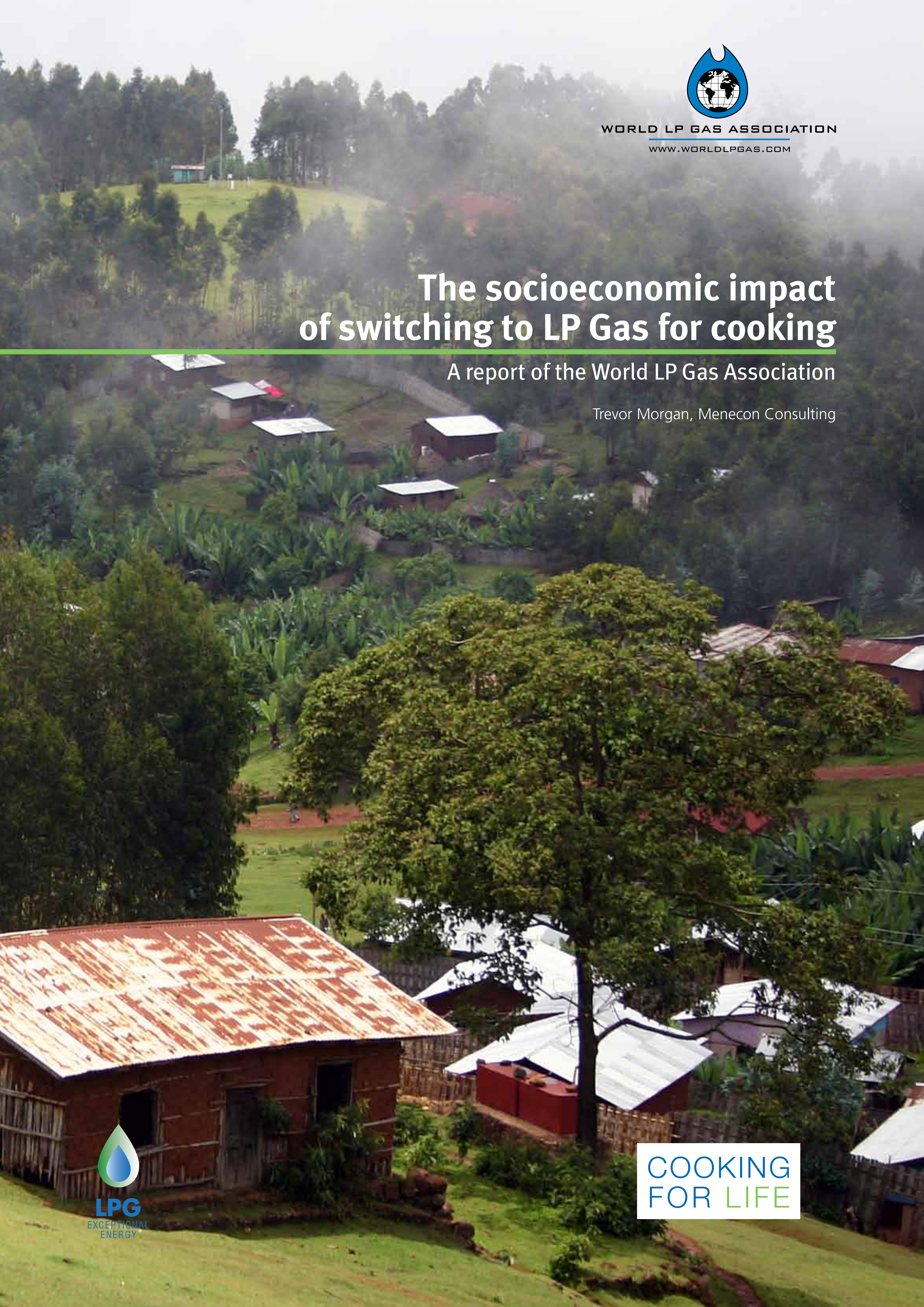

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The socioeconomic impact of switching to LP Gas for cooking

A report of the World LP Gas Association

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LPG EXCEPTIONAL ENERGY

COOKING FOR LIFE

Contents

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Summary

Around three billion people across the developing world still rely on solid fuels – traditional biomass or coal – for cooking on primitive stoves or open fires. The socioeconomic cost is enormous: exposure to indoor air pollution from cooking this way causes the premature deaths of an estimated four million people annually from lung cancer, cardiovascular disease, pneumonia and chronic obstructive pulmonary disease, as well as ill-health and the loss of productivity among millions more. It also entails a waste of productive time and energy, as traditional fuels usually have to be collected and transported to the home and cooking with biomass is slow. The local and global environment may also be degraded, as the demand for biomass encourages deforestation, the use of animal waste degrades soil quality and, to the extent that it is used unsustainably, burning biomass contributes to global warming and to local and regional air pollution. Switching to LP Gas, which is particularly well-suited to domestic cooking, would improve greatly the quality of these people's lives and bring far-reaching social, economic and environmental benefits.

Quantitative studies of the socioeconomic impact of household energy interventions in developing countries carried out in recent years suggest that the socioeconomic gains from switching to LP Gas are large. In the most extensive study, carried out by the World Health Organization (WHO) in 2006, in a scenario in which 50% of the people using solid fuels worldwide switch to using LP Gas, total economic benefits amount to roughly US$ 90 billion per year compared with net intervention costs of only US$ 13 billion (i.e. a benefit-cost ratio of 6.9). Time savings account for half of the gross economic benefits and health-related productivity gains for most of the rest. In a pro-poor scenario, in which priority is given to households using the most polluting fuels, the economic benefits are even higher, at US$ 102 billion, with a net intervention cost of just US$ 15 billion. Other recent studies of national programmes demonstrate that the benefits always outweigh the costs, in most cases by a wide margin.

Over time, rising incomes will tend to boost the proportion of poor people using modern fuels such as LP Gas for cooking in developing countries. Yet that process will remain unacceptably slow unless governments intervene – in part because incomes are held back by the very fact that households do not have access to modern energy. The International Energy Agency projects that the number of people without access to clean cooking facilities in 2030 will be barely lower than in 2010 in a central scenario, which assumes no change in government policy. In its Energy for All Case, in which all households gain access to modern cooking fuels by 2030, more than 40% of the households currently lacking access that switch from solid fuels, or 1.1 billion people, choose LP Gas. Based on the WHO analysis, meeting this goal would be expected to generate over $60 billion per year in today's money of on-going net benefits, the benefits outweighing the costs by a factor of seven to one. These benefits provide a strong justification for decisive policy action by governments to accelerate switching to LP Gas and other clean fuels and facilities.

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Introduction

There is enormous potential for poor people in developing countries to switch to Liquefied Petroleum Gas (LPG, or LP Gas) and other modern fuels for cooking; exploiting that potential promises to improve the quality of their lives and bring major social, economic and environmental benefits – locally, regionally and globally. Around three billion people across the developing world still rely on solid fuels – traditional biomass (wood, charcoal, agricultural residues and animal waste) or coal – for cooking on primitive stoves or open fires (WHO/UNDP, 2009). They have little or no access to more efficient, modern forms of energy. Unsurprisingly, traditional biomass is most commonly used in rural areas, where access to affordable modern energy is most restricted.

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The consequences of poor people using solid fuels for cooking are far-reaching and dramatic. Exposure to indoor air pollution from cooking this way causes the premature deaths of an estimated two million people annually from pneumonia, chronic lung disease and lung cancer, as well as ill-health and the loss of productivity among millions more.[1] The majority of the people affected are women and children, as women are usually responsible for cooking and small children often remain close to their mothers. In fact, