixes that occur in other contexts. The assumptions that are

made at this stage should be clearly stated and may be subject to later sensitivity analysis.

- This question is dealt with in chapter 5, section 5.3 and chapter 6, section 6.3 relating to costs and impacts, respectively.

Question 6. Were costs and consequences valued credibly?

- Methods for the estimation of prices of unit costs should be given.
- Adjustments to observed market or non-market prices should be justified.
- The currency values (exchange rates) and prices of goods and services that applied on the date on which they were obtained should be recorded and details of any adjustment for inflation, or currency conversion, given.
- Details should be given of the methods used in the valuation of consequences – for example, time trade-off, standard gamble,¹ contingent valuation – and the subjects for whom valuations were obtained – for example, patients, members of the general public or health-care professionals.

As described in the introductory chapter of these guidelines, resources used or affected by an intervention are valued in order to reflect the overall economic impact of the intervention. Therefore, it is important to justify and state the sources of the economic values for resources that are used. Where market or government prices have been adjusted, or where economic values have been computed from other data sources, the rationale and approach should be described.

- This question is dealt with in chapter 5, section 5.4 and chapter 6, section 6.4 relating to costs and impacts, respectively.

Question 7. Were costs and consequences adjusted for differential timing?

- The time horizon over which costs and benefits are considered should be reported.

- The discount rate(s) should be stated and the choice of rate(s) justified.
- If costs or benefits are not discounted an explanation should be given.

Future costs and impacts should be adjusted to reflect the values society places on resources over time. The existence of interest rates testifies to the fact that a unit of currency is worth more now than at any point in the future, a phenomenon known as “time preference”. On the one hand, time preference can be related to the fact that people prefer consumption now to consumption in the future (termed “the pure rate of time preference”). On the other hand, people may expect their real incomes to grow over time, and thus the nominal value of money declines as income grows. People may also prefer consumption in the present due to the possibility of premature death or the advancement of technology which makes goods obsolete over time. Therefore, future costs and impacts should be discounted by an appropriate discount rate to the present time period, using a rate that reflects society’s time preference.

- This question is dealt with in chapter 5, section 5.4 and chapter 6, section 6.4 relating to costs and impacts, respectively.

Question 8. Was an incremental analysis of costs and consequences of alternatives performed?

- An incremental analysis – for example, incremental cost per life year gained – should be reported, comparing the relevant alternatives.

Policy-makers face a limited range of interventions that can be financed, and rarely (if ever) do they have the opportunity to completely reallocate sector budgets. Consequently, it is relevant to present what is called an “incremental benefit–cost ratio”. This ratio compares the costs and impacts under the current set of interventions with the costs and impacts expected under alternative sets of interventions. This information gives the policy-maker an indication of where to reduce or increase budget allocations.

- This question is dealt with in chapter 3 “Choosing alternative interventions to evaluate” and chapter 8 “Presentation and interpretation”.

¹ A method to elicit preferences which measures the risk a person is willing to take in a trade-off between potentially enhanced quality of life (i.e. being cured) and a defined possibility that the treatment will be fatal. The standard gamble is the main tool used for health state preference measurement.

Question 9. Was allowance made for uncertainty in the estimates of costs and consequences?

- Details should be given of any modelling used in the economic study – for example, a decision tree model or regression model.
- When stochastic data are reported, information should be provided regarding the statistical tests performed and the confidence intervals around the main variables.
- The approach of any sensitivity analysis should be clearly reflected – for example, multivariate, univariate, threshold analysis – and justification given for the choice of variables and the ranges over which they are varied.

Cost–benefit analysis is full of uncertainty, given the often hypothetical nature of the costs and impacts of the new interventions being considered, and the measurement error that exists in assessing the costs and impacts of existing interventions. Therefore, the types and levels of uncertainty need to be identified, and the variables with a major influence on overall results pinpointed to enable uncertainty analysis to be conducted. This usually involves the presentation of the results of the cost–benefit analysis under alternative data inputs for included variables, as well as choice of different boundaries (e.g. inclusion or exclusion of variables). The resulting ranges in the benefit–cost ratio indicate the level of confidence in the base-case or point benefit–cost ratio. Where variables have stochastic variation, a confidence interval can be presented for the benefit–cost ratio, for example reflecting a 95% confidence range.

- This question is dealt with in chapter 7 “Dealing with uncertainty”.

Question 10. Did the presentation and discussion of study results include all issues of concern to users?

- The answer to the original study question should be given; any conclusions drawn should follow clearly from the data reported and should be accompanied by appropriate qualifications or reservations.

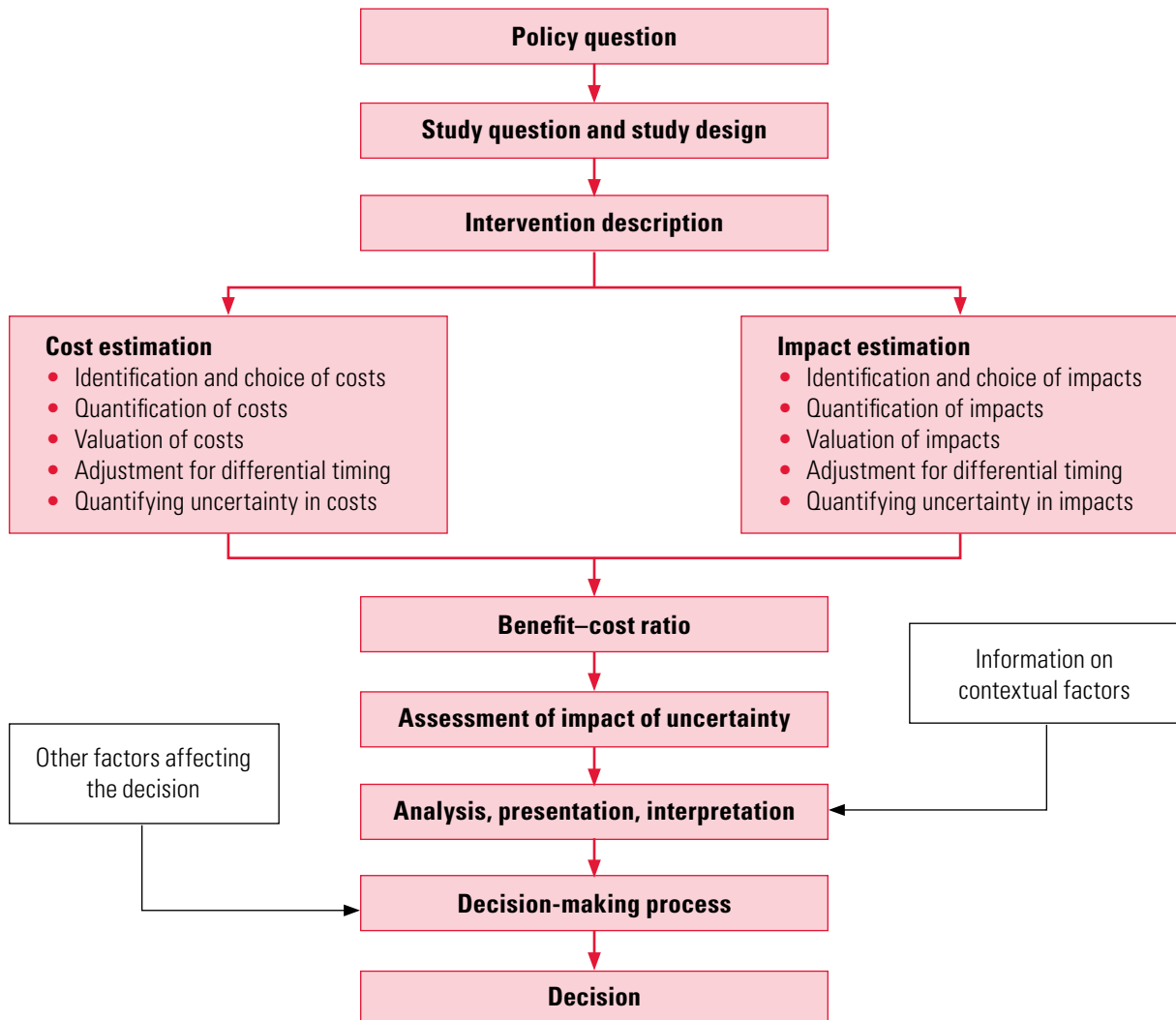
- Important outcomes – for example, impact on quality of life – should be presented in an aggregated as well as a disaggregated form.
- Quantities of resources should be reported separately from the prices (unit costs) of those resources.
- Any comparison with other health interventions – for example, in terms of relative cost–benefit – should be made only when close similarity in study methods and contexts can be demonstrated.
- Accompanying data should be provided to aid interpretation of results in the study context and to allow for generalizability to other decision-making contexts.

How results are presented and interpreted is crucial to the usefulness and use of a CBA. Decision-makers usually demand summary measures of cost and impact, accompanied by relevant qualifications, such as confidence ranges on the benefit–cost ratio, that allow them to interpret the figures appropriately. Policy-makers need to be confident that the analysis was conducted objectively and with minimum bias or risk of misleading conclusions. Furthermore, comparison with the results of similar studies, further data analyses and other background information on implementation issues may be required to aid interpretation of the results, and to place them in a decision-making context.

- This question is dealt with in chapter 8 “Presentation and interpretation of results”.

To summarize, Figure 4 presents the sequence for conducting a CBA, from formulating the policy question, through defining and executing the analytical framework for the conduct of a CBA, to the contribution of the results to a policy decision. Figure 4 does not show the feedback loop following the resource allocation decision or policy change associated with the initial CBA. This feedback loop, via programme monitoring and evaluation, helps define new research questions and provides better data for subsequent CBAs.

Figure 4. Step-by-step approach to cost–benefit analysis, from formulating a policy question to making a policy decision



3. Choosing interventions

3.1 Policy-relevant alternatives

To maximize the policy relevance of CBA, the alternative interventions selected should reflect realistic policy options for the study setting. Policy options include interventions that can be supported through public policy and public resources, and interventions that are available and feasible for implementation through the nongovernmental sector (NGOs or private companies), and suitable for private decisions of households and communities.

Policy-relevant household energy interventions for reducing exposure to IAP in developing countries are listed in Table 3.

Interventions use three main approaches: (1) modifying the source of the pollution; (2) altering the living environment; and (3) changing user behaviour (Bruce et al., 2006). It is recognized that the placement of the interventions in one of the three categories can be difficult, as some interventions can easily be included under more than one category.¹ In the absence of a published alternative, the present categorization is adopted for the purposes of these guidelines.

Table 3 illustrates the numerous intervention options. Evaluating all of them in any one setting would be inappropriate. Therefore, the relevance of each intervention option for the setting of a given intervention programme should be assessed according to the following criteria:

- *Relevance and appropriateness.* This covers issues such as cultural acceptability, technical feasibility (e.g. amenability to altering or renewing buildings), availability of resources (such as electricity and LPG) and affordability. The

¹ For example, efficient housing could equally fall under living environment; pre-cooked food could instead be included with reduced need for fire; and solar water heating could be classified as different fuel/stove combinations.

selection of an intervention in the analysis can also reflect future potential, such as biofuels,² or targeting of specific groups, such as poor households, as was done in the global CBA conducted by WHO (Hutton et al., 2006).

- *Availability of evidence.* Limited evidence on the costs or the impacts of a given intervention may disqualify the intervention from evaluation. For some options, no documented evidence from local studies or international sources may exist, suggesting the need for further research. The reader is referred to scientific evidence on the effectiveness of different interventions (Bruce et al., 2000; Bruce et al., 2006) and encouraged to conduct further literature searches.
- *Level of analysis.* When conducting CBA at different levels of population aggregation, the interventions will be specified at different levels of detail. On the one hand, a global or country-level analysis may simply examine the consequences of switching from traditional to cleaner fuel sources, giving a population average in the resulting ratios (Hutton et al., 2006). On the other hand, when a locality is selected within a country, the patterns of fuel use of specific sub-populations can be identified and interventions modelled accordingly. Therefore, the scale is linked to the boundaries set for the analysis.

Furthermore, the incremental costs and impacts of a given intervention depend on the current scenario, and on its potential combination with other interventions. It is important to recognize

² A biofuel is any processed fuel in gas or liquid form derived from biomass, especially plant biomass and treated municipal and industrial wastes. A longer list of possible sources of biofuel includes wood, wood waste, wood liquors, peat, railroad ties, wood sludge, plant oils, spent sulfite liquors, agricultural waste, straw, tyres, fish oils, tall oil, 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.

Table 3. Household energy interventions to reduce exposure to indoor air pollution

Changing the source of pollution	Improving the living environment	Modifying user behaviour
<p>Improved cooking devices</p> <ul style="list-style-type: none"> • Improved stoves without flues • Improved stoves with flues <p>Alternative fuel–cooker combinations</p> <ul style="list-style-type: none"> • Briquettes and pellets • Kerosene • Liquefied petroleum gas • Biogas • Natural gas • Producer gas • Solar cookers • Modern biofuels (e.g. methanol, ethanol, plant oils) • Electricity <p>Reduced need for fire</p> <ul style="list-style-type: none"> • Retained heat cooker (haybox) • Efficient housing design and construction • Solar water heating • Pressure cooker 	<p>Improved ventilation</p> <ul style="list-style-type: none"> • Smoke hoods • Eaves spaces • Windows <p>Kitchen design and placement of the stove</p> <ul style="list-style-type: none"> • Kitchen separate from house reduces exposure of family (less so for cook) • Stove at waist height reduces direct exposure of the cook leaning over fire 	<p>Reduced exposure by changing cooking practices</p> <ul style="list-style-type: none"> • Fuel drying • Pot lids to conserve heat • Food preparation to reduce cooking time (e.g. soaking beans) • Good maintenance of stoves, chimneys and other appliances <p>Reduced exposure by avoiding smoke</p> <ul style="list-style-type: none"> • Keeping children away from smoke (e.g. in another room if available and safe to do so)

Source: extracted from Bruce et al. (2006).

that the impacts of two interventions implemented jointly are not simply additive, nor are the costs, such as in the case of joint production (sharing of resource inputs between two or more interventions) (Tan-Torres Edejer et al., 2003). For example, Mehta & Shahpar assessed the cost–effectiveness of fuel source changes (LPG or kerosene) alone, improved stoves alone, as well as of the combination of fuel source changes and improved stoves (Mehta & Shahpar, 2004). These options can not only be compared with a no-intervention scenario, but the various options can also be compared with each other. This is especially useful with respect to changes in fuel use because there may be a partial substitution of fuels for different household tasks and a gradual move up the energy ladder towards cleaner and more efficient fuels as households become richer (incremental change with income growth). This gives rise to a possible expansion path, as more expensive but more effective interventions become options for households (Tan-Torres Edejer et al., 2003). It is therefore most useful for policy-makers to have the results of the CBA for interventions in combination as well as alone.

In addition to a “business as usual” alternative, the WHO generalized CEA guidelines recommend the

inclusion of the counterfactual (or null) scenario which essentially requires the modelling of costs and effects if no intervention were in place (Tan-Torres Edejer et al., 2003). In the health field, this type of analysis is theoretically possible and practicable, although it requires assumptions about the levels of disease that would be observed following a complete withdrawal of the current set of health interventions. In the area of household energy, the obvious counterfactual scenario is 100% solid fuel use on open fires or traditional stoves with no ventilation and no steps being taken to reduce IAP exposure. This is in fact the situation in a significant proportion of households in developing countries, and hence facilitates inclusion of the counterfactual scenario in the analysis.

3.2 Description of interventions

One element of a well-conducted economic evaluation is to provide a clear and detailed description of the alternative interventions assessed. This provides a firm foundation for the identification of the full range of possible intervention costs and impacts (internal validity). A detailed description also increases the replicability of the analy-

sis, and allows the reader to compare the methods and results with those of similar studies (external validity).

What is a sufficiently detailed description of the intervention alternatives? Taking the example of the medical literature, economists are encouraged to describe health interventions in the following way: “*who does what to whom, and how often?*” (Drummond & Jefferson, 1996; Drummond et al., 1997):

- The “*who?*” refers to the intervener, whether it is a physician, a community health worker, the ministry of health, energy or environment, a nongovernmental agency, a private company or a combination of these.
- The “*does what?*” refers to the action of the intervener, and what service is provided to the client (e.g. LPG cylinder and stove), or what change of conditions the client eventually benefits from (e.g. a microcredit scheme that enables poor households to purchase LPG). It also describes the place of action of the intervention, whether it is the home, the community or the workplace.

- The “*to whom?*” refers to the person or people directly or indirectly affected by the intervention. Clearly the major impact in most cases is on those directly affected by IAP, such as women and young children living in polluted homes. In some cases, however, a community effect (such as a company that manufactures improved stoves creating new jobs) or an indirect effect (such as when the health of one person affects the actions of another, such as the ability to work or attend school), must also be captured.
- The “*how often?*” refers to the repeated nature of the intervention (e.g. monthly fuel purchase) or its impacts (e.g. prevention of repeated episodes of pneumonia in young children). It recognizes that the intervention or its impacts continue during a specified period (e.g. a well-constructed improved stove may last 10 years) or indefinitely.

Each of these questions needs to be considered for every intervention included in the analysis.

4. Boundaries

The boundary essentially describes which costs and impacts are to be included in the economic analysis, and which excluded. This is an important stage in the study design because the results of an economic analysis can be highly sensitive to the choice of variables. However, there is no single rule for defining boundaries in any given analysis. As illustrated in Box 1, it is not possible to expect the same economic evaluation framework to be applicable in all decision-making circumstances, as the viewpoints to be represented and the analytical boundaries will vary depending on the policy goals.

This chapter covers three important aspects related to defining the boundary: the objective of the analysis; the directness of the association between the intervention and the costs or impacts; and the time horizon of the analysis.

4.1 Viewpoint or perspective

It is crucial to decide the viewpoint or perspective of the analysis at the outset, and to state it clearly. An understanding of the perspective of the analysis is important for three main reasons:

- to decide which costs and impacts will be included or excluded;
- to form the basis for appropriate interpretation of the results; and
- to choose policy-relevant disaggregations of the data.

Viewpoints that could be taken in the economic evaluation of household energy and health interventions could include those of society; the energy ministry; the health ministry; other associated government ministries; the government in general (e.g. the finance ministry); the patient or targeted beneficiary; employers of those affected; insurance providers of those affected (e.g. medical insurance

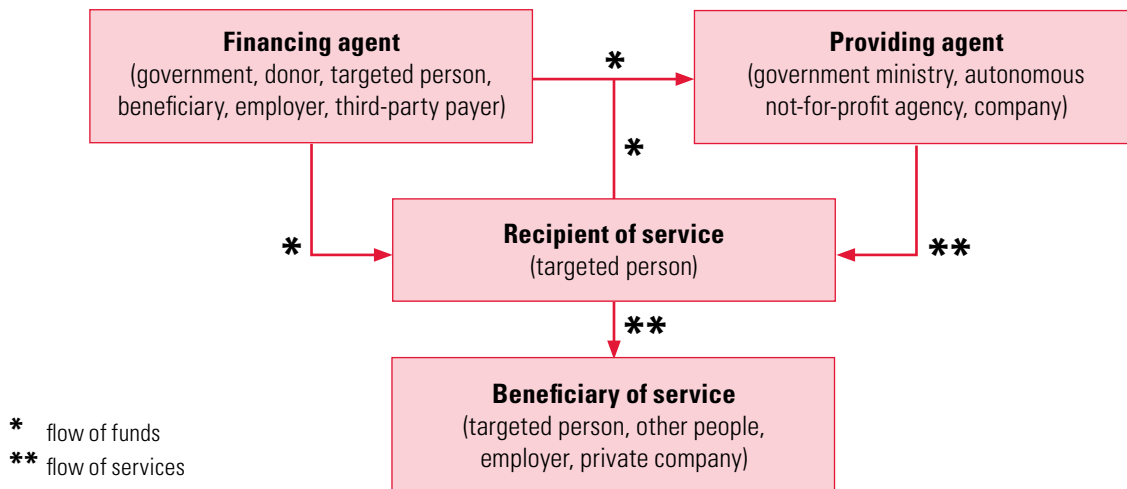
BOX 1

Influences on the interpretation and use of the economic evaluation framework^a

- The existence of *different understandings of the role of economic evaluation*. From an economic theory perspective, the emphasis is on the values individuals place on outcomes. These values are informed by the individuals' ability to pay. From a health sector perspective, the focus is on the health gains that can be achieved with a given budget, where society's values about the relative weight of different health states are central.
- *Measurement difficulties* may compromise the analytical approach. For example, some costs of impacts may be excluded owing to lack of reliable data or the cost of obtaining them.
- The *institutional context* may influence how the components of cost and impact are assembled and measured. For example, if health services are free to the patient or charged at costs below the market value, the demand curve does not reflect the willingness of individuals to pay to use these services at the true economic value.
- *Different approaches exist to capture costs and benefits* in the benefit–cost ratio. For example, subtracting a cost saving from cost (the numerator) to give net cost will produce a different benefit–cost ratio than adding the cost saving to the benefit (the denominator). For any single economic evaluation study, this does not present a problem if the methodology is described and interpretations made appropriately. However, this may cause difficulties when comparing benefit–cost ratios across different studies.

^a Source: Drummond et al. (1997).

Figure 5. Distinction between different players in providing an intervention



company); the selling agent; or the agency providing the programme (Drummond et al., 1997). Various agencies may be involved in implementing the programme, covering government ministries, nongovernmental or community-based organizations, and/or commercial enterprises.

Figure 5 distinguishes between financing agent, providing agent, recipient of service and beneficiary of service. In some cases, these roles overlap and, given the variety of interventions and the different ways in which services are financed and provided, many different combinations are possible:

- The *financing agent* could be the government (through general taxes), an external donor, an NGO, a targeted person, a beneficiary (through a tax on a specific product), an employer, or a third-party payer such as an insurance company. As a general rule, the net costs of each financing agent should be summated to add up to the total cost of an intervention. This approach avoids the double-counting of costs that are covered by more than one financing agent. For example, the government may finance infrastructure investments for an LPG distribution network and a subsidy on LPG cylinders, while an NGO (funded by an international donor) sets up a revolving fund, and the end-consumer pays for the subsidized intervention.
- The *providing agent* could be a government ministry, an autonomous not-for-profit agent (NGO), an implementing agency financed by a donor or a commercial enterprise.

- The *recipient of service* is a targeted person, household or group of individuals, based on pre-defined characteristics, such as geographical location, current fuel use, socioeconomic status, gender or age.
- The *beneficiary of a service* is usually the targeted person whose circumstances, practices or habits are changed. However, other people directly associated with the targeted person may benefit, such as other household members, guests, the employer of the beneficiaries (who has healthier workers), or the enterprise providing the service (due to the profit made on selling the services or goods).

Therefore, whose viewpoint should be adopted?

Traditionally, as CBA is a tool of welfare economics, the viewpoint for the analysis is the *societal viewpoint*. This is essentially a combination of different viewpoints, reflecting the range of players involved. However, as stated above, the societal viewpoint is not exactly a sum of the various viewpoints identified above, due to the problem of double-counting. Moreover, some costs simply represent the transfer of resources from one agent to another, such as in the case of the profit made by a commercial enterprise in selling goods or services. Therefore, it is crucial to identify the groups for which there are real (economic) resource consequences, and to quantify these. Figure 6 gives a hypothetical example of how to aggregate costs (column 1) and impacts (column 2) when several agencies are involved.

Figure 6. Example of aggregating costs and impacts at the societal level from implementing an improved stove intervention

Cost		Impact	
Government imports stoves:	US\$ 20 p.u.	Healthier women earn more	
Government transports:	US\$ 2 p.u.	income from salaried work:	US\$ 200 p.w.
Government sells subsidized stoves		Employer's sales increase:	US\$ 500 p.w.
to companies for distribution:	US\$ 15 p.u.	Employer's value-added increases:	US\$ 200 p.w.
Company costs of selling:	US\$ 3 p.u.	Employer's profits increase:	US\$ 100 p.w.
Companies sell stoves to population:	US\$ 20 p.u.		
Economic cost =		Economic gain* =	
original purchase price on international market		Real gain to employee (profit US\$ 100) + salary to	
(US\$ 20) + domestic distribution cost (US\$ 2) + costs		woman (US\$ 200) = US\$ 300	
associated with selling the stoves (US\$ 3) = US\$ 25		* In theory, this economic gain is only realized when there	
p.u. = per unit (stove)		is no unemployment.	
		p.w. = per woman with avoided illness	

4.2 Directness of association

As well as identifying the perspective or viewpoint of the analysis, it is important to understand how closely resource consequences are associated with the original intervention. One of the ongoing controversies in the application of CEA in the health sector relates to the inclusion versus exclusion of those costs and economic impacts that are not closely associated with the intervention (Tan-Torres Edejer et al., 2003). "Direct" and "indirect" are the terms often used in expressing directness of association (Gold et al., 1996), yet the use and interpretation of these terms is a potential cause of confusion (Drummond et al., 1997). Therefore, instead of a simple distinction between "direct" and "indirect", the analyst should identify how closely the costs and impacts are associated with the original intervention, and make a judgement about whether:

- they are too indirect or their association with the intervention is too uncertain to allow them to be included; and
- whether their inclusion or exclusion has important implications for the results of the analysis – especially whether there is likely to be a biasing effect.

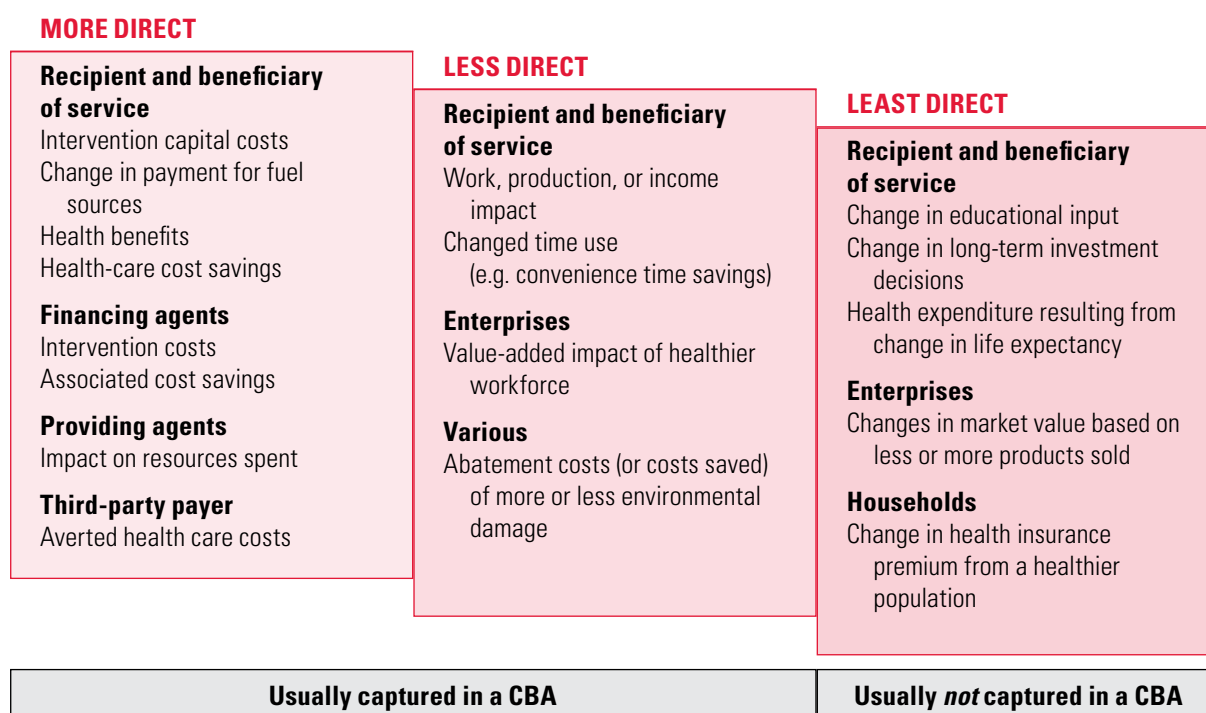
A common way to deal with the latter is to justify why certain variables are included or excluded, and to discuss the likely direction of impact on the overall results (refer to uncertainty analysis, chapter 7).

Figure 7 distinguishes between different types of cost and impact based on their directness of association with a typical household energy intervention to reduce exposure to IAP. The first set of costs and impacts are those most closely associated with the intervention or its impact, such as intervention costs, health benefits and health-care cost savings. The second set of costs and impacts is a direct consequence of these primary impacts, such as use of time, or costs or cost savings associated with intervention impacts. The third set of costs and impacts tend to be longer term and least related to the direct beneficiaries and are therefore least certain.

Including only the more direct costs and impacts in the study boundary will fail to capture the cycles of effect resulting from the intervention. For example, the vicious cycle theory describes the self-perpetuating loop of negative effects that lead to a downward spiral and cause households to fall into poverty or stop them from escaping from poverty. Likewise, more recently, the theory of the virtuous cycle of development (for example, linking improved health and education with a self-reinforcing upward cycle of development) has been used to justify increased investment in social and productive sectors of the economy.

Therefore, should CBA attempt to capture less direct as well as long-term and self-feeding but least direct effects? There are serious challenges involved in estimating these effects. Cost-benefit analyses are usually modelling exercises based on hypothesized effects (using secondary data sources). Therefore,

Figure 7. Distinction between more direct, less direct and least direct effects of household energy interventions to reduce exposure to indoor air pollution



CBA, cost–benefit analysis.

the more indirect the effect, the greater the level of uncertainty. For the long-term and least direct effects, this level of uncertainty would invalidate the results of CBA, as confidence intervals would be too wide to give a meaningful result. Furthermore, even if a CBA used observations from the field and over a long time, the analyst would need to assess the degree of causality and apportion the effect accordingly.

For these reasons, CBA does not necessarily need to capture least direct effects. Such benefits should, however, be described during the decision-making process and it is recommended that researchers include and quantify less direct effects as far as possible.

4.3 Time horizon of analysis

The question of timing of costs and impacts is a fundamental issue in CBA given that directness of effect declines over time (see section 4.2). Two questions relate to the time horizon: what is the time period of the intervention? and what is the time period for following up the impact of the intervention? (Tan-Torres Edejer et al., 2003).

4.3.1 Time period of intervention

The WHO generalized CEA guidelines recognize that the time horizon of health decision-makers is probably rather short, and recommend generalized CEA to evaluate interventions implemented over a period of 10 years but taking into account impacts over a life-course horizon of 100 years (see discussion under section 4.3.2). They do however recognize that the time horizon can be tailored to fit the intervention in question.

4.3.2 Time period of impact

Traditionally, CBA evaluates investment projects, where intervention costs are front-loaded (i.e. principally incurred at or near the beginning of the project) and benefits tend to be delayed and spread over a longer period. Therefore, the time horizon of the CBA can be central to the outcome of the analysis. For example, a CBA with a short time horizon would tend to reduce the benefit–cost ratio of the intervention. On the other hand, when the discount rate is relatively high (e.g. more than 5%), the costs and impacts occurring in the distant future are relatively small compared to the current

ones. For example, in 50 years, one US dollar will be worth 23% of the present value at a 3% discount rate, and only 9% of the present value at a 5% discount rate. Hence cost–benefit analyses traditionally measure intervention effects for a maximum of 15–20 years.

An additional problem with extending the time horizon of the analysis to the long-term, e.g. beyond 20 years, is that costs and impacts become increasingly uncertain. Nevertheless, using their software PopMod (Population Model) the WHO’s cost–effectiveness tool WHO-CHOICE¹ evaluates the impact of interventions over a period of 100 years, recognizing that the health impacts of interventions change over time and may not be realized

for several decades (Tan-Torres Edejer et al., 2003). For example, any reduction in morbidity and mortality due to lung cancer following an intervention to reduce coal use will only become apparent after a long latency period.

It should be noted that the issue of time horizon of the analysis is different from the question of the physical length of life of the equipment being purchased for the intervention. This latter question is dealt with either by converting the capital costs to annual values (termed “annualization”) and using these in the calculations, or by allocating a proportion of the capital cost corresponding to the fraction of the time horizon of the study compared to equipment life (see chapter 5).

¹ WHO-CHOICE – CHOosing Interventions that are Cost Effective: <http://www.who.int/choice/en/>

5. Cost estimation

Four main steps in cost estimation are covered in this chapter:

- identification and choice of main intervention costs for inclusion;
- identification of sources of data on intervention costs;
- quantification of intervention costs in physical units; and
- valuation of intervention costs in monetary units, and discounting.

Other issues related to cost estimation are presented in later chapters:

- uncertainty in costs in chapter 7; and
- cost presentation and interpretation in chapter 8.

5.1 Cost identification and inclusion

It was stated in chapter 2 that the analysis should compare alternative policy-relevant options with the current situation, thus conducting an “incremental” analysis. In terms of costs, this requires the analyst to identify and measure the incremental changes. This can be done in two ways (see Figure 8):

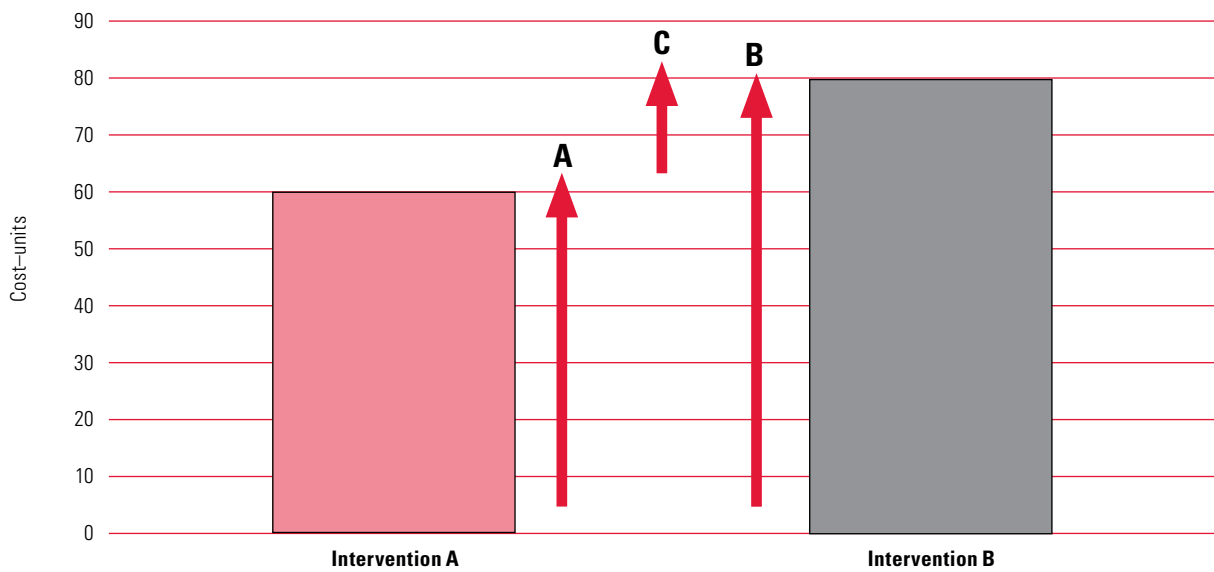
- Estimate the total costs of option A and the total costs of option B, and calculate the incremental cost as the difference between the two. This is usually done when the interventions being compared are different in content. For example, substituting one fuel technology with another also requires replacement of hardware. In Figure 8, this involves estimating arrow A and arrow B, and subtracting A from B to get the incremental cost.
- Estimate the incremental cost of moving from option A to option B. This approach is especially relevant when option B requires option A as a base. This is usually done when an intervention

consists of adding or subtracting activities from other interventions, for example, purchasing an additional piece of hardware but continuing with the same fuel type. In Figure 8, this involves estimating arrow C only, and there is no need to estimate the non-incremental costs.

The calculation of incremental cost consists of summing all the resources required to put in place and maintain the interventions. Sunk costs (the research and development (R & D) costs of bringing a new technology to market) are usually not included, unless the intervention requires additional investments to complete the current project. However, in this case the additional R & D costs required should be spread over the production levels expected once the technology is more widely adopted. The option of including sunk costs ensures that large-scale programmes are not embarked upon without recognizing the scale of this cost.

Costs are classified according to the input category (e.g. salaries, supplies and capital), intervention activity (e.g. administration, planning and supervision), organizational level (e.g. national, district or community) and financing agent (e.g. government, donor, NGO or household) (Tan-Torres Edejer et al., 2003).

A further distinction often made for health interventions is between the costs of providing health interventions and the costs of accessing health interventions. The cost of providing health interventions is essentially the cost of the health service: an outpatient visit, an inpatient day or an outreach service. The costs of accessing health interventions include the resources used in seeking or obtaining an intervention (e.g. transport and food) as well as related time costs. Such a distinction raises questions about who is financing the intervention. In fact, the simple dichotomy provider–beneficiary is

Figure 8. Illustration of two methods for estimating incremental cost

not recommended for measures to reduce exposure to IAP, as there are potentially many more actors. The analysis should state the identity of the agent incurring each set of costs, and the types of resources involved (e.g. equipment, parts, building or labour). This information is also useful for assessing willingness and ability to pay for interventions.

A recommended starting point for identifying intervention costs is to distinguish between those costs incurred only at the start of the intervention, and whose benefit lasts for more than 1 year (termed “investment” costs), and those costs that recur every year (termed “recurrent” costs). The main types of investment and recurrent costs are listed below, and Table 4 indicates which of these are likely to be incurred for different interventions.

Investment costs

- planning and supervision (e.g. project management, technical support);
- marketing;¹
- hardware (e.g. purchase of equipment and parts for cooking or heating) and hardware installation;

¹ Marketing and the installation of hardware could be treated either as investment or recurrent costs. From a beneficiary point of view, marketing represents a one-off activity that prompts a household to adopt and/or purchase an intervention. From a programmatic point of view, marketing as well as the installation of hardware represent recurrent costs.

- construction (e.g. house alteration or laying cables or pipelines);
- education accompanying an intervention;
- transportation (e.g. vehicle purchase);
- communication and market development (e.g. radio programmes or promotional events).

Recurrent costs

- operating materials and services;
- maintenance of hardware and replacement of parts;
- monitoring and regulation;
- ongoing education activities;
- transportation (e.g. vehicle hire, fuel expenses);
- interest repayment on loans.

Different types of intervention will vary in terms of where the main cost lies. For example, the adoption of a solar cooker or the enlargement of eaves spaces involve largely investment costs, whereas a change in fuel from collected wood to purchased charcoal, using the same stove, involves largely recurrent costs. On the other hand, an intervention combining a cleaner fuel and an improved stove (e.g. switching to LPG and an LPG cooker) may involve significant investment as well as recurrent costs.

A distinction is made in economic evaluation between average and marginal costs as follows:

- *Average cost* per person reached includes both purely economic costs (already paid or supported by the existing system) and additional costs (further financial or economic costs required to deliver an intervention).
- *Marginal cost* per person reached includes only additional costs (further financial or economic costs) required to deliver an intervention.

Table 4 shows the main cost elements associated with a selection of interventions (refer to Table 3). All interventions require planning and supervision to ensure that they are implemented appropriately. Similarly, educational inputs (e.g. how to use a new stove, how to store kerosene safely and out of children’s reach) are delivered at the stage of the major investment, for example through radio programmes, specific training, focus group discussions and other information dissemination activities.

In addition to the initial investment period, some continuing maintenance and education, as well as monitoring and regulation, may be necessary to ensure the continued effectiveness of the interventions. For example, improved stoves with chimneys require considerable follow-up to ensure that the flues are kept clean and the lowered IAP levels are maintained.

Changes in user behaviour, on the other hand, require very little investment, except for purchasing pot lids or partially pre-cooked food. The main type of cost involved in changing user behaviour is that of educational input, and perhaps monitoring. Participatory approaches, such as interviews with key informants and focus group discussions have been found to be equally (or more) successful than “educational input”.

In a first step, the analyst must identify the inputs necessary for an intervention. Subsequently, a decision is needed about which costs will be included

Table 4. Activities and resource requirements of different interventions^a

Activity	Source of pollution		Living environment	User behaviour	
	Improved stove	Changed fuel source	Improved ventilation or kitchen design	Higher efficiency in fuel use	Reduced exposure to smoke
INVESTMENT COSTS					
Planning and supervision	X	X	X	X	X
Marketing	X	X	X	(X)	(X)
Hardware/materials	X	(X)	X	(X)	
House alterations (software, hardware)	X	(X)	X		
Education/instructions	X	X	X	X	X
Transportation	X	X	X	X	X
Communications	X	X	X	X	X
RECURRENT COSTS					
Operating materials		X			
Premises/storage rental	X	X	X		
Maintenance and repair	X	(X)	(X)		
Monitoring and regulation	X	X	(X)	(X)	(X)
Education/instructions	X	X	X	X	X
Interest repayment on loan	X	X	X		

^a Refer to Table 3 in chapter 3 for the classification of intervention categories.
X, costs are relevant for interventions; (X), costs may be relevant for interventions.

Table 5. Overview of data sources for costs of household energy and health interventions

Cost type	Data sources
Planning and supervision	Government accounts or survey of line ministries/agencies Contracted company or NGO
Hardware/materials	Market prices Contracted company or NGO Focus group discussions
House alterations (software; hardware)	Construction company or NGO Company selling materials Household survey Focus group discussions
Premises and storage rental	Market prices Contracted company or NGO
Education/instructions	Contracted company or NGO Government accounts or survey of line ministries/agencies
Labour/staff	Labour market statistics Contracted company or NGO
Transportation/communications	Market prices (transport, communication) Contracted company or NGO
Maintenance and repair	Market prices Contracted company or NGO
Monitoring and regulation	Government accounts or survey of line ministries/agencies
Interest repayment on loan	Government accounts or survey of line ministries/agencies NGOs administering revolving funds Banks administering micro-credit schemes

NGO, nongovernmental organization.

in the cost estimation. Although the contribution of different cost components towards the total costs is not known in advance, it is important to understand which costs are considerable and which are minor. This helps to focus data collection on those costs which contribute significantly to overall cost and thus determine the results of the CBA. As a general rule, any costs constituting less than 1% of the total cost can be excluded to reduce the research cost. However, when a programme is being implemented on a very large scale (such as a national programme), cost components below 1% may need to be taken into account as the absolute financial values are large.

5.2 Sources of data on costs

5.2.1 Overview

Data on costs – on both physical quantities and economic values of resources – can be obtained from a variety of sources. Table 5 gives an overview of

major data sources by cost type. Where the required information cannot be collected from routine and periodic information sources, analysts may draw on specialist surveys or studies or resort to expert opinion to formulate assumptions on costs.

5.2.2 Routine information sources

Market prices

Where no data are available from an implementing agency, as in the case of a modelling exercise for a hypothetical programme, market prices can be used. However, if used for a service which includes a mixture of inputs, this source may not provide disaggregated costs by resource or activity.

Labour market statistics

Where labour is a major input to an intervention, the market prices of different types of labour are an important data source. An appropriate estimation

of the economic value of labour may need to draw on additional labour market statistics that give an indication of the availability of each labour type in different settings and the unemployment rates.

Cost data extracted from these routine information sources are reliable and tend to be made available on an annual basis. Also, the cost of collecting these data is minimal.

5.2.3 Periodic information sources

Programme information

These data may be collected from a contracted company, government ministry or NGO. The agency implementing a pilot or scaling-up programme is likely to keep accounts and collect other routine data which give reliable information on the investment cost of the intervention. The implementing agency is unlikely to follow the intervention over longer time periods to measure recurrent costs.

5.2.4 Special surveys or studies

Household surveys

Separate household surveys for the collection of cost data, as well as other data (see section 6.2.3) may be justified. Their usefulness depends on the proportion of the overall intervention cost met by households. Where households purchase stoves and fuel, change practices and behaviour, or pay for alterations to their homes, data on costs from a household survey are invaluable. Other sources of data on these costs may not be needed unless validation of prices is required. A household survey may also give more reliable data on product efficiency and use in a real-life situation than could be obtained under laboratory conditions. Furthermore, if a household survey is already planned for the measurement of the impacts of an intervention, a cost survey component can be added at little additional cost. However, such surveys may require respondents to recall information over extended periods of time which may produce misleading results.

Scientific studies

When the health impact of an intervention is being tested in a trial setting, costs can be measured and reported at little extra cost. Experimental studies

potentially provide detailed information with high internal validity, but such studies are rare and very expensive to conduct. Furthermore, the external validity of cost data from experimental studies should be assessed, as the actions within such studies may be more intensive, and therefore more successful, than under normal conditions.

Expert opinion and assumptions

Expert opinion and assumptions must be based on the best available knowledge about the likely resource requirements. When no research can be done on intervention costs, they represent a useful and inexpensive fall-back method, but have questionable reliability.

In conclusion, it will be necessary for the analyst to compare the data needs with the different sources of available data, and the pros and cons of each (see Table 6), before choosing which to use.

5.3 Cost quantification

Once the costs to be included have been decided and appropriate data sources identified, the physical inputs of each of these resources must be measured. This is usually necessary as an intermediate stage before costs can be valued in monetary terms (see section 5.4). However, direct cost valuation is sometimes justified. For example, when an intervention is provided by a private company that declines to share information on invoicing, sales and resource inputs, a breakdown of cost into physical units will not be possible. However, this approach reduces the transparency and understanding of costs, and ultimately the generalizability of the findings to other settings.

The description of the intervention (section 3.2) should clearly identify the activities, and these should be further broken down by resource type. Table 7 shows an example of a simultaneous change of fuel source and a switch to an improved stove. The main resource inputs are human labour (hours, days, and proportion of full-time equivalent), the costs of the stove and the recurrent fuel costs.

It is important to measure and present the resources in physical quantities using the appropriate unit of measurement. Table 8 shows the options for units of measurement for each main category of resource.

Table 6. Pros and cons of different sources of data for cost information

Data source	Availability	Cost	Reliability	Frequency	Generalizability
Market prices	Readily available	Low cost	High reliability	Regular	Low – time- and location-specific
Labour market statistics	Generally available, may need additional collection	Low cost if from routine sources	High reliability	At least annually	Low – time- and location-specific
Programme information	Low – special information systems needed	Low to medium cost	High reliability	Can be regular; at least annually	Low – depends on contextual differences
Household surveys	Implemented to answer specific questions	High cost	High reliability	Infrequent	Low – depends on contextual differences
Cost data from scientific studies	Low – few published studies	Low to medium cost	High reliability	Infrequent	Low – adjustments possible
Expert opinion and assumptions	Medium to high	Low cost	Variable reliability	As and when needed	Medium – can be assessed by experts

Table 7. Example of resource inputs associated with an improved stove and cleaner fuel intervention

Activity	Resource(s) by activity	Financing sources
INVESTMENT COSTS		
Development and research	Labour, materials, infrastructure	Government or private sources
Planning and supervision	Labour and overhead costs ^a	Energy ministry
Hardware/materials	Stove and parts	Household, donor, NGO
Installation	Labour and equipment	Household, donor, NGO
Education/instructions	Labour and overhead costs ^a	Energy ministry, health ministry, NGO
RECURRENT COSTS		
Operating materials	New fuel costs (additional costs compared to before)	Household
Maintenance	Labour and overhead costs, ^a spare parts	Household or NGO
Monitoring and regulation	Labour and overhead costs ^a	Energy ministry, health ministry, NGO
Education/instructions	Labour and overhead costs ^a	Energy ministry, health ministry, NGO

NGO, nongovernmental organization.

^a Overhead costs include those resources that are necessary for the personnel to do their work, including transport and administration.

To estimate the net increase in fuel costs of the intervention, the concept of incremental cost needs to be applied:

- When a new fuel source is introduced, the net cost of the fuel is the cost of the new fuel (total per year) minus the cost of the old fuel. The figures should not be presented in unit terms,
- but in terms of total cost per year, given that the quantities of fuel used may vary according to the season.
- When a new improved stove is purchased, the net intervention cost is the cost of the new stove model minus the cost of the previously available model.

Table 8. Units of measurement for main categories of resource

Resource	Item	Unit of measurement
Labour	<ul style="list-style-type: none"> • Time worked per labour category 	<ul style="list-style-type: none"> • Hours or days worked, by labour category • Number of full-time equivalent labour units
Vehicles	<ul style="list-style-type: none"> • Vehicle count • Distance travelled • Fuel consumption efficiency of vehicle 	<ul style="list-style-type: none"> • Number of vehicles • Kilometres • Kilometres per litre of fuel
Materials	<ul style="list-style-type: none"> • Material count • Useful life 	<ul style="list-style-type: none"> • Units • Useful life in months or years
Equipment, parts	<ul style="list-style-type: none"> • Equipment count • Useful life • Resale 	<ul style="list-style-type: none"> • Units • Useful life (in years or units of usage) • Resale possible (yes or no)
Fuel	<ul style="list-style-type: none"> • Weight • Volume • Fuel efficiency 	<ul style="list-style-type: none"> • Kilograms • Litres or hundred litres • Kilograms or litres per hour

- When exposure to air pollution is taken into account when new buildings are constructed, the net cost of the intervention to reduce exposure is the cost of the new building model minus the cost of the old model (e.g. the costs of addition of a hood or chimney, or different window size or fitting).

However, in some situations, the incremental cost is the cost of the new intervention without subtracting the cost of the old intervention:

- When the new fuel source replaces an old fuel source that was not paid for (e.g. collected firewood, although collecting firewood has an implicit time cost, which should be included under the convenience time savings).
- When the new stove is being purchased to replace an old stove, which was not due for replacement.

In some instances, it is possible that an intervention does not cost more than the traditional alternative being phased out. For fuel sources, depending on relative prices and the fuel efficiency of the stove, the change to a new fuel source can result in a reduction in annual fuel cost (Hutton et al., 2006).

One variable with considerable range and uncertainty is the lifespan of an intervention, such as the expected length of useful life of a new stove, or the period of time an educational activity is effective for. Such information is not routinely available and can only be generated by long-term follow-up (e.g. by monitoring a programme).

5.4 Cost valuation

5.4.1 Overview

The valuation of costs is a crucial stage in CBA, as the specific methodology used for resource valuation in economic evaluation is what distinguishes it from financial analysis. Therefore, it is important to pay special attention to identifying, specifying and justifying the economic values chosen.

It is important to recognize that the observed market price often does not reflect the economic value¹ or the “competitive” market price. Such distortions in the market can have several causes (outlined in Box 2). Furthermore, projects themselves may influence prices, by creating demand for a product or by supplying new products to the market. Therefore, the observed current prices do not reflect the prices that will exist after the project is implemented (Curry & Weiss, 1993).

In all the above situations, guidelines on cost–benefit analysis generally recommend that the analyst makes adjustments to the observed prices, called “shadow prices”. Early guidelines proposed a set of procedures, sometimes lengthy and complex, to identify these shadow prices (Little & Mirrlees, 1968; United Nations Industrial Development Organization, 1972); these were subsequently

¹ In fact, the theory of perfect competition states that for an observed market price to reflect economic value, the market of the product or service concerned should be characterized by the following: (a) the number of buyers and sellers is very large, and none can individually affect the market price; (b) products offered are homogeneous; and (c) perfect information is available.

BOX 2**Examples of instances where the observed price in a market does not reflect the economic value**

- *Direct government interventions* in product pricing (subsidies, taxes or price-fixing) or artificial pricing of the currency through foreign exchange controls. An example of price-fixing is the imposition of legislation on minimum wages which raises the wages for unskilled labourers. It may also include the government-controlled pricing of goods where importation or sale is handled or regulated by the government (e.g. price paid by the health sector for generic drugs). Taxes, duties and subsidies are called transfer payments. In general, they should be excluded from the economic value of a good or service because they transfer command over resources from one party (taxpayers or subsidy receivers) to another (government, tax receivers or subsidy givers) without reducing or increasing the amount of real resources available to the economy as a whole.
- *Indirect impact of government intervention* on prices through international barriers to trade, and regulations or conditions which discourage competitive practices. Also, where the government controls the capital market, the commercial cost of capital (interest rates) may not reflect the socially optimal rates.
- *Natural monopoly* (either public or private provider). This may exist in markets such as power supply, postal services or rail networks where having more than one producer may render service provision less efficient. Furthermore, early guidelines on cost–benefit analysis recognized that development projects have the potential to affect market prices, requiring a specific set of rules for resource valuation.
- *Uncompetitive practices* in the market. In this case the price includes the excess profits of a monopolist provider, or is inflated in an oligopolistic market (with few providers who have implicit or explicit agreements to maintain high prices) where price collusion is common.
- *The good is donated*, such as in the case of a donated stove or donated (free) time of a voluntary worker of an NGO.

refined and simplified (Little & Mirrlees, 1968; Dasgupta, 1970; Layard, 1972; United Nations Industrial Development Organization, 1972; Little & Mirrlees, 1974; Mishan, 1975; Sugden & Williams, 1978; Asian Development Bank, 1997; MacArthur, 1997; Pearce & Nash, 1981).

In the context of the present guidelines, these approaches have several drawbacks. For example, understanding the complexity of the procedures requires training in applied economics methods. Even if the procedures are fully understood, they are difficult to apply due to stringent data needs. Moreover, the guidelines were written for application to major development projects with the primary aim of maximizing national income.

The guidelines on economic evaluation from the health domain have recognized these weaknesses. Whereas health guidelines maintain that measurement of the *economic* cost is the guiding principle, a more pragmatic approach to the valuation of costs has been proposed (Drummond et al., 1997). In general, this approach to costing takes existing market prices unless there is some justified reason to do otherwise. Drummond et al. recommend that in making adjustments to market prices, analysts should be convinced that:

- leaving prices unadjusted would introduce substantial biases into the study; and
- there is a clear and objective way of making the adjustments (Drummond et al., 1997).

The United States panel for the establishment of CEA guidelines recommends the use of opportunity cost, and adjustment to prices when markets are not “perfect” (Gold et al., 1996).

In a more recent publication on approaches to cost valuation in the health sector, a step-by-step approach is proposed. The first step is to identify whether the good is, or could be, traded on the international market (termed “traded goods”) (Tan-Torres Edejer et al., 2003; Hutton & Baltussen, 2005). Different recommendations are made for traded goods and non-traded goods, as described below.

5.4.2 Traded goods

Traded goods are those goods that move freely across borders. Usually, goods that could be traded, but are not because of trade restrictions or lack

of market exploitation, are also included in this category. For clarity these are often labelled “potentially traded goods”. However, categorization of goods relevant to control of IAP is not always straightforward. For example, it does not make sense to trade wood fuel, locally-produced simple stoves, or locally-made but low-quality building material internationally. These types of products should be considered as non-traded goods. Also, electricity and labour are generally treated as non-traded goods, although there are clear instances of these resources being traded between countries. Kerosene, LPG or electric cookers, on the other hand, are more likely to be traded by the country in question (whether imported or exported), and should therefore be classified as traded goods.

The opportunity cost for traded goods can be considered to be the foreign exchange that leaves the country in order to pay for the inputs. Similarly, the value of an input to an intervention that is produced locally, but could be exported, is the value it could have obtained on the international market. Therefore, the international market price should be used as a basis for estimating the opportunity cost of traded or potentially traded goods. The international market price should be adjusted to include cost, insurance and freight (c.i.f.) for imported goods and free on board (f.o.b.) for exported goods. The c.i.f. price should exclude import duties and subsidies, and include the selling price of the producing country, freight, insurance and unloading charges. In addition, the costs of local transport and distribution (termed “domestic margin”) should be added to the c.i.f. international price to approximate the local opportunity cost. The f.o.b. price should include the production cost as well as the costs of getting the product to the point of departure of the exporting country, and includes local marketing and transport costs and local airport or port charges. In the absence of data on the import cost or margin, it is possible to use the WHO price multiplier available on the WHO-CHOICE website.¹ This refers to the average import cost margin for medical goods imported to different WHO sub-regions (Johns et al., 2002).

The reason for excluding import duties and subsidies from the price is that these are simply transfers from one part of society to another. They do not use

resources but transfer the power to use resources from one agent to another.

Even when international market prices are readily available, similar products sold internationally often have different prices. The choice of the economic value depends on the cause of the price variation.

- If the variation is due to *product differentiation* (where products are similar but not identical), some if not all of the price difference may be justified. This may be due purely to differences in quality, or to differences in the uses and functions of a product. Therefore, it is important to identify the price of a good with similar, even if not identical, characteristics and quality.
- If the variation is due to *pure price discrimination*, where the same product is sold to different countries at varying prices, the price taken should be one that reflects the purchase opportunities of the country in question. Price differences may arise due to bulk purchase agreements, or market exploitation by the seller (where prices tend to be higher in countries with higher income or more market potential). If these differences are due to changes during the life-time of the project, prices should be updated (at that point in time).
- If the variation is due to *differences in international and domestic distribution costs*, the international market price should be chosen to take into account the cost of the product available to the country in question. The final price used by the analyst should also reflect the local distribution costs that are likely to occur in the project under study. Johns et al. derive a simple method for calculating the domestic price margin, based on distance from the assumed point-of-entry of a good into a country (Johns et al., 2002).

Where the price of a traded good includes “excess” profits (that is, above “normal” profits in economic terminology), the literature on cost–benefit analysis does not provide clear instructions on how to deal with these. If the “transfer payment” argument is applied, it is clear that no opportunity cost is incurred with income transfers and profits, and therefore these should be subtracted from the international price of the good in question.

However, when considering the welfare of a particular country, the opportunity cost of a resource

¹ http://www.who.int/choice/costs/price_multiplier/en/index.html

is the foreign exchange cost, which would include excess profits of traded goods (if they exist). A second argument for including excess profits says that some markets exist because they are the result of market protection given by the patent system. Patents are argued to be a justifiable way of encouraging new discoveries, which is essential in the area of technology development. Therefore, at the between-country level, the rule on excluding transfer payment does not apply. However, if a similar product (e.g. a generic stove instead of a patented stove, with the same characteristics) is available locally, the price of the cheaper alternative should be used. This solution reflects the buyers' opportunities: on the one hand, it does not stop health programmes from going ahead if generic products can be used instead of branded products; on the other hand, it does not mistakenly support expensive programmes where generic products are not yet available.

The prices used must reflect the scale on which production or distribution is likely to take place. Greater coverage of the intervention may lead to reductions in price due to bulk purchase agreements, or the exploitation of economies of scale in production and distribution.

5.4.3 Non-traded goods

In CBA, goods that do not move freely across borders are termed non-traded goods (NTG). These include resources such as human labour, utilities, buildings and domestic transport.

Cost-benefit analysis recognizes that labour market prices might not reflect the true opportunity cost of human input. To determine the economic value of labour employed, labour prices should be adjusted for distortions in the labour market, to estimate the so-called "shadow wage rate" (SWR). Labour is traditionally divided into two basic categories: scarce labour and labour which is not scarce locally. Further labour categories, voluntary labour and beneficiary time, are also covered below. The distinction between "scarce" and "non-scarce" labour will vary by setting. In some countries, it is not uncommon for skilled staff to be unemployed. Similarly, in some countries, unskilled (or low-skilled) labour is in short supply, for example, at harvest time in the agriculture sector. Therefore, analysts should make their own judgements, and justify their choices.

Scarce labour is typically labour which involves skilled workers for which there is little or no unemployment. For this type of labour, it is recommended to take prevailing market wages and fringe benefits, which together approximate the opportunity cost. This may well lead to an underestimate of the true opportunity cost of skilled health workers in countries where the private sector does not function and governments control salaries. In fact, in most instances it is inappropriate to call a government salary a "market" wage. In the health sector of many countries, the government has a near-monopoly on health staff, and in many other countries, although a private sector may exist, it is not well developed. The salaries paid in the private health sector generally do not reflect the opportunity cost of labour, as the prospects for the majority of health staff to work in the private sector are severely limited. However, the means to derive a shadow price of skilled labour where a free market does not exist are limited. Therefore, it is recommended that the opportunity cost of labour is reflected by the gross salary, plus the monetary value of fringe benefits (employers' contributions to social security, pension plans, health and life insurance, and other job perks such as use of a car, free accommodation or a financial contribution to private accommodation).

An important question is how to deal with the valuation of *expatriate labour* employed in a country on salaries which may be much higher than those paid to local staff with similar skills. The answer depends on whether the intervention requires the supposedly higher quality of expatriate labour, and whether the expatriate labour could be replaced with local labour based on the same qualifications, skills and efficiency levels. If there is an absolute need for expatriate labour, it should be considered as a traded good and valued accordingly. However, if it is possible to implement the intervention using local labour and with no significant loss in programme quality, local labour costs should be used. If the intervention is likely to be scaled up considerably, then it is unlikely that the same level of input of expatriate labour would be used, and therefore using local salary rates is justifiable.

Non-scarce labour covers those labour categories where there is a surplus of supply over demand. The cost to the economy of using unskilled labour is the opportunity cost of net output lost in the next

best use of that person's effort, and is traditionally disaggregated by rural and urban populations:

- Where labour is drawn from *rural* areas and would otherwise have been employed in agricultural production, the opportunity cost is often taken to equal the value of lost production. This can be estimated indirectly using the rural wage rate, adjusting for seasonality. At certain times of the year the value of lost production might be zero or close to zero.
- Where labour is drawn from *urban* areas, the economic price of labour in the urban areas can be approximated by estimates of annual incomes in the urban informal sector. However, this could well be an overestimate of the true opportunity cost of unskilled labour in countries where minimum wage laws apply to the urban sector.

Voluntary labour has little or no financial cost, but should also be valued at economic cost in a CBA. Voluntary labour has an opportunity cost, which is the value generated if used in the next best alternative. For example, community workers who are not paid can equally employ their effort in other useful community-related or private activities. The opportunity cost of voluntary labour will vary from one volunteer to the next, based on qualifications and experience. The recommendation is to take the wage rate of personnel who would normally be employed to do the same job in the absence of the volunteer.

Beneficiary time includes inputs provided by the person receiving the intervention, and should be treated similarly to voluntary labour. In health care evaluations, a number of alternative options exist for valuing the opportunity cost of a patient's time. The most tangible cost is that of lost earnings, where the beneficiary actually forfeits income while seeking health care. When the employee is granted time off to seek care, the employer loses the added value of the person seeking care for the time he or she is absent from work. The opportunity cost of the income or production forgone can be represented by the wage rates of individuals with specific skills and qualifications (see above). However, wage rates do not exactly reflect welfare effects, as these are related not only to the value of the monetary gain, but also to the impact on the individual or household (which varies, especially between rich and poor households). Also, it should be noted that willingness to pay values for disease

avoided may implicitly include the value of these forgone earnings, which requires the analyst to check that the benefits of disease avoided are not double-counted (Gold et al., 1996).

Where there is no direct monetized income or "formal" production loss, there are still welfare effects of beneficiary time input to an intervention. This may be lost production time in unpaid agricultural work or childcare, lost time from school, or simply lost leisure time. Following the principle of opportunity cost, CBA estimates a shadow price for this input. There are various ways of identifying the shadow price, and some of these lead to different estimates than for forgone income or production (see paragraph above). However, it is most equitable to use a value similar or identical to that used for forgone income and production, to avoid the ethical dilemma associated with valuing different beneficiaries at different economic values.

Utilities include gas, electricity, water and telephone services which can be provided both privately and publicly. Whoever the provider, it is important to assess whether the prices charged to the consumer reflect competitive rates, by examining the degree of competition (e.g. if the provider is a monopolist) and whether the provider receives subsidies from the government. In fact, many providers of utilities in the developing world are public and in a monopolist position. The problem the analyst faces is that, without an in-depth knowledge of the accounting and pricing system of a public utility company, it is not clear how prices are set. Given this uncertainty, and based on the assumption that utilities represent only a small proportion of total cost, it is recommended to use the tariff rates of the utility provider, and apportion costs to the intervention based on the observed or presumed use.

Building and transport costs for an intervention can be approximated using either of two methods. The first method is based on the current market purchase cost of the building or vehicle. To estimate annual equivalent cost an annualization factor should be applied that incorporates the useful life of the building or vehicle (i.e. depreciation) and the opportunity costs (i.e. interest rate) of the funds tied up in this asset (Creese & Parker, 1994; Drummond et al., 1997). Costs are commonly annualized using the following formulae. Formula (1) calculates the capital value of the good to be annualized; formula (2) calculates the annual value of the good.

$$P = K - (S / (1+r)^n) \quad (1)$$

Where P is the net price of the good taking into account the resale of the good (after it has been used by the intervention), K is the nominal purchase value of the good, S is the resale value at time n, r is the interest rate, and n is the period after which the capital is replaced.

$$E = (P / A(n,r)) \quad (2)$$

Where E is the equivalent annual value of the good, and A(n,r) reflects the annualization factor, which equals $(1 - (1+r)^{-n}) / r$.

The annual maintenance and operational costs should be added to the equivalent annual cost of the investment. Once the total annual equivalent value is known, then allocations to different activities can be made based on observed or approximated allocation criteria (e.g. percentage of floor space).

Where possible, the costs should be disaggregated by the traded good component (e.g. hardware, gasoline) and the non-traded good component (e.g. labour). Also, an assessment should be made of whether local prices reflect competitive market rates. Where construction work or transportation are carried out by the private sector, it can be assumed that the prices charged include the full costs of both traded and non-traded goods. However, unless the company provides free access to information on its accounts, it will be difficult to disaggregate building and transport costs by component. In the public sector, it will be necessary to determine an economic cost based on the resources used.

The second method involves identifying the rental value of a similar building or vehicle which fulfils the same function. The rental value incorporates both the depreciation and the opportunity costs of the asset, but usually excludes the operational costs. It should be ascertained whether the current rental market is competitive, and if not, what would be a reasonable market rate.

5.4.4 Unit of presentation

All costs and impacts should be expressed in a common currency, with a stated base year. For reasons of comparability and generalizability at global level, it is common practice in economic evaluation to present the results in a foreign currency. One option is to use US\$, where the current market exchange rate (if free floating) or an adjusted

exchange rate (if fixed) is used. Another option is to use international dollars (I\$) by applying country-specific purchasing power parity (PPP) to non-traded goods. A PPP exchange rate is the number of units of a country's currency required to buy the same number of goods and services as one unit of currency in a reference country, in this case the United States (Tan-Torres Edejer et al., 2003). An international dollar is therefore a hypothetical currency that is used as a means of translating and comparing costs from one country to another. The results in I\$ can be translated back to local currency units, or US\$, for appropriate interpretation and policy-making at the country level.

To translate I\$ into local currency units, the traded goods component should be exchanged at the official exchange rate, whereas the non-traded goods component should be exchanged at the PPP value for the given currency. PPP exchange rates are available from the WHO-CHOICE web site at www.who.int/evidence/cea. If the study is aimed at national or subnational policy-makers, it makes less sense to value costs in I\$; therefore, presentation in US\$ or local currency units is acceptable.

If the collected costs and benefits are available for time periods other than the base year, the costs must be inflated or deflated by the rate of inflation in the setting or country of the study. Also, when costs are expressed in other currencies, the exchange rate for the stated base year should be used. For example, if the costs are in 1998 Indian rupees, and the costs need to be expressed in US\$ in the year 2000, the costs should first be inflated to year 2000 Indian rupees, and then converted at the year 2000 US\$/rupee exchange rate (Kumaranayake, 2000).

5.4.5 Differential timing of costs

As explained in chapter 2, the current value of a given amount of money will change in the future due to the time preference for money. This effect is separate from the issue of inflation, where prices change from period to period due to relative imbalances between the supply of goods and the demand for them.

The differential timing of costs is typically dealt with in economic evaluation by applying a discount rate to future costs, thus calculating a present value for future costs. This requires knowledge of the following:

- The *value of the good* at a time in the future. It is generally assumed that the future price of any single good will rise at the same rate as the general inflation rate. As incomes and budgets are expected to grow at roughly the same rate, the purchasing power remains the same and this effect can be ignored in the CBA. However, if the price of the good in question is expected to rise at a rate significantly greater than the general rate of inflation, the real price increase should be reflected in the CBA. Unless there is good reason to believe this will occur, the analyst can safely assume a constant real price of the good in question.
- The choice of the *discount rate*. The actual value of the discount rate is important, as it has a potentially large impact on the results. Values used in the literature vary between 0% and 10%, and arguments can be found to support this wide range. The sources generally argued to best reflect social time preference are the market interest rate or the government discount rate; it should be recognized that the latter is often based on the former. A competitive market interest rate reflects the average preference for

future over present consumption. However, this can be strongly influenced by the level of economic development of a society.¹ Furthermore, the gross market interest rate does not reflect the return on investment to private investors, who have to pay tax on the income they earn from interest payments. Also, private investment decisions do not (fully) reflect the interests of future generations. Hence, a lower discount rate would give future generations greater weight in the analysis, both on the cost and impact side. For consistency with previous guidelines, a discount rate of 3% is recommended.

The discrete time formula for estimating the present value of any stream of costs (NPV_{costs}) is:

$$NPV_{costs} = \sum_t^T costs / (1 + r)^t \quad (3)$$

Where $\sum (t, T)$ is the sum of all the costs incurred at differential time periods ($t = 0$ to the end of the evaluation period T), with costs at each time period (t) discounted to the present using the discount rate (r).

¹ For example, in a developing country the amount of savings people can put aside means that there is limited capital available for entrepreneurs or households to borrow. Hence, interest rates may be higher than in developed countries.

6. Impact estimation

As with costs, there are four main steps in impact estimation:

- identification and choice of main intervention impacts for inclusion;
- identification of data sources for intervention impacts;
- quantification of intervention impacts in physical units; and
- valuation of intervention impacts in monetary units.

Other issues related to impact estimation are presented in later chapters:

- uncertainty in impacts in chapter 7; and
- impact presentation and interpretation in chapter 8.

6.1 Impact identification and inclusion

As with the estimation of cost, the first step in impact estimation is to identify all the possible impacts of the intervention, and to select the relevant ones for inclusion in the analysis. It should be noted that the impacts of an intervention can be negative as well as positive. For example, depending on the stove type, switching from biomass or coal to the cleaner fuel, kerosene, may increase the risk of kerosene poisoning by ingestion. A change in technology may also imply other costs, such as the need for a new source of lighting in a house where an improved stove is used, because the fire, the original source of light, is no longer available. Therefore throughout this section the term “impact” is used instead of “benefit” to reflect both the positive and negative impacts of an intervention.

There are many and diverse potential impacts associated with household energy and health

interventions. They range from the easily identifiable and quantifiable to the intangible and difficult to measure. The guiding principle, however, is to include all major impacts, irrespective of the feasibility of measuring them.

Therefore, it will be necessary to identify the major impacts from previous published studies at the international and national levels. Where CBA is conducted at the subnational level, discussions with community members and other key players can ensure that context-specific impacts and perspectives are identified. Once a list of significant impacts has been drawn up, the next step is to evaluate the availability of evidence and/or the potential for gathering the data and the associated costs. Naturally, some balance will be required between pragmatism and reliability of data, as it may be very costly or difficult to obtain or generate robust data sets for some impacts. However, the decision is context-specific, depending on the availability and quality of data, the costs of collecting additional data, the added value of collecting additional data and the overall budget available.

As in cost estimation, the value of interest is primarily the *incremental* impact of the intervention. As shown in Figure 8 of chapter 5, for incremental cost estimation, incremental impacts can be estimated either:

- by measuring the total impact of all interventions and calculating the difference between these; or
- by identifying the differences in impact between two different interventions.

Usually, the less data-intensive method is the latter approach – identifying the change in impacts when moving from one intervention to another.

Due to the numerous and diverse potential impacts of household energy and health interventions, it

is useful to categorize different types of impact. These are summarized in Table 9. An important set of economic impacts are related to health:

1. Health effects

These essentially include the changes in health-related quality of life, and changes in life expectancy (quantity) associated with an intervention. As stated in chapter 1, exposure to IAP is associated with a number of respiratory diseases, in particular acute lower respiratory infection (ALRI), chronic obstructive pulmonary disease (COPD) and lung cancer (from coal smoke) (Smith & Mehta, 2003). Other health effects are not due to the smoke per se, such as burns and scalds from open fires and unsafe cooking arrangements. Changing the fuel source, in particular switching from collected to purchased fuels, could reduce the risks from carrying heavy loads and dangers from mines, snakebites and violence during fuel collection. However, the inclusion of these potential health impacts needs to be based on the best scientific evidence available. Health impacts whose association with exposure to indoor air pollution is uncertain should, in general, be excluded. For example, WHO's global cost–benefit study included only ALRI in children under 5 years of age, and COPD and lung cancer in adults over 30 years of age, i.e. those health outcomes for which the scientific evidence is strongest (Hutton et al., 2006).

2. Health expenditure

The impacts on health of changes in household energy practices are also associated with changes in expenditures for preventive and curative (treatment) health care. Health expenditures can fall on the government (subsidized care through a public health system), the patient (fee for service, and non-service costs such as transport and food), or the patient's employer or health insurance company. In addition to expenditure on health for patients, other economic impacts are associated with treatment-seeking, such as income loss or productive time loss. More indirectly, health expenditures – if they reduce mortality or disability – are associated with extended life expectancies. It is important, however, to include the health-related expenditures only where the underlying health impact has been included in the CBA (see point 1 above).

3. Health-related income effects

Health impacts due to an intervention also have implications for the number of days lost from daily activities. Such daily activities can include income-earning activities (formal employment, informal employment or self-employment), other productive activities in the household or on the land (e.g. subsistence agriculture or childcare), leisure time or school attendance (for children). The realization of these impacts can be both immediate (e.g. income) and distant (e.g. the impact of school attendance on educational attainment). In addition to the direct impact on productive days gained due to an episode of illness avoided, there are also longer-term effects on production and income from the extended years of life. Again, it is important to include only the health-related effects on income where the underlying health impact has been included in the CBA (see point 1 above).

A second set of impacts are the non-health related ones that result directly from adopting household energy and health interventions:

4. Time impacts

Depending on the fuel source, households can spend considerable time collecting, preparing and using fuels. The impact on time required for fuel collection relates mainly to changing from wood and dung, which are mostly collected (and prepared in the case of dung cakes) by households from the local environment. These fuels may also be collected and sold to generate an income. Depending on demand and local availability, people may need to travel for hours every week to collect sufficient amounts of fuel. Other types of fuel, such as coal and charcoal, are generally purchased, but considerable time may still be required for travelling to the nearest supplier. In terms of time required for fuel use – mainly for cooking – lower-grade fuels and stoves burn less completely and generate less heat than higher-grade fuels and stoves, thereby increasing cooking times. Switching from a one-pot to a two-pot stove, for example, allows two dishes to be cooked at the same time. Indoor air pollution deposits soot on pots and walls. Anecdotal evidence suggests that women value interventions that keep their environment soot-free as these reduce the time they have to spend cleaning.

Table 9. Summary of potential positive and negative impacts of household energy and health interventions

Impact	Possible positive impacts	Possible negative impacts
DIRECT IMPACTS RELATED TO HEALTH		
Health effects	Multiple health benefits of reduced exposure to indoor air pollution, fewer accidents with open fires, and reduced hazards during fuel collection.	Switching to kerosene can increase the risk of children being poisoned and of burns, scalds and explosions (depending on conditions of kerosene storage and use).
Health expenditure	Cost savings related to less ill health (depends on use of services).	Costs related to more ill health (depends on use of services). Costs of health care in extended life period.
Health-related income effects	Impact on income of avoided illness (depends on severity and duration of illness and type of employment). Income earned in extended years of life.	Impact on income related to more ill health (depends on severity and duration of illness and type of employment).
DIRECT IMPACTS NOT RELATED TO HEALTH		
Time impacts	Households moving up the energy ladder or using more fuel-efficient stoves will spend less time collecting fuel. More efficient fuels or more fuel-efficient equipment will reduce cooking time.	
Household environment	An electricity connection or more natural light allows more educational and productive activities during daytime and evening. Cleaner fuel or equipment alternatives can improve the quality of the living environment, and reduce time spent on cleaning.	
Fuel and equipment cost	The use of more efficient fuel types and equipment may reduce fuel costs (if more inefficient fuel alternatives were purchased before the intervention, e.g. in urban slum settings).	Switching to purchased fuel will increase recurrent household costs. An improved stove must be purchased. Increased use of units may increase fuel bill.
INDIRECT IMPACTS RELATED TO THE ENVIRONMENT		
Environmental impacts at the local level	Environmental impacts depend on local factors, such as availability of fuel wood and sensitivity to environmental damage.	Some fuel changes may have an impact on the local environment. For example, the production of modern biomass fuels such as ethanol or plant oils results in changed patterns of land use.
Environmental impacts at the global level	Overall net impact depends on change in net greenhouse gas emissions resulting from the intervention. This depends on whether the fuel is harvested renewably.	

5. Household environment

Changing household energy practices can have many effects, such as:

- *Lighting.* There may be an impact on the level of lighting available for accomplishing household activities. For example, a new window lets in more light in the daytime; an improved source of lighting extends the number of hours available for productive activities or studying.
- *Ergonomics.* Household energy and health interventions may have an impact on ergonomics related to cooking and carrying, and thus health outcomes. Carrying heavy loads may be associated with an increased risk of prolapse, and a more accessible source of fuel will reduce labour burdens and associated health risks. Women have also reported experiencing less back pain when using an improved stove that is raised above floor level.
- *Hygiene practices.* These may change in response to a cleaner environment, including changes in food drying habits.
- *Electricity.* The availability of electricity enables the operation of machinery that runs more reliably or efficiently on electricity, or may encourage the purchase of new equipment, such as a refrigerator, thus improving food safety.

6. Fuel and equipment cost

A major impact of changes in fuel sources and stove efficiency is the change in the proportion of the household budget spent on fuel. The net impact on household budget can be positive or negative, depending on fuel use before an intervention is introduced. The calculation of impact requires information on the quantity of fuel currently collected by the household or purchased on the market; the efficiency of the fuel and the stove; the consumption of fuel for different uses such as cooking and space heating; and the unit cost of the fuel. These same variables must be calculated for the new type of fuel used or new technology adopted. However, given that the fuel switch or purchase of an improved stove are part of the intervention, it is possible to deduct any fuel cost savings from the gross intervention costs (in the denominator of the benefit–cost ratio), to produce the net intervention cost. It is also methodologically acceptable to

include these savings in the economic impact (in the numerator of the benefit–cost ratio).

A third set of impacts represent the less direct consequences of adopting household energy and health interventions. These apply only in relation to switching to cleaner, more efficient fuels or in relation to improved stoves that reduce emissions and increase fuel efficiency. These impacts are largely of a public nature where public resources that are freely available and consumed in an unregulated way are depleted more rapidly than if they were in private hands. While this phenomenon, also referred to as the “tragedy of the commons” by economists, may not have immediate consequences for households and businesses (such as agriculture), such unregulated behaviour will eventually have negative implications for people (as well as for biodiversity and the animal kingdom). The impact may, however, not be felt for a very long time. Related intervention impacts can occur at two principal levels:

7. Environmental impacts at the local level

Environmental damage at the local level results from biomass harvesting for fuel purposes. Increased demand for fuel (e.g. through population growth) or reduced availability of fuel may add to deforestation and land degradation, and increase the risk of natural disasters, such as floods and landslides. Insufficient availability of fuel may also cause people to change to lower-grade fuels, such as dung and crop residues, depriving soil of its natural fertilizer to the detriment of agricultural production. Ultimately, these impacts on the local environment can have important health and economic implications. Some household energy and health interventions counter these effects by reducing the need for biomass fuel through higher energy efficiency (e.g. a fuel-efficient stove) or by eliminating the use of dung and wood altogether (e.g. switching to a cleaner fuel).

8. Environmental impacts at the global level

Environmental damage occurs at the global level through the release of greenhouse gases produced during fuel combustion. This damage is caused by two different mechanisms:

- When fuel is not harvested renewably, the carbon dioxide released during burning is a net

addition to greenhouse gases in the atmosphere. This is always the case with fossil fuels, but can also occur when wood and other biomass fuels are harvested in a non-renewable fashion.

- Even when a fuel is renewably harvested, solid fuels can be net greenhouse gas emitters if they are inefficiently combusted in open fires or simple stoves and emit products of incomplete combustion (PIC).

If a fuel is not both renewably harvested and efficiently combusted, its use will produce a net contribution to global warming. Consequently, any household energy and health intervention that improves fuel combustion, reduces fuel use or includes a reforestation scheme will contribute to a reduction in greenhouse gas emissions.

It should be noted that environmental impacts are the least certain of all intervention impacts, not only in terms of their size, but also in terms of who is affected.

A salient feature of all eight categories of impact is the range of agents affected, and the complex chains of causation. Therefore, it is recommended that empirical data are disaggregated by gender, age, and income or poverty level, and that the causal links are understood and described. As pointed out earlier, women and young children are most likely to experience the benefits that accrue through improved health. However, when valuing these benefits in economic terms, the impacts on these groups may be considerably undervalued if traditional economic valuation techniques such as the human capital approach are used (see section 6.4).

On the other hand, the non-health benefits to the household accrue not only to women and children (i.e. through reductions in time spent collecting fuel or cooking), but also to those members of the household who are most likely to use electricity and other commercial fuels for income-generating activities. These benefits can be enjoyed equally by both men and women. As the poorest households most frequently lack access to electricity, it is probable that such interventions will be of greatest benefit to the poor.

6.2 Sources of data on impact

6.2.1 Overview

Sources of data on the impacts of household energy and health interventions will depend on the impact

being measured. Table 10 summarizes various possible data sources. The main types of information sources are discussed below.

Given the complexity of economic evaluation studies, which combine both epidemiological and economic components, a range of approaches are possible, which combine different sources of data. Based on the three major sources of information – routine, periodic and special surveys or studies – four levels of evidence are distinguishable: primary data collected from a study set up to answer the specific research questions; secondary sources from the literature selected based on relevance and convenience; studies synthesizing published studies; and modelled data or assumptions. A summary of their performance is presented below; most cost–benefit studies draw on several if not all of these data sources to obtain information on intervention impacts. Some of the points that should be borne in mind when using the various sources are listed below.

Primary studies

- Internal validity can be influenced by the analyst.
- Transfer of trial results to real life can be problematic, depending on whether the study design is pragmatic.
- Primary studies usually do not involve long-term follow-up of impacts.
- Collection of primary data is associated with a high research cost.

Secondary studies

- Internal validity needs to be assessed before the results of secondary studies from other contexts are used.
- External validity should be examined on a case-by-case basis, and adjustments made where necessary.

Synthesis studies

- Where several good-quality studies are available, the results of a meta-analysis give more accurate and precise estimates of impact.
- Problems with the interpretation of results may occur when evidence is synthesized from heterogeneous studies.

Table 10. Overview of sources of data on intervention impacts

Impact	Data type	Data sources
DIRECT IMPACTS RELATED TO HEALTH		
Health effects	<ul style="list-style-type: none"> – Type and incidence of illness – Duration and severity of illness – Mortality by cause 	<ul style="list-style-type: none"> – Health information system – Household health survey – Sentinel surveillance site – Experimental study
Health expenditure	<ul style="list-style-type: none"> – Health facility coverage – Use and cost of services, including outpatient and inpatient care – Use and cost of transport – Time lost due to health care seeking 	<ul style="list-style-type: none"> – Health information system – National health accounts – Facility survey – Patient (exit) survey – Household survey – Company survey – Experimental study
Health-related income effects	<ul style="list-style-type: none"> – Time lost due to illness – Income lost due to illness – Time use patterns (fuel collection, cooking) 	<ul style="list-style-type: none"> – Household questionnaire – Patient (exit) survey – Sentinel surveillance site – Experimental study
DIRECT IMPACTS NOT RELATED TO HEALTH		
Time impacts	<ul style="list-style-type: none"> – Time use patterns (fuel collection, cooking) – Value of time or wage rates – Alternative time uses 	<ul style="list-style-type: none"> – Household questionnaire – Observational study – Focus group discussion – National wage tables
Household environment	<ul style="list-style-type: none"> – Educational activities – Productive activities – Cleaning activities – Ergonomics – Light availability 	<ul style="list-style-type: none"> – Household questionnaire – Observational study – Focus group discussion
Fuel and equipment cost	<ul style="list-style-type: none"> – Fuel efficiency – Units of fuel use – Cost per unit of fuel use – Changes in fuel use – Number of meals cooked per day 	<ul style="list-style-type: none"> – Product information – Household questionnaire – Market data (prices and sales)
INDIRECT IMPACTS RELATED TO THE ENVIRONMENT		
Environmental impacts at the local level	<ul style="list-style-type: none"> – Fuel availability and collection practices – Environmental impact (e.g. rate of deforestation or land erosion) – Agricultural output 	<ul style="list-style-type: none"> – Environmental survey – Household questionnaire – Focus group discussion – Observational study – Agricultural statistics
Environmental impacts at the global level	<ul style="list-style-type: none"> – Renewable fuel harvesting – Greenhouse gas emission 	<ul style="list-style-type: none"> – Household questionnaire – Global literature, databases

- Methods for the synthesis of epidemiological evidence are more advanced than those for economic evidence.
- Synthesis studies can be costly to conduct (cost increases with the number of studies included).

Modelling studies

- The representation of reality in a model may be questionable, and thus the reliability of estimates is relatively low.
- Advanced methods of sensitivity analysis can help provide a more robust assessment of the implications of lack of precision in selected input variables.
- Modelling studies draw on a range of data sources to yield the best input data for the model.

6.2.2 Routine information sources

Data from routine information sources is of high reliability and tends to be the cheapest to obtain. It is usually available on a monthly or on an annual basis. In some countries, however, data quality may be low due to poorly functioning government information systems.

Health information systems. Data from the health information systems in developing countries are often of variable quality, sometimes due to poor data entry and incomplete, irregular transmission of data to higher levels of administration. Information is usually available on reported diseases. Owing to the lack of diagnostic tools at primary care level, and the poorly functioning referral systems of many countries, data from health facility records on the numbers of reported cases and deaths by cause may not be reliable. Moreover, cases of illness often go unreported in health facilities as people may not seek treatment at modern facilities or they may self-treat. Furthermore, in some countries significant proportions of the population also seek treatment from traditional practitioners.

National wage data. National wage data are routinely available, and updated annually.

Market data on sales. Sales data may only be available for larger companies that are registered for tax-paying and that provide sales information. Data on the sales volume of imported products are the most accurate because of the additional reporting mechanisms in place for imported goods.

Agricultural statistics. Agricultural statistics are often available from the national census bureau, and include information on production, sales, imports, exports and labour force.

Global databases on greenhouse gas emissions. Some data on greenhouse gas emissions are available by sector (e.g. transport, agriculture and domestic energy), from national reports to the United Nations Framework Convention on Climate Change.

Product information. For registered products, information on their characteristics, such as combustion efficiency, should be routinely made available.

6.2.3 Periodic information sources

National health accounts. National health accounts are drawn up annually in some countries; in other countries, they tend to be done irregularly, every few years. National health accounts state the main sources of health expenditure in a country in a given year, and where this money is spent (e.g. in public/private or primary/secondary facilities). The information is not fully representative of a country, but samples are taken throughout the country. The information is cross-validated with government accounts and the receipts of facilities, and sometimes involves a household survey component.

Household questionnaires. Household questionnaires are increasingly being used throughout the developing world, to capture quality of life and consumption indicators at the micro-level of society. The questionnaires can be focused on economic indicators (e.g. household budget surveys), population demographics (census), or specific aspects of quality of life (e.g. health and demographic surveys). National household surveys are usually conducted on a large scale and designed to be representative at the national and often at the subnational level. Household questionnaires also collect large amounts of information, although often not specific enough for use in answering a particular research question such as on the impacts of indoor air pollution.

6.2.4 Special surveys or studies

Sentinel surveillance. Sentinel surveillance sites are specified areas where surveys are regularly conducted to collect detailed information about specific aspects of a population, in particular their health. These surveys therefore provide more accurate

data than health information systems for studies trying to understand population health. However, considerable financial and human resources are required to conduct them.

Special household surveys. For the purposes of a research study on a specific question that is not adequately addressed in existing household surveys, a separate household survey could be conducted. In some cases, it may be possible to utilize the sampling frame of an existing household survey, thereby linking the newly collected information to other existing information.

Company surveys. These can be targeted at companies that are expected to benefit from an intervention, ideally before and after the intervention takes place. However, such surveys require the company to collect data routinely on the variables of interest, such as health expenditures by disease, or numbers of days of absence of workers by disease.

Patient exit survey. Patient exit surveys are conducted with patients after they have completed their visit to a health facility. Such surveys are useful as they capture the characteristics of a specific target population. Furthermore, the answers are usually a reliable source of information, as they are asked immediately after the health visit, thereby minimizing recall bias. However, exit surveys can be affected by response problems when people do not feel comfortable about responding truthfully to the interviewer, or when the purpose of the interview is misunderstood. For example, if patients expect to gain by misrepresenting the costs they incurred, they may claim to have paid more than they did. Special patient surveys require resources to conduct data collection and analysis, yet they provide only a small part of the total data on impacts.

Focus group discussions. There is an added value of community members discussing certain changes (e.g. in time use, cleanliness) and reaching a consensus on general community-level impacts. This information can also be useful for interpreting values derived from quantitative surveys.

Observational studies. Observational studies are useful to measure the time required for specified activities, and they provide more accurate information than household interviews. However, the presence of researchers may influence the amount of time people allocate to different tasks. Furthermore, sufficient samples are required to make sure that variability is adequately captured, mak-

ing observational studies very research-intensive undertakings.

Experimental studies. Experimental studies, such as randomized controlled trials, are used to determine the health effects of an intervention, in particular changes in the morbidity and mortality due to childhood pneumonia. Randomization and blinding of researchers are employed to reduce the possibility of bias (e.g. a physician diagnosing childhood pneumonia should not know whether the child being examined lives in a home using solid fuels or cleaner fuels). Owing to the presence of confounding factors, experimental studies often require large samples and long-term intensive follow-up, making them expensive to conduct.

Expert opinion. As stated in chapter 5, expert opinion is based on the knowledge of selected individuals familiar with the likely impact of an intervention. Expert opinion is particularly useful in sensitivity analysis, where ranges on variable means (or confidence intervals) have to be chosen. It is a useful and inexpensive fall-back method, but is the least reliable of all the data sources.

6.3 Impact quantification

6.3.1 Overview

The main data needs and data sources are used as the basis for the quantification of intervention impacts. Table 11 shows the “units” required to calculate the various impacts.

6.3.2 Health benefits and health service use

One of the difficulties in considering the wide range of health effects in Table 11 is the highly variable nature and quality of evidence. The body of epidemiological evidence linking exposure to IAP with different health effects was discussed in sections 1.1 and 6.1. In addition, evidence of the impacts of different interventions on selected health outcomes is required. The most robust evidence on the impacts of interventions is derived from a randomized controlled trial, or a quasi-random trial. These studies are difficult to conduct in the field of household energy and health. Furthermore, the necessity of meeting strict research design criteria may result in an intervention that is more tightly controlled and delivered than if diffused more “naturally” through community development and market mechanisms.

Table 11. Data required for quantification of impacts

Impact category	Variables or elements	Specific data needs for quantification
DIRECT IMPACTS RELATED TO HEALTH		
Health status	Health-related quality of life	<ul style="list-style-type: none"> – Type of illness – Duration of illness, by type – Impact of illness on quality of life
	Health-related quantity of life	<ul style="list-style-type: none"> – Rate of illness, by age/gender – Case fatality rate, by illness type and age/gender
Expenditure and time for health-care seeking	Health service use of those with diseases caused by exposure to IAP, or injuries due to fuel use (burns, poisoning, injuries during fuel collection)	<ul style="list-style-type: none"> – Cases of illness, by type – Number of consultations per case, by illness type – Number of hospital admissions per case, by illness type
Time gained due to less illness and death	Reduced morbidity	<ul style="list-style-type: none"> – Time gained per illness prevented, by illness type – Use of time gained for activities
	Reduced mortality	<ul style="list-style-type: none"> – Numbers of premature deaths, by age and gender
DIRECT IMPACTS NOT RELATED TO HEALTH		
Impact on time use	Time spent collecting or purchasing fuel	<ul style="list-style-type: none"> – Changes in amount of time per person per day
	Time spent cooking	<ul style="list-style-type: none"> – Changes in amount of time per person per day
Changes in household environment	Impact of improved lighting on education activities	<ul style="list-style-type: none"> – Changes in education activities
	Impact of improved lighting and availability of electricity on household production activities	<ul style="list-style-type: none"> – Changes in production activities
	Impact on ergonomics related to cooking and carrying fuel	<ul style="list-style-type: none"> – Related health complaints, and impact on quality of life
	Impact on household cleanliness and hygiene, and need for cleaning	<ul style="list-style-type: none"> – Related health complaints, and impact on quality of life – Time spent cleaning
Fuel savings	Impact on fuel use and cost of fuel due to switch in fuel type or stove technology	<ul style="list-style-type: none"> – Changes in fuel use, by type
INDIRECT IMPACTS RELATED TO THE ENVIRONMENT		
Quality of local environment, future capacity	Extent of deforestation	<ul style="list-style-type: none"> – Changes in tree or forest cover
	Changed environment (e.g. soil fertility) and risks of disasters (e.g. flooding, landslides)	<ul style="list-style-type: none"> – Changes in land use and agricultural output – Changes in risk of disaster
Quality of global environment, future capacity	Contribution of local area to greenhouse gas emissions	<ul style="list-style-type: none"> – Changes in fuel burned, by type
IAP, indoor air pollution.		

For the range of health impacts that are unrelated to IAP (see sections 1.1 and 6.1), the evidence available is even less consistent. Although there have been some scientific studies of communities and groups of patients (for example children with burns, or kerosene ingestion in hospitals), the “evidence” is drawn from a mixture of anecdote, case-studies (for which the methods for information gathering are often unclear), and the verbal or written experience of people working in the various settings. Yet, these effects are very important, and together may have the potential for as great an impact on health and well-being as the more easily identifiable and better-studied effects of exposure to IAP.

Given the difficulties in scientifically evaluating the health impacts of interventions to reduce IAP, it is necessary to combine knowledge from a wide range of sources of varying reliability. Stories and practical experience should not be dismissed out of hand just because they are “unscientific”. On the other hand, it is important not to let reports of benefits that might have been significant in specific circumstances become accepted as generalizable truths.

The amount of time lost due to morbidity and mortality is quantified as follows:

Morbidity. The number of cases of illness averted is multiplied by the average duration of illness. As this approach assumes a 1 to 1 relationship between the illness and the number of days worked, it raises the question of whether the value of avoided days of work loss due to illness should be based on actual days of work loss, or on days of illness. For example, WHO’s global CBA assumed a 5-day working week (Hutton et al., 2006). In social welfare terms, however, the value of improved health extends beyond whether or not the person works.

Mortality. The number of deaths averted in each age category is multiplied by the life expectancy within each age category. If the intervention alters the age-specific life expectancies, the population in each age category should be multiplied by the change in life expectancy within that age category.

6.3.3 Time use

Ideally, time use should first be presented in number of hours or days and then be valued in monetary units, due to the assumptions associated

with valuing the time inputs or time savings associated with household energy interventions. This approach lends transparency to the analysis, and can provide additional information to decision-makers interested in changes in the time use of specific population groups.

It may be necessary to draw on a variety of sources to estimate time use. Currently, gender surveys ask about the main activities of women and some household economic surveys, such as the World Bank’s Living Standard Measurement Study, enquire about fuel sources and use of time by adults. For example, a World Bank survey in India, covering six states, compared time use of women between households with and without electricity provided by a grid (World Bank, 2000). Additional household surveys or focus group discussions may be necessary, especially if there are doubts about the reliability of routinely conducted surveys.

6.3.4 Household environment

Changes in the household environment may have noticeable but difficult-to-quantify impacts on the household. Some aspects of the intervention, such as stove features and placement, will have already been captured under health effects (e.g. changed risk of injuries due to burns, reduced exposure to IAP). Other aspects, such as less soot deposited on pots and household surfaces, or the lighting conditions of the living areas, will not have been captured. The analyst will need to decide on the most directly associated economic impact of these aspects. For example, dirty pots require extra time and materials for cleaning, and may need to be replaced sooner than pots used for cooking with gas or other cleaner fuels. Improved lighting associated with more windows for ventilation or connection to a supply of electricity will increase opportunities to work (e.g. deskwork for professionals and homework for schoolchildren) and read inside (for leisure or adult education), as well as having a positive effect on the general quality of life. When valuing these welfare benefits, it is crucial to describe all assumptions clearly.

6.3.5 Fuel savings

Another main focus of household energy and health interventions is increased fuel efficiency. Any impact on existing fuel use patterns therefore becomes a crucial variable to be included. Given

the variability in fuel prices over time, and the non-market features of some fuels (such as firewood), it is important to quantify such changes before valuing them in economic terms. The appropriate physical unit needs to be chosen – in some cases it will be the weight of the fuel in kilograms, while in other instances it may need to be converted to another unit, such as numbers of journeys per day for fuel collection (and average weight of fuel in kilograms collected per journey). For cooking fuels where some measures are available as weights (e.g. US\$ per kg) and others in litres (e.g. greenhouse gas emissions per litre and heat emissions per litre), a conversion is necessary between the two physical measures.

6.3.6 Environmental impacts

As illustrated in Table 9, the environmental impact can be measured at both the local and global levels. The local environmental impact is associated with loss of tree cover, which has implications at certain thresholds (e.g. landslides due to erosion, or desertification at the immediate local level; outdoor air pollution, weather system changes and flooding at a wider local level). In this case, it is necessary to measure the number of trees lost and/or the equivalent loss of tree volume (m^3) and tree weight (kg). Where a link is made between tree loss and probability of events such as landslides, the change in risk used must be taken from credible literature sources or expert judgement. An alternative and simpler method for assessing the economic implications of local environmental impact is to determine how many trees would need to be planted to replace those lost. Hence the impact of less consumption of firewood or charcoal is to reduce the need for tree-planting schemes. On the other hand, dung and other agricultural residues can be quantified according to the equivalent weight of fertilizer to estimate the value lost in using agricultural residues for fuel instead of returning them to the soil.

The global environmental impact is associated with emission of greenhouse gases (GHGs) due to the incomplete combustion of fuel used for domestic cooking purposes. Therefore, the value of different fuel and stove options is the extent to which they reduce emission of GHGs relative to current practices. While on a fuel-weight basis, fuel options other than biomass do not necessarily emit less GHGs, modern fuels burn considerably more efficiently owing to a more directed flame, better

user control during cooking, and less heat loss during lighting the fire and putting it out (before and after the cooking process). Hence, the analyst will need to measure the weight or volume of fuel used in each fuel and/or stove intervention, and apply values for the emission of GHG per kg or per litre of each fuel, as done in WHO's global cost-benefit study (Hutton et al., 2006). Relevant GHGs include carbon dioxide, methane, carbon monoxide, nitrogen dioxide and black carbon. The analyst should be pragmatic and include the GHGs with the most impact, or that show the greatest differences between fuel options. The global study chose to include only carbon dioxide and methane, as these are the only two GHGs currently included in the Clean Development Mechanism under the Kyoto Protocol. However, this narrow selection will undervalue the overall benefits of reducing the use of inefficient fuels and stoves (Hutton et al., 2006).

6.4 Impact valuation

6.4.1 Overview

In social CBA, valuation means the measurement of a cost or impact in monetary units, and the assessment of the economic value of the resource consequences. While the inclusion of all impacts is important for making appropriate policy decisions, not all impacts can be easily valued (Arrow et al., 1996). As described above, the choice of benefits for inclusion should, in part, depend on whether the benefits can be quantified and eventually monetized. However, if the methods for valuation are very unreliable, it may be preferable to leave the impacts in "natural" (non-monetary) units. Table 12 provides a summary of those variables for which economic values are required; please refer to Table 11 for information on the specific data needed for quantifying impacts.

Various methods exist for valuing economic benefits, which are further discussed in this section under three main approaches: the human capital approach (including market prices), revealed preferences and contingent valuation (Hanley & Spash, 1993; Organisation for Economic Cooperation and Development, 1995; Drummond et al., 1997; Postle, 1997). In choosing an appropriate valuation approach, the methods should be compared using criteria, such as reliability, precision, generalizability, time period and cost. Table 13 summarizes the recommended valuation methods for different impacts.

Table 12. Data required for valuation of impacts

Impact category	Variables or elements	Specific data needs for economic valuation
DIRECT IMPACTS RELATED TO HEALTH		
Health status	Health-related quality of life	– See below under “Time gained due to less illness and death”
	Health-related quantity of life	
Expenditure and time for health-care seeking	Health service use of those with diseases caused by exposure to IAP, or injuries due to fuel use (burns, poisoning, injuries during fuel collection)	– Consultation cost, based on unit cost of outpatient and inpatient services
		– Treatment cost, by type of illness and severity
		– Transport cost, based on mode of transport and distance
		– Other costs per visit or admission, such as food
		– Value of time per unit (hour, day)
Time gained due to less illness and death	Reduced morbidity	– Value of time, for activities identified
	Reduced mortality	– Income stream for each age group (mid-age group)
DIRECT IMPACTS NOT RELATED TO HEALTH		
Impact on time use	Time spent collecting or purchasing fuel	– Value of time, per person, based on activities undertaken
	Time spent cooking	– Value of time, per person, based on activities undertaken
Changes in household environment	Impact of improved lighting on educational activities	– Value of change (per hour)
	Impact of improved lighting and availability of electricity on household production activities	– Value of change (per hour)
	Impact on ergonomics related to cooking and carrying fuel	– Value of reduced morbidity
	Impact on household cleanliness, hygiene, need for cleaning	– Value of reduced morbidity – Value of time
Fuel savings	Impact on fuel use and cost of fuel due to switch in fuel type or stove technology	– Unit prices of different fuels
INDIRECT IMPACTS RELATED TO THE ENVIRONMENT		
Quality of local environment, future capacity	Extent of deforestation	– Kilometres squared
	Changed environment (e.g. soil fertility) and risks of disasters (e.g. flooding, landslides)	– Value of changes in land use – Cost of disasters
Quality of global environment, future capacity	Contribution of local area to GHG emissions	– Market value per tonne of emission reduction units, by GHG type

IAP, indoor air pollution; GHG, greenhouse gas.

Scientific considerations, however, must also be balanced with pragmatic ones, given that some methods require considerably greater data collection efforts than others. As indicated in Table 13, the human capital approach and contingent valuation method are the most widely recommended for impact valuation, and in most cases either can be used. Where markets do not exist and a proxy market value (e.g. using the human capital approach) is too unreliable for measuring the impact in question, the contingent valuation method is preferred. Hence, in most cases, improved health, convenience, amenity, prestige and non-use impacts are best valued using the contingent valuation method. At the same time, the weaknesses and potential flaws of the contingent valuation method must be well understood (see section 6.4.4).

Where a market exists (e.g. fuel savings) or an adequate proxy value is readily available (e.g. value of increased productive time using average wage or minimum wage), resource prices can be used, although their weaknesses should also be noted (see section 6.4.2). Occasionally the revealed preference method can give more reliable estimates than the human capital and contingent valuation approaches (see section 6.4.3).

6.4.2 Human capital approach

Health-seeking behaviour can be viewed as an investment in a person's human capital (or value). The payback on an investment could be measured as the person's renewed or increased production in the marketplace (Drummond et al., 1997). The

Table 13. Recommended methods for valuing impacts

Type of benefit	Human capital and market prices	Revealed preference	Contingent valuation
HEALTH-RELATED IMPACTS			
Improved health-related quality of life	(✓)		✓
Increased length of life	(✓)		✓
Medical costs avoided	✓		(✓)
Reduced time spent in health care	✓		(✓)
Reduced travel costs for health care seeking	✓		(✓)
Reduced avertive expenditure	(✓)	✓	(✓)
Increased productivity	✓		(✓)
Reduced sick leave	✓		(✓)
IMPACTS NOT RELATED TO HEALTH			
Time gains	✓		(✓)
Fuel savings	✓		(✓)
Increased home production	✓		(✓)
Increased education opportunities	✓		(✓)
Reduced damage to environment	(✓)		✓
Increased convenience	(✓)	(✓)	✓
Increased amenity	(✓)	(✓)	✓
Prestige			✓
Non-use, existence and bequest			✓

✓, preferred method; (✓), second-best method or method for certain types of benefit.

human capital approach uses market prices from the labour market to value changes in health states for their duration:

- For morbidity, improved health is valued using approximations of the value of the increased productivity of individuals through fewer work-loss days (WLD) or restricted-activity days (RAD).
- For premature mortality, avoided death is valued using the discounted sum a person would have earned if he or she had not died. For those not yet in the workforce, the current value for the future income stream is further discounted to account for the lag before these population groups start earning.

For interventions that affect people's time use, such as the impact on fuel collection time, the human capital approach is equally suitable.

While this approach is relatively simple and represents the valuation method most extensively used in the health-care literature (Zarnke et al., 1997), it has a number of disadvantages. First, it is not consistent with the theoretical foundations of CBA (that is, welfare economics) (Mishan, 1971; Freeman, 1993; Hanley & Spash, 1993). Wage impacts at the individual or household level do not reflect changes in individual welfare, nor do they reflect changes in societal welfare when aggregated. The approach does not provide information about what society (whether the individual or the government) would be willing to pay to obtain given time savings or a given reduction in the probability of loss of life. At the individual level, welfare effects depend not only on the absolute wage (or production) gains, but also on the starting wage level, due to the declining marginal utility of consumption as income rises. Furthermore, individuals value not only their wage-earning time, but also time for the pursuit of other activities.

Second, the human capital approach does not value pain and suffering or the individual's own well-being and preferences, nor does it take into account the shared sentiments of groups of individuals, such as a given community.

Third, there is an aggregation problem. While it is relatively easy to predict the impacts of events at the individual level, it is not appropriate to simply aggregate these impacts to reflect the overall impact at the level of society. One argument often used to prove how simple aggregation overvalues societal

impact draws on unemployment, which, to different degrees, is present in all societies. When unemployment exists, if a worker falls sick and does not get better, he or she will be replaced. Therefore, the net economic loss to society of a worker falling sick and/or dying is less in a society with unemployment than it would be in a society with no unemployment. On the other hand, some characteristics of the labour markets of developing countries – such as subsistence farming, informal sector, seasonality of labour needs and high disease burden – may support the making of stronger assumptions on the impact of disease on the labour market. Hence, the net economic impact would need to be assessed on a case-by-case basis.

Fourth, there are some measurement difficulties with the human capital approach. The widespread existence of imperfections in labour markets means that the wage rate does not reflect closely the marginal productivity of labour. The wage rate measures the gross contribution of individuals to society and not their net contribution, the latter being the correct value to use from an economic perspective (i.e. production value minus consumption value).

Fifth, there is a distributional argument against the use of wage rates to value time spent being ill. If the value used reflects the value of a person in the labour market, it implicitly undervalues those who are not part of the labour force, such as retired people and children. Hence, to avoid a strong bias against these population groups in the analysis, their time also needs to be valued.

While the above arguments suggest the use of a gross wage rate to value time, an opposing position argues that the number of workdays lost is not the only activity with a bearing on social welfare. Valuing time spent on non-paid productive activities, such as homemaking and subsistence farming, would require the application of a shadow wage. The shadow wage can equal either the wage that such a person could earn in the formal sector, or it can equal the cost of replacing the homemaker with paid labour using the current market wage for the type of work undertaken.

6.4.3 Revealed preferences

Human behaviour can reveal preferences and thus economic value. Commonly used techniques to assess this include the household production function, the hedonic pricing method and the travel

cost method.¹ These are described briefly below, except for the travel cost method which is unlikely to be useful in valuing the impacts of interventions to reduce exposure to IAP.

The *household production function* approach values expenditure on activities or goods that substitute for, or complement, an environmental or health-related good. The most relevant approach for valuing reductions in IAP uses “avertive expenditures” (AE) that are made to reduce morbidity or mortality risks. For example, a household may react to the risks posed by smoke either by purchasing cleaner fuels or by improving ventilation, both of which involve changes in expenditure patterns and the use of time. However, some expenditures may not reflect a response to risk, and the motivation for the purchase decision may be different, for example, it may be for convenience purposes or to improve the quality of the household environment.

The value of statistical life (VOSL) can be estimated by identifying the associated change in risk resulting from AE and multiplying it by the inverse of the change in risk

$$\text{VOSL} = (1 / \text{change in risk}) \times \text{AE} \quad (4)$$

The approach requires surveys of individual behaviour that reveal the wage rates associated with different types of work that entail different risks. However, the results from these surveys are likely to be highly setting-specific and are related to the characteristics of labour markets as well as the many contextual factors that affect human behaviour.

The household production function approach could be applicable in the case of a change in fuel source. If households are willing to pay more for a cleaner or more efficient fuel and the associated investments (e.g. a stove and house alterations), the additional costs can be approximated as the value gained from time freed up plus the avoided health costs. However, this approach cannot easily separate the overall value gained from the different perceived improvements, such as health effects, time use and other effects on consumption.

A study by Larson and Rosen has developed a methodological framework for identifying household demand for the control of IAP (Larson &

Rosen, 2002). Using studies presenting monetary values of reductions in mortality risk from the non-IAP literature, the authors disaggregate household demand into the health effect (child and adult) and the direct consumption effect. Based on the results from several countries, this study claims that the theoretical willingness to pay for control measures is relatively high, and considerably exceeds the costs.

The *hedonic pricing method* seeks to find a relationship between the characteristics of a good and the prices of marketed goods. The prices paid for goods implicitly reflect the buyer’s willingness to pay for a particular attribute or to accept an increased risk. Examples of application of this approach include:

- measuring the economic value of health by comparing similar jobs that have different health risks – that is, the higher wage acts as a reward for the employee accepting greater risk; and
- measuring the willingness to pay for characteristics of property and housing, by comparing house prices in different areas and with different facilities, or comparing houses with different features.

However, the hedonic pricing method has various drawbacks including methodological flaws, modelling complexity and a shortage of routinely available data (Hanley & Spash, 1993). Also, it is not very relevant for valuing benefits arising from the control of IAP.

The strength of the two revealed preferences approaches described above is that they observe and value actual consumer choices involving welfare effects (e.g. health and convenience) and money. However, their application in different settings has resulted in a wide variation of values for the value of life and the value of time. This is partially explained by the difficulty of disentangling the many factors that motivate individuals and determine their behaviour, and the imperfections in labour markets (Viscusi, 1992).

6.4.4 Contingent valuation method

The contingent valuation method (CVM) uses hypothetical survey methods to elicit willingness to pay (WTP) values for goods in a hypothetical market (Freeman, 1993; Hanley & Spash, 1993; Field, 1997), and has been proposed as an appealing alternative and/or complement to existing

¹ The travel cost method values the amount that people are willing to spend for amenity or leisure facilities which are created or improved by the interventions under evaluation.

methods (Johannesson & Jönsson, 1991). It is useful in estimating economic values for a wide range of commodities not traded in markets, such as:

- directly consumed goods, such as health and public goods (e.g. clean air and scenery);
- non-use value or “option” value (the possibility that the person may want to use a good in the future);
- existence value (the person values the fact that a good exists, irrespective of use); and
- bequest value (the person wants future generations to enjoy a good).

The value of statistical life (VOSL) can also be estimated using the CVM by asking respondents to state the maximum amount they would be willing to pay for reductions in risk, and then multiplying it by the inverse of the change in risk:

$$\text{VOSL} = (1 / \text{change in risk}) \times \text{WTP} \quad (5)$$

In this case, it is crucial to apply the concept of decision-making under uncertainty. If an individual is asked what they would be willing to pay to avoid certain death, the WTP value would be infinite (Drummond et al., 1997). Therefore, individuals must be presented with choices over small risk reductions.

Following many empirical and theoretical refinements during the 1970s and 1980s, the CVM is now widely accepted by resource economists (Hanley & Spash, 1993). CVM works directly by soliciting from a sample of consumers their WTP for an improvement and/or their willingness to accept (WTA) a deterioration in the level of provision of an environmental service, in a carefully structured hypothetical market. Bids are then obtained from the consumers, bid curves estimated and the data aggregated to estimate the implied market demand curve.

One useful aspect of CVM is that questions can be structured so that respondents value only the benefit(s) relevant to the research question. This means that respondents’ WTP for different benefits (e.g. health, amenity and non-use benefits) of the same environmental health interventions can be presented separately.

The potential application of CVM to stoves in the context of IAP has recently been discussed by Dhanapala (2003), who argues that the method

has many advantages for valuing the benefits of reducing exposure to IAP, as it can value the multi-attribute nature of stoves in real market-like decision contexts.

However, there are several weaknesses associated with CVM that should be understood when interpreting the results of a cost–benefit analysis. These are listed below.

- Weaknesses associated with questionnaire design and application may elicit biased estimates of value from respondents. These may be due to differences between the responses of men and women, and protest bids that may arise when the respondent does not agree with a scenario. Also, for some interventions, the change in risk may be perceived to be so small that WTP is zero or close to zero.
- Empirical analyses have shown that the sum of benefits may not equal the total WTP for an intervention when different benefits are valued separately.
- WTA may not equal WTP when individuals are “risk averse” or have income constraints. For example, income constraints limit the individual’s WTP bids compared to the unconstrained WTA, therefore giving a biased estimate of benefits. Empirical evidence shows that WTA is significantly greater than WTP for reducing the risk of road traffic accidents (Dubourg et al., 1993). The fact that WTP is closely associated with ability to pay (i.e. income constraints), and given that incomes vary within study populations as well as externally, there are difficulties in interpretation related to the equity effect and the non-generalizability of CVM results beyond the study setting.

6.4.5 Differential timing of impacts

As explained earlier, costs and impacts in the present have a different value to the same costs and impacts in the future, due to the time preference for money and health. Individuals generally prefer these goods in the present rather than in the future, although documented instances exist of individuals preferring future to current health.

As with costs, the differential timing of impacts is typically dealt with in economic evaluation by applying a discount rate to future values of impacts, thus calculating a present value of these impacts.

This requires knowledge of the value of the impact at a future time, and the choice of the appropriate discount rate. The consensus is that the discount rate chosen for impacts should be the same as that for costs. Some arguments have been put forward in favour of discounting health effects at a different (usually lower) rate than costs (Gold et al., 1996). Some theorists also argue that the social discount rate decreases over time. These arguments are summarized in the WHO generalized CEA guide-

lines (Tan-Torres Edejer et al., 2003). However, there are problems associated with the choice of a different discount rate for costs and health effects. These would give rise to the time paradox, where the results of economic evaluation would recommend postponing health interventions indefinitely. Therefore, for reasons of consistency, it is best to discount all future costs and impacts at the same rate of 3%.

7. Dealing with uncertainty

The issue of uncertainty and how to deal with it plays an important role in economic evaluation, and has received considerable attention in the medical literature since the use of economic evaluation in health began to grow (Briggs, et al., 1994; O'Brien et al., 1994; Briggs & Sculpher, 1995; Gold et al., 1996; Drummond et al., 1997; Briggs & Gray, 1999). Analysts should ensure that they consider the implications of uncertainty for the results of their analysis. Quantification is preferable to a simple descriptive (qualification) of the level of uncertainty, as it gives the analyst or decision-maker a better idea of the actual degree of uncertainty in the results. Therefore, in presenting the results of a cost-benefit analysis, estimates of confidence intervals should accompany the point estimate.

Five main stages in quantifying uncertainty through sensitivity analysis are dealt with in this chapter. They are as follows:

- Identify the main types of uncertainty present in the study.
- Identify where uncertainty is likely to have the greatest impact on the results, and select which parameters to vary in the sensitivity analysis.
- Specify the plausible ranges (upper and/or lower values) over which uncertain parameters are thought to vary, and their actual or presumed distribution.
- Establish what kind of sensitivity analysis will be conducted.
- Present the results under alternative scenarios using these ranges and distributions.

7.1 Types of uncertainty

Uncertainty stems from several sources (Briggs et al., 1994). These are discussed below.

1. Model or analytical uncertainty

Although the methodology used in the base-case (“reference”) analysis, as described in these guidelines, should be made explicit and should be fully justified, it is likely that considerable uncertainty will persist. For example, it may not always be clear which variables to include and which to exclude owing to uncertain directness and size of impact. For example, in promoting a switch from charcoal to LPG use, it may be difficult to compare the economic implications of investment in new LPG distribution networks with those of disinvestment in charcoal production facilities. Also, there are arguments for using different discount rates for different methodological reasons, but also due to the different time preferences of different societies.

2. Data uncertainty

Data, or parameter, uncertainty refers to a lack of information or knowledge about the inputs required for an intervention or the consequences of a given action. This can be for the following reasons, alone or in combination:

- *Insufficient observations on a parameter that is known to vary.* For example, when introducing improved stoves, it will be impossible to assess their impact on emissions of GHGs unless emissions and fuel efficiency are carefully measured in real-life settings. Also, information on the impact on the health of people who do not seek health care is not available from the health surveillance system. Consequently, such health data are unlikely to capture all the cases and, moreover, tend to be biased in relation to socioeconomic status: relatively well-off people with access to cleaner fuels or equipment tend to seek care whereas relatively poorer people tend to make use of the informal health sector or to self-treat.

- *Natural variability around a mean, due to differences in the response to interventions.* For example, the impact of better household lighting on the time children spend doing their homework will vary from household to household. Also, the emissions and fuel efficiency of an improved stove critically depend on correct manufacture, operation and maintenance. Although a new and correctly installed stove is likely to perform well, lack of maintenance and differences in user behaviour are likely to lead to a wide variation in performance over time. This variation can only be captured if the performance of stoves is assessed in a sufficiently large number of households.
- *Inaccuracies in recording systems, including missing data* (see section 6.2.2).
- *Instability in values, such as changes in price over time, and the response of purchasers to price changes* (e.g. price elasticity of demand).
- *Lack of observed values for variables of interest and substitution with values derived from proxy variables.* For example, owing to a lack of randomized controlled studies on health impact, the prediction of such impacts is currently based on levels of exposure to IAP. The appropriate use of the best available scientific evidence to develop exposure–response assumptions is therefore crucial for the health impact analysis.
- *Uncertainties about the method used for measurement or valuation.* For example, there are uncertainties regarding the measurement of unit cost, such as the method of apportioning overhead costs to different interventions, the method for calculating the annual value of capital items, and, importantly, the choice of valuation method for economic cost.

3. Uncertainty associated with the transfer of results from one setting to another

Although results may be scientifically valid in a specific setting, there may be differences between the specific circumstances of a study and other policy-making contexts which should be taken into account when interpreting study results. These differences arise due to variations in: environmental conditions; socioeconomic and demographic characteristics of populations; the existing set of interventions against

which the alternatives are being compared; and the predicted impacts of interventions. Even within a given country, there may be significant geographical differences (e.g. mountainous regions versus open plains) that have an impact on household energy practices. For example, heating during the cold season is commonly required in high-altitude regions, but not in tropical regions. Similarly, different ethnic populations consume different types of food and not all interventions are equally suitable for preparing special types of food. For example, an Indian community in Gujjar increased the size of the firebox of their improved stove to enable them to cook large roti breads (World Bank, 2001). The cost of intervention hardware is also likely to vary between countries and different regions within a country depending on the need for importation, transport and the local market mechanism.

7.2 Choosing the type of uncertainty analysis

Uncertainty analysis improves the understanding of an issue by showing more clearly how a change in one variable affects other variables or the overall results of the cost–benefit analysis. Uncertainty analysis therefore reduces the risk of drawing false conclusions by suggesting areas to which particular attention must be paid. It also identifies key variables in the analysis and thus where future research would be best targeted (Postle, 1997).

The impact of uncertainty can be examined using various approaches, all of which fall under the umbrella term “sensitivity analysis”. These methods can be used alone or in combination (Briggs et al., 1994).

1. Varying data inputs over plausible ranges

The first approach examines the impact of changes in the values of input variables on the overall results. This approach reflects the uncertainty associated with imprecise data, due to variability within the populations studied, imperfect study design or data collection methods. This can be done in three ways:

- *One-way (univariate) analysis of extreme values* varies the values of different variables one by one and observes the impact on the results and conclusions of the CBA.
- *Multi-way (multivariate) analysis of extreme values* varies the values of different carefully selected

variables together, and observes the impact on the results and conclusions of the CBA. The output of multi-way sensitivity analysis provides extreme values for the costs, benefits and benefit–cost ratio, but no indication of the probability associated with these extremes.

- *Probabilistic sensitivity analysis.* In probabilistic sensitivity analysis, a technique known as the Monte Carlo method is used (Doubilet et al., 1985; Polsky et al., 1997; Briggs et al., 1999). A draw is taken from the uncertainty range around all uncertain parameters simultaneously, and repeated many times, in order to determine the probability distribution of the benefit–cost ratio. The number of draws should be sufficiently large for the ratio to stabilize, usually a minimum of about 1000. From this, uncertainty intervals of 90% or 95% confidence can be generated. When sampled data are available (i.e. data with a probability distribution), repeated draws can be taken with no need to specify a particular probability distribution. Where sampled data are not available, the analyst needs to specify the upper and lower limits for each parameter to be used in the draw, and the type of probability distribution that is likely to characterize the parameter. Analysis can be undertaken using many different statistical software packages. The advantage of this approach over the analysis of extremes described above is that it gives a more robust indication of uncertainty in the results of the CBA due to the incorporation of probability distributions of the values of all uncertain parameters simultaneously.

2. Threshold analysis

The second type of uncertainty analysis computes the value that certain input variables would need to take in order to achieve a predefined result of the cost–benefit analysis (called the “threshold”). The threshold can be either some pre-defined target benefit–cost ratio or rate of return, or the point at which the main findings or conclusions change. For example, what LPG price would deliver a net loss instead of a net benefit of a fuel change programme?

3. Changing model assumptions

The third type of uncertainty analysis is to examine the impact of changes in selected methodo-

logical assumptions. This may involve, for example:

- *Changing inclusion/exclusion of costs or impacts.* This involves including costs or impacts that had been left out of the base-case analysis or excluding costs or impacts that had been included in the base-case analysis, and examining how the results and conclusions change. The choice of which costs and benefits to change can be based on different perspectives of the analysis – for example, a household versus a government perspective.
- *Changing assumptions about time preference.* This involves varying the discount rate for future costs and benefits, or the interest rate used for the annualization of capital items. The WHO generalized CEA guidelines recommend using a discount rate of 3% in the base-case analysis, and in sensitivity analysis they use a 0% discount rate for health effects and a 6% rate for costs, with no age-weighting of health benefits.
- *Changing distributional weights.* Social CBA may include distributional weights that give preference to selected population groups. Therefore, it may be necessary to re-run the analysis without these weights or to use different weights to investigate their impact on the study conclusions.
- *Changing the benefit–cost ratio calculation.* In some instances, it will not be clear whether an economic impact associated with an intervention should be classified as part of the net intervention cost, or as an economic impact. For example, when switching away from one type of fuel to another, the fuel cost savings associated with a reduction in the amount of firewood or charcoal purchased could be classified either as a cost saving or as an economic benefit. In this case, the choice of methodology for the base-case presentation should be stated and justified, and the results under the alternative approach should be presented in a sensitivity analysis.

7.3 Choosing which parameters to vary

Where sensitivity analysis is employed to estimate a confidence interval, analysis should be as comprehensive as possible, and include all variables for which uncertainty is quantifiable.

It is advisable to vary the main contributing variables, and the variables that are known to contain the greatest amount of uncertainty. In the case of reducing exposure to IAP, these may include (Hutton et al., 2006):

- Variation in the methods for quantification and valuation of the main components of economic cost, such as fuel use, fuel price, stove price and useful life of hardware.
- Variation in the methods for quantification and valuation of the main components of economic impact, such as health impacts, time benefits and environmental impacts. One key variable of economic impact is the choice of value for time gain. An aggregate nationwide measure such as gross national income per capita may be substituted with alternatives such as the minimum wage or the average agricultural wage. When setting-specific or national wage rates are used, beneficiaries could be interviewed about the value of time, or studies conducted on the use of time gained from the interventions. A second key variable with a high level of uncertainty is the value of environmental gains, such as the implicit value of forest cover or the value of reducing emissions of GHGs.
- Exclusion of certain economic costs and benefits, and inclusion of other possible costs and benefits left out in the base-case analysis. On the one hand, where economic benefits of health gains are an important component of overall economic benefit, diseases excluded from the base-case analysis may be included in sensitivity analysis. On the other hand, if there were no health effect of an intervention, would the intervention be justified on non-health grounds?
- Discount rate.

7.4 Choosing the ranges and distribution of uncertain parameters

Choosing an appropriate range is crucial, and should where possible be based on observed vari-

ability of the parameter. In the medical field, for the purposes of choosing the range and distribution of uncertain parameters, the distinction between deterministic, partially stochastic and wholly stochastic sensitivity analysis is useful (Drummond et al., 1997):

- *Deterministic sensitivity analysis*, where cost and impact variables are estimated as a point estimate. Sampling variation is not available because of lack of data (e.g. when secondary sources are used) or the nature of the variable (e.g. choice of discount rate). In this case, a deterministic point estimate of the benefit–cost ratio can be subject to detailed sensitivity analysis, using plausible ranges for variables and thus providing lower and upper extreme values. In early economic evaluation studies, analysts simply halved and doubled the average values in the absence of better data on plausible ranges (Drummond et al., 1987). However, today the analyst is expected to identify a plausible range with justification.
- *Partially stochastic sensitivity analysis*, where the mean values of some variables have associated variance, whereas other variables have only extreme lower and upper values with no indication of their distribution. The distribution on the stochastic variables is either known (from stochastic data sets) or determined using an informed guess (e.g. normal distribution, triangle or rectangle) based on knowledge about the variable.
- *Wholly stochastic sensitivity analysis*, where all the parameters included in the sensitivity analysis have an associated variance.

Although the fully stochastic analysis is clearly the most scientific and has the most value for policymakers, it can also be useful and interesting to simply examine the impact of extreme values in a deterministic sensitivity analysis. This can be done alone (in a one-way sensitivity analysis) or in combination (in a multi-way sensitivity analysis) to assess the implications of freak occurrences or worst assumptions.

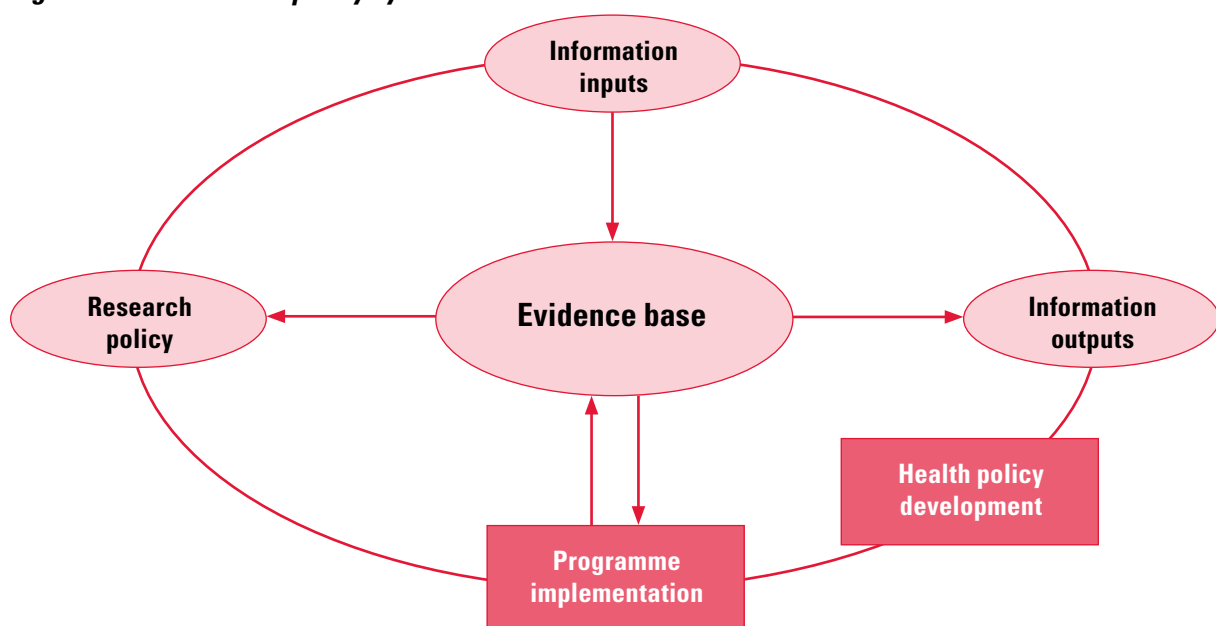
8. Presentation and interpretation of results

8.1 Who can use the results of an economic evaluation?

A range of decision-makers will be interested in the results of CBA in different contexts. These decision-makers include:

- national governments, interested in how to allocate national budgets across sectors, deciding what interventions to promote, and estimating future budget needs (see the evidence–policy cycle in Figure 9);
- local governments, interested in deciding how to allocate budgets across sectors, what interventions to provide, what prices to set for public services, how efficiently different service providers are performing and how to increase the efficiency of an intervention;
- companies (i.e. actual or potential service suppliers), interested in identifying potential profitable markets in which to provide their services, and setting prices;
- nongovernmental organizations, which are active in the household energy sector, interested in comparing the efficiency of one intervention with that of another, and their distributional impact;
- private households, interested in understanding what they stand to gain compared to the cost associated with an intervention;
- research funding agencies, interested in financing research that will reveal effective and low-cost options for improving household energy;
- donors, interested in how to argue for targeting interventions and subsidies to vulnerable populations, and in economic development; and

Figure 9. The evidence–policy cycle



Source: WHO (2000).

BOX 3**Examples of economic research questions for national-level decision-makers**

The following research questions are relevant to *national-level decision-makers*, including donors:

- What does it cost to increase coverage of improved household energy practices, to meet the goal of reducing by half those currently not using cleaner fuels, or to achieve full coverage?
- Where should household energy investments be made, based on allocative and distributive efficiency criteria? Which localities (provinces/districts) and which population groups should be targeted?
- What is the relative attractiveness of investments in household energy compared to other public investments, based on economic criteria (benefit–cost ratio, rate of return, net present value, payback period)?
- How should evidence be presented to provide meaningful guidance to local governments and local health departments on allocating resources to household energy and on choosing the optimal technologies and providers?
- How can investments in household energy be supported at the national level?
- How does household energy improvement contribute to economic growth and poverty reduction?

BOX 4**Examples of economic research questions for implementing agencies**

The following research questions are relevant to *implementing agencies*, such as a local government unit, nongovernmental organization or private company:

- What is the population demand (willingness to pay) for improved household energy in different contexts?
- Based on the production cost, what is the potential for meeting population demand through the private sector?
- What are the economic and welfare outcomes of granting service provision contracts to different types of provider?
- Which technologies and improvement options are most suited to different local circumstances?
- Based on efficiency criteria, how should local budgets be allocated between sectors?
- How should public subsidies of household energy be targeted?
- Are there sufficient and sustainable fuel resources available locally at the new “market equilibrium”?
- What other factors and information influence (or should influence) decisions made by the implementing agency?

- development banks, interested in financing interventions that have a high social and economic return, and thus contribute to rapid economic development of a locality or nation.

Some examples of common research questions for national-level decision-makers and implementing agencies, respectively, are presented in Boxes 3 and 4.

8.2 Presentation of results

The primary goal of the CBA is to identify whether the benefits of an intervention exceed its costs, and to assess the nature and timing of the stream of costs and benefits that result from the intervention. In simple terms, a positive net economic benefit indicates that an intervention is *worthwhile from*

the economic perspective. However, as public funds are limited and cannot cover all interventions with net economic benefits, it is necessary to compare alternative interventions to find out which are the *most economically beneficial* to implement, based on the resource constraints that prevail within any given society. Thus a number of simple summary measures have been developed and are presented in this section (see also sections 1.3 and 1.4).

8.2.1 Basic presentation

The results of a CBA can be presented in a variety of forms as discussed below:

Benefit–cost ratio. A principal output of a CBA is the benefit–cost ratio, which shows the factor by which the economic benefits exceed the economic costs

of an intervention, taking into account the flow of costs and benefits that occurs over the entire period during which the intervention is implemented.

The benefit–cost ratio is equal to the total intervention benefit divided by the total intervention cost, presented in a base year. Therefore, costs and benefits in future years must all be discounted back to a common date. Similarly, any price or cost values from previous years should be adjusted forward to take into account different prices in the base year.

$$\text{BCR} = \frac{\text{Total net intervention benefit}}{\text{Total net intervention cost}} \quad (6)$$

where BCR is the benefit–cost ratio.

When presenting the benefit–cost ratio, the variables which appear in the net benefit calculation (numerator) should be clearly distinguished from those which appear in the net cost calculation (denominator) (see section 7.2). The key principle is to recognize that the calculation method (algorithm) chosen has implications for the size of the eventual benefit–cost ratio. When comparing ratios the same methodology should be used so that like is being compared with like.

The results can also be presented in terms of:

- total costs and total benefits in absolute terms (US\$ and/or I\$ and/or local currency units, in base year);
- average cost and benefit per person with improvement (US\$ in base year); or
- average cost and benefit per capita (whole population) (US\$ in base year).

Economic internal rate of return. The economic internal rate of return (EIRR) is the rate of interest at which the future expected stream of benefits equals the future expected stream of costs. It can be estimated by adjusting the discount rate downwards (or upwards in the case of a non-cost-beneficial ratio) until the benefit–cost ratio is 1, or the net present value equals zero (see below). The EIRR is then compared with a standard chosen by the implementing or lending agency, to decide whether or not the intervention produces an adequate rate of return.

Net present value. The net present value (NPV) shows the economic gain that can be expected from the intervention in currency units of the base year (usually the start year of the intervention). It is

calculated by subtracting the economic costs of the intervention from the economic benefits.

It should be noted that the resulting value is not a “profit” in the traditional sense of the word, as the net present value is a measure of societal welfare, and not a measure of narrow financial gain. Furthermore, it reflects the economic benefit over the entire life of the intervention, and not over a single year. However, it can be converted to an annual equivalent.

The NPV can be presented in terms of:

- total costs and total benefits;
- average cost and benefit per person who receives the intervention; or
- average cost and benefit per capita, spread over the entire population of a community, region or country.

Payback period. The payback period (also termed the break-even point) is the period of time after which the benefits from an intervention equal the resources invested in the intervention. It defines the point in time at which an intervention starts to produce net economic benefits. This is a traditional measure used in project appraisals because projects typically involve a large initial investment and smaller annual recurrent costs and only start producing benefits after a time delay. Hence, it is important to know how many years a project needs to run and be financed at a net loss.

Demand analysis. Demand analysis forms an implicit part of a CBA as the impacts valued are hypothetically demanded by a population that seeks improvements in their standard of living. A demand analysis is important not only to ensure that there is a demand for the intervention being evaluated, but also to assess financing options if the intervention is not entirely financed through public funds. For example, in projects that require substantial investments in infrastructure, a high proportion of the costs must be met up-front. Although there may be demand for the services, the beneficiaries may not be willing or have the capacity to finance the entire investment costs during the initial period. Populations may either lack access to the necessary funds for an investment, or they may be unwilling to make a large investment for an uncertain long-term benefit. Hence, market mechanisms, such as bank loans or micro-credit schemes or public intervention may be required to overcome these financial barriers.

Other analyses. In addition to the presentations discussed above, the component parts of a CBA, such as cost or outcome data, can be used for decision-making. For example, a comparative cost analysis of a latrine manufacture and distribution programme in several regions of a country would allow policy-makers to draw conclusions about which ones perform better and why. An economic costing also contributes to price-setting for public services, and to allocating government budgets. Furthermore, the financial viewpoint can easily be presented by disaggregating cost and outcome data into economic impact versus purely financial impact (see section 1.5).

8.2.2 Viewpoint

It is important and necessary to disaggregate the benefits and costs according to different viewpoints. Relevant viewpoints will vary by setting and intervention type, and include different sectors (health, environment, energy, agriculture and industry), population subgroups (geographical location, income quintile, gender and age group), various levels of government (central, regional or district) or societal organization (household, community or societal). The disaggregation chosen will depend on the target audience. Given the disproportionate bearing of household energy practices on women, children and the poor, special attention should be paid to assessing and valuing the impacts interventions have on these groups. This focus is necessary not only for the purposes of choosing interventions which maximize the benefit–cost ratio for these groups, but also in promoting household energy interventions more generally in international and government agency policies and programmes.

8.2.3 Currency

The results should be expressed in a common currency, with a stated base year. The two main options for currency are foreign or local. The advantage of using a foreign currency is that it increases international comparability, and facilitates publication of studies in international journals. The currency most commonly used is US\$. Increasingly the currency I\$ is being employed, which uses purchasing power parity to adjust the value of non-traded goods relative to the US\$. This enables international comparisons based on the relative values of different currencies. The advantage of using a local currency in

the context of an analysis conducted at the national or subnational level is that it makes the results more relevant to the decision-makers concerned.

8.2.4 Capacity level

Unit costs of activities are related to the level of capacity utilization of a programme (Tan-Torres Edejer et al., 2003; Hutton et al., 2004). Capacity utilization is calculated by dividing the actual capacity use of a given service or programme by the capacity available. Because the level of capacity utilization varies over time and between contexts, economic analysts have recognized that a certain level of standardization of practice is necessary to ensure validity and comparability of results across studies. Moreover, the presentation of the results of a CBA should state the level of capacity utilization at which the intervention is running. This applies to intervention activities, such as domestic fuel or stove programmes, as well as to the estimation of the value of intervention impacts.

One option is to present the results according to the capacity level observed, and report results under alternative levels in the sensitivity analysis. A second option, and one preferred by WHO (Tan-Torres Edejer et al., 2003), is to present the results under a target level of capacity utilization – defined as 80% – which also reflects recommendations made in other economic evaluation guidelines (Gold et al., 1996; Drummond et al., 1997). Eighty per cent is seen as a good choice for an optimal level of capacity utilization in the health sector, to allow for spare capacity for unexpected or emergency cases, reflecting the life and death implications of having health services available. For other types of public sector programme such as stove programmes, the optimal capacity utilization level may be defined as being higher, perhaps 90% or 95%.

8.3 Interpretation of results in a decision-making context

8.3.1 Efficiency considerations highlighted by cost–benefit analysis

The first aspect of interpretation is the set of base-case scenario results, as described in section 8.2. These results need to be interpreted not only on their own but also in comparison with other possible uses of funds. In a given decision-making context, benchmarks may exist that facilitate the

interpretation of the results of economic evaluation, irrespective of the results of studies evaluating other uses of public finances. For example, such benchmarks can be based on the benefit–cost ratio (e.g. over US\$ 2 economic return per US\$ 1 invested) or on the economic internal rate of return (e.g. above 10% compared to a real interest rate of 6%). However, although these thresholds are indicative of efficiency, the results of a CBA should not be used in a purely formulaic way.

In particular, the decision-maker should understand who the intervention favours in terms of socioeconomic class (e.g. income quintile), gender and age group. If certain groups are the target of government subsidies, interventions with a benefit–cost ratio favourable for these groups may be selected above the alternatives. Moreover, as the marginal utility of consumption declines with rising income, the least poor are most able to benefit from government subsidies.

Once the base-case scenario results and their distributional impacts are understood, it is important to supplement these preliminary conclusions with the results of the sensitivity analysis, as outlined in chapter 7. If large variations in the assumptions or estimates of the analysis do not produce significant alterations in the results, policy-makers can be relatively confident about the results (Briggs et al., 1994; Drummond et al., 1997). However, if changes to the model or input data over a plausible range of variation lead to large differences in the results, decision-makers may be motivated to find out more about the interventions in question, or to favour interventions with less variable benefit–cost ratios. Indeed, an uncertain result should prompt further research to provide more precise estimates.

Another important question relates to the quality and relevance of the results for a given decision-making context. The policy-maker should understand scientific quality, or internal validity, and any possible biases in the study, before basing a decision on the results. Moreover, study relevance, or external validity, is critical. Even if a study is of high scientific quality, it may be based on populations and environments that are very different from the decision-making context in question. In this case, the data can either be disregarded or adjustments can be made to increase the relevance of the results to the given setting. Hence, it is important that published studies provide background information

to help decision-makers decide whether the findings can be generalized.

8.3.2 Other considerations

A whole range of factors affect policies and decisions on resource allocation made by governments. Some of these considerations are linked to efficiency, while others are not.

As service providers, governments are (or should be) concerned about the availability of a choice of alternatives, the responsiveness of government services to population needs, and the eventual satisfaction of the targeted clients (WHO, 2000b). This may be on the basis of objectively observed conditions or population needs; it may also be based on perceptions of population needs by the population itself or by a researcher or policy-maker.

One of the strongest determinants of future patterns of resource allocation is the current pattern of resource allocation. Budgeting works on a historical basis, not only because it is simple and risk averse, but also because it reflects the existing infrastructure and the current set of interventions.

A further consideration which often plays a dominant role in government decisions is the political angle of government policies or funding decisions. This is true not only of sovereign governments in their own country, but also affects the foreign policy of governments active in these countries (donors).

In the health field, interventions are often chosen on the basis of their effectiveness and the associated burden of disease, often irrespective of whether their efficiency is known or not. Moreover, distributional and ethical considerations often play an important role, too.

Finally, assigning economic values involves implicit value judgements about what is worthwhile and what is not. For example, if an analysis places values on lives saved according to individual earnings, an intervention that targets elderly people will be “worth” less than one targeting productive adults. Hence, efficiency criteria (in a purely economic sense) need to be tempered with other considerations, such as distributional and equity dimensions. These can be taken into account in economic evaluation by assigning average values to beneficiaries irrespective of their age or gender,

reflecting a measure of social welfare rather than expected financial impact. However, assigning equity weights does not necessarily solve the complex distributional problem resulting from attempting to improve resource allocation using efficiency criteria (Green & Barker, 1988).

In addition to the above-discussed validity and applicability of the instruments for measuring value, concerns have been voiced about the use of the willingness to pay (WTP) approach. While WTP is widely accepted by economists, there are several methodological problems associated with conducting studies of WTP. These include the assumption that individuals are rational and well informed about the choices they make, and that the market is functioning efficiently. This assumption can be untenable when it comes to health and health care, where people do not have the information or training necessary to correctly value a particular health service or intervention (McGuire et al., 1989; Mooney, 1994). In other words, the willingness of households to pay for cleaner household energy options is more likely to reflect non-health factors than health considerations. Also, there are doubts about whether people can make reasoned and consistent choices concerning the value they place on options which increase or reduce the statistical risk of death from various causes.

8.4 Constraints to using the results of economic evaluation in decision-making

This section describes the different types of constraint to using the results of economic evaluation in decision-making.

Constraint 1: Lack of relevance of evidence from cost–benefit analysis

Research is often not targeted to real policy questions, or does not cover all relevant scenarios. Addressing this problem requires increased researcher interest in policy, tying research funding to policy relevance and emphasizing pragmatic study design. Moreover, decision-makers should be closely involved with the research from beginning to end. To avoid research quickly becoming out of date, updates may be necessary.

Constraint 2: Low quality and lack of standard application of methods to cost–benefit analysis

Current standards for economic evaluation are often not followed in conducting CBA (Udvarhelyi et al., 1992). Overcoming this limitation requires greater standardization of methods and their consistent application. In many cost–benefit studies the key assumptions are not explicitly described and justified. Another common weakness is that sensitivity analyses tend to be one-way or multi-way analyses of extremes, but do not use measures of stochastic variation in the variables tested to produce confidence intervals on the benefit–cost ratio.

Constraint 3. Non-generalizability of results of cost–benefit analysis

The use of incremental economic analysis means that results are not relevant where a different baseline exists. A solution proposed by WHO is to use a similar baseline in all studies, i.e. the counterfactual scenario without any possible intervention. However, even when using the same baseline, differences in the characteristics of settings (e.g. income, disease burden or existing infrastructure) will render results difficult to interpret in other settings. Therefore, it is important to present background data with the results, and to add clear interpretations, qualifications and caveats. A well-conducted sensitivity analysis, including subset (or subpopulation) analysis, will also increase the meaningfulness of results in other settings.

Constraint 4: Failure to disseminate results of cost–benefit analysis

Key results often do not reach decision-makers – either because the results are not well presented or because they are not disseminated to the relevant audience. Clear structured reporting on the study, its findings and their interpretation is essential. Short summaries that convey the main messages and are written for a non-technical audience may help the uptake of research results in decision-making. Important communication channels for the dissemination of results include articles presenting key findings, the Internet and regular research-policy seminars.

Constraint 5: Failure to use the results of cost–benefit analysis in decision-making

As described above, efficiency is only one of many factors that influence policy decisions. In a transparent decision-making process, the different arguments for or against a given policy are

described and each given their due weight. Where this process concludes that recommendations based on a cost–benefit analysis should be followed, it is important to ensure their efficient implementation on the ground.

9. Conclusions

Economic evaluation of policy options is becoming an increasingly important tool for decision-making in the health and development field. In the context of interventions that generate both health and non-health benefits, CBA offers a method by which all benefits can be valued against all costs from a societal perspective. It can therefore help policy-makers to select the most efficient intervention to meet a given aim in a specific sector, or to allocate funds to programmes in different sectors. There are many advantages and disadvantages in using the results of economic evaluation. These are summarized below.

Advantages

- Economic evaluation provides a convincing technical solution to the question of resource allocation, with a comprehensive analysis of the economic costs and benefits of a range of policy-relevant options.
- Economic evaluation can be adapted to answer different types of question and take into account different viewpoints.
- Economic evaluation is a systematic and explicit approach, which clearly states its basic assumptions and weaknesses, thus giving transparency to policy questions that are otherwise often treated as a “black box”.
- Some of the weaknesses can be partially dealt with through sensitivity analysis and scenario analysis.

Disadvantages

- Benefit–cost ratios are based on economic (societal) values and not on financial values. Decision-makers faced with budget constraints, however, are often more interested in purely financial values.

- Too often, results are not used because there is poor communication between researchers and policy-makers.
- Research can be costly and time-consuming, and often does not provide answers at the time the decision needs to be made.
- Economic evaluation is based on implicit values about what is right, and is naive in the sense that political feasibility is often the determining factor.

In conclusion, these guidelines for conducting CBA of household energy and health interventions are an attempt to provide economists and researchers involved with household energy and health interventions with the methodological background for undertaking CBA. They describe the approach in a step-by-step manner, from choosing policy-relevant alternatives to presenting and using the results. They identify the main cost components, categorize various intervention impacts, describe the main sources for obtaining data on costs and impacts and discuss the most widely used approaches for valuing different types of benefits. Moreover, they provide the reader with guidance on how to conduct uncertainty analysis and on how to present key conclusions and associated caveats to decision-makers.

The guidelines try to reflect as closely as possible the wealth of past contributions on the subject. Nevertheless, it is difficult to do justice to all the details associated with a robust economic evaluation. Wherever possible, relevant references are provided and the interested reader is encouraged to consult these references for guidance when facing and responding to the many challenges of conducting an economic evaluation of household energy and health programmes and policy scenarios.

References

- Arrow K et al. (1996). Is there a role for benefit–cost analysis in environmental, health, and safety regulation? *Science*, 272:221–222.
- Asian Development Bank (1997). *Guidelines for the economic analysis of projects*. Manila, Philippines, Asian Development Bank.
- Asian Development Bank (1999). *Handbook for the economic analysis of water supply projects*. Manila, Asian Development Bank.
- Baladi J-F (1996). *A guidance process for the costing process*. Ottawa, Canadian Coordinating Office for Health Technology Assessment.
- Baltussen R (2002). *The economic foundations of generalized CEA*. Geneva, World Health Organization. Global Programme on Evidence for Health Policy discussion paper.
- Briggs A, Gray A (1999). Handling uncertainty when performing economic evaluation of health-care interventions. *Health Technology Assessment*, 3:1–134.
- Briggs A, Sculpher M (1995). Sensitivity analysis in economic evaluation: a review of published studies. *Health Economics*, 4:355–371.
- Briggs A, Mooney C, Wonderling D (1999). Constructing confidence intervals for cost–effectiveness ratios: an evaluation of parametric and non-parametric techniques using Monte Carlo simulation. *Statistics in Medicine*, 18:3245–3262.
- Briggs A, Sculpher M, Buxton M (1994). Uncertainty in the economic evaluation of health care technologies: the role of sensitivity analysis. *Health Economics*, 3:95–104.
- Bruce N, Perez-Padilla R, Albalak R (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization*, 78:1078–1092.
- Bruce N et al. (2006). Indoor air pollution. In: Jamison D et al., eds. *Disease control priorities in developing countries*, 2nd ed. Oxford, World Bank and Oxford University Press.
- Creese A, Parker D (1994). *Cost analysis in primary health care: a training manual for programme managers*. Geneva, World Health Organization.
- Curry S, Weiss J (1993). *Project analysis in developing countries*. Basingstoke and London, MacMillan.
- Dasgupta P (1970). An analysis of two approaches to project evaluation in developing countries. *Industrialization and Productivity Bulletin, UNIDO*, 15.
- Dhanapala K (2003). Valuing the invisible health benefits of stoves. *Glow*, 29:8–10.
- Doubilet P et al. (1985). Probabilistic sensitivity analysis using Monte Carlo simulation: a practical approach. *Medical Decision Making*, 5:157–177.
- Drummond MF, Jefferson TO (1996). Guidelines for authors and peer reviewers of economic submissions to the BMJ. *British Medical Journal*, 313:275–283.
- Drummond MF, McGuire A (2001). *Economic evaluation in health care: merging theory with practice*. Oxford, Oxford University Press.
- Drummond MF, Stoddart GL, Torrance GW (1987). *Methods for the economic evaluation of health care programmes*, 1st ed. Oxford, Oxford University Press.
- Drummond MF, O'Brien B, Stoddart GL, Torrance GW (1997). *Methods for the economic evaluation of health care programmes*, 2nd ed. Oxford, Oxford University Press.
- Dubourg W et al. (1993). *The contingent valuation of transport safety: imprecise preferences and the disparity between willingness to pay and willingness to accept*. Norwich, Centre for Social and Economic Research on the Global Environment (CSERGE Working Paper GEC 93–16).

- Elixhauser A, Luce B, Taylor W, Reblando J (1993). Health care CBA/CEA: an update on the growth and composition of the literature. *Medical Care*, 31(7 Supplement):JS1–11, JS18–149.
- Ezzati M, Kammen DM (2002). The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. *Environmental Health Perspectives*, 110:1057–1068.
- Field B (1997). *Environmental economics*. New York, McGraw-Hill.
- Freeman AM (1993). *The measurement of environmental resource values. Theory and methods*. Washington, DC, Resources for the Future.
- Gangopadhyay S, Ramaswami B, Wadhwa W (2005). Reducing subsidies on household fuels in India: how will it affect the poor? *Energy Policy*, 33:2326–2336.
- Gittinger J (1984). *Economic analysis of agricultural projects*. Baltimore, MD, Johns Hopkins Press.
- Global Forum for Health Research (1999). *The 10/90 report on health research*. Geneva, Global Forum for Health Research.
- Gold MR, Siegel JE, Russell LB, Weinstein MC (1996). *Cost-effectiveness in health and medicine*. Oxford, Oxford University Press.
- Green A, Barker C (1988). Priority setting and economic appraisal: whose priorities – the community or the economist? *Social Science and Medicine*, 26:919–929.
- Habermehl H (1999). *The economics of improved stoves. Guide to micro- and macroeconomic analysis and data assessment*. Eschborn, German Development Cooperation (GTZ).
- Hanley N, Spash C (1993). *Cost-benefit analysis and the environment*. Cheltenham, Edward Elgar.
- Hutton G (2000). *Considerations in evaluating the cost-effectiveness of environmental health interventions*. Geneva, World Health Organization (WHO/SDE/WSH/00.10).
- Hutton G, Baltussen R (2005). Cost valuation in resource-poor settings. *Health Policy and Planning*, 20:252–259.
- Hutton G, Haller L (2004). *Evaluation of the non-health costs and benefits of water and sanitation improvements at global level*. Geneva, World Health Organization (WHO/SDE/WSH/04.04).
- Hutton G, Rehfues E, Tediosi F, Weiss S (2006). *Cost-benefit analysis of household energy and health interventions at global and regional levels*. Geneva, World Health Organization.
- Hutton G et al. (2004). Examining within country variation of maternity costs in the context of a multi-country multi-centre randomised controlled trial. *Applied Health Economics and Health Policy*, 3:161–170.
- Johannesson M (1996). *Theory and methods of economic evaluation of health care*. Kluwer, Dordrecht.
- Johannesson M, Jönsson B (1991). Economic evaluation in health care: is there a role for cost-benefit analysis? *Health Policy*, 17:1–23.
- Johns B, Baltussen R, Hutubessy R (2002). Programme costs in the economic evaluation of interventions. *Cost-effectiveness and Resource Allocation*, 1:1.
- Kumaranayake L (2000). The real and the nominal? Making inflationary adjustments to cost and other economic data. *Health Policy and Planning*, 15:230–234.
- Kumaranayake L et al. (2000). *Costing guidelines for HIV/AIDS prevention strategies. A companion volume to "Cost analysis in primary health care: a training tool for programme managers"*. London, London School of Hygiene and Tropical Medicine.
- Larsen B (2004). *Cost of environmental damage: a socio-economic and environmental health risk assessment*. Bogotá, Ministry of Environment, Housing and Land Development, Republic of Colombia.
- Larson B, Rosen S (2002). Understanding household demand for indoor air pollution control in developing countries. *Social Science and Medicine*, 55:571–584.
- Layard R (1972). *Cost-benefit analysis*. Harmondsworth, Penguin.
- Levin HM (1983). Cost-effectiveness – a primer, Vol. 4. In: Smith NL, ed. *New perspectives in evaluation*. Beverly Hills, Sage Publications.
- Little IMD, Mirrlees JA (1968). *Manual of industrial project analysis in developing countries*. Organisation for Economic Co-operation and Development, Paris.
- Little I, Mirrlees J (1974). *Project appraisal and planning for developing countries*. London, Heinemann Editorial Books.

- Luce B, Manning W, Siegel J, Lipscomb J (1996). Estimating costs in cost–effectiveness analysis. In: Gold MR et al., eds. *Cost–effectiveness in health and medicine*. Oxford, Oxford University Press.
- MacArthur J (1997). Shadow pricing simplified: estimating acceptably accurate economic rates of return using limited data. *Journal of International Development*, 9:367–382.
- McGuire A, Henderson J, Mooney G (1989). *The economics of health care*. London, Routledge and Kegan Paul.
- Mehta S, Shahpar C (2004). The health benefits of interventions to reduce indoor air pollution from solid fuel use: a cost–effectiveness analysis. *Energy for Sustainable Development*, 8:53–59.
- Mishan E (1971). Evaluation of life and limb: a theoretical approach. *Journal of Political Economy*, 79:687–706.
- Mishan E (1975). *Cost benefit analysis*, 2nd ed. London, Allen and Unwin.
- Mooney G (1994). *Key issues in health economics*. London, Harvester.
- Murray C, Evans D, Acharya A, Baltussen R (2000). Development of WHO guidelines on generalized cost–effectiveness analysis. *Health Economics*, 9:235–251.
- O’Brien B, Drummond M, Labelle R, Willan A (1994). In search of power and significance: issues in the design and analysis of stochastic cost–effectiveness studies in health care. *Medical Care*, 32:150–163.
- Organisation for Economic Cooperation and Development (1995). *The economic appraisal of environmental projects and policies*. Paris, Organisation for Economic Cooperation and Development.
- Pearce D, Nash C (1981). *The social appraisal of projects: a text in cost–benefit analysis*. Hounslow and London, Macmillan.
- Pepperall J et al. (1994). *Costing guidelines for HIV/AIDS prevention strategies*. London, London School of Hygiene and Tropical Medicine.
- Philips M, Mills A, Dye C (1993). *Guidelines for cost–effectiveness analysis of vector control*. Geneva, World Health Organization (PEEM Secretariat, WHO/CSW/93.4).
- Polsky D, Glick HA, Willke R, Schulman K (1997). Confidence intervals for cost–effectiveness ratios: a comparison of four methods. *Health Economics*, 6:243–252.
- Postle M (1997). *Cost–benefit analysis and chemical risk management*. Ontario, Canada, International Council on Metals and the Environment.
- Preker AS, Brenzel L, Ratta A (1997). *Project and economic analysis – health, nutrition and population sector. A conceptual framework and portfolio review*. Washington, DC, World Bank (Health, Nutrition and Population Publication Series).
- Rehfuess E, Mehta S, Prüss-Üstün A (2006). Assessing household solid fuel use – multiple implications for the millennium development goals. *Environmental Health Perspectives*, 114:373–378.
- Rovira J (1994). Standardising economic appraisal of health technology in the European Community. *Social Science and Medicine*, 38:1675–1678.
- Sawert H (1996). *Cost analysis and cost containment in tuberculosis programmes: the case of Malawi*. Geneva, World Health Organization.
- Smith KR (2002). Indoor air pollution in developing countries: recommendations for research. *Indoor Air*, 12:198–207.
- Smith K, Mehta S (2003). The burden of disease from indoor air pollution in developing countries: comparison of estimates. *International Journal of Hygiene and Environmental Health*, 206:279–289.
- Smith K, Mehta S, Feuz M (2004). Indoor smoke from household solid fuels. In: Ezzati M et al., eds. *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors*, Vol. 2. Geneva, World Health Organization, 1435–1493.
- Smith K, Samet J, Romieu I, Bruce N (2000). Indoor air pollution in developing countries and acute respiratory infections in children. *Thorax*, 55:518–532.
- Sugden R, Williams A (1978). *Principles of practical cost–benefit analysis*. Oxford, Oxford University Press.
- Tan-Torres Edejer T et al. (2003). *Making choices in health: WHO guide to cost–effectiveness analysis*. Geneva, World Health Organization.

- Tse M, Chau C, Lee W (2004). Assessing the benefit and cost for a voluntary indoor air quality certification scheme in Hong Kong. *The Science of the Total Environment*, 320:89–107.
- Udvarhelyi IS, Colditz GA, Rai A, Epstein AM (1992). Cost–effectiveness and cost–benefit analyses in the medical literature. Are the methods being used correctly? *Annals of Internal Medicine*, 116:238–244.
- United Nations Industrial Development Organization (1972). *Guidelines for project evaluation*. New York, United Nations.
- Viscusi K (1992). *Fatal trade-offs*. Oxford, Oxford University Press.
- Weinstein M, Siegel J, Gold M, Kamlet M, Russel L and the Panel on Cost–effectiveness in Health and Medicine (1996). Recommendations of the Panel on Cost–effectiveness in Medicine. *Journal of the American Medical Association*, 276:1253–1341.
- World Bank (2000). *Energy strategies for rural India: evidence from six states*. Washington, DC, Joint UNDP/World Bank Energy Sector Management Assistance Program.
- World Bank (2001). Energy and health for the poor. *Indoor Air Pollution*, 4.
- World Health Organization (1979). *Expanded Programme on Immunization: costing guidelines*. Geneva, World Health Organization (EPI/GEN/79.5).
- World Health Organization (1988). *Estimating costs for cost–effectiveness analysis: Guidelines for managers of diarrhoeal disease control programmes*. Geneva, World Health Organization (WHO/CDD/SER/88.3).
- World Health Organization (1998). *Safe blood and blood products: costing blood transfusion services*. Geneva, World Health Organization.
- World Health Organization (2000a). *World Health Report 2000. Health systems: improving performance*. Geneva, World Health Organization.
- World Health Organization (2000b). *Evidence and information for policy. Empowering people to make better decisions*. Geneva, World Health Organization (WHO/EIP/00.1).
- World Health Organization (2002). *Addressing the impact of household energy and indoor air pollution on the health of the poor – implications for policy action and intervention measures*. Geneva, World Health Organization.
- World Health Organization (2006). *Fuel for life: household energy and health*. Geneva, World Health Organization.
- Wyon D (2004). The effects of indoor air quality on performance and productivity. *Indoor Air*, 14:92–101.
- Zarnke K, Levine M, O’Brien B (1997). Cost–benefit analysis in the health care literature: don’t judge a study by its label. *Clinical Epidemiology*, 50:813–822.

ISBN 92 4 159481 0



9 789241 594813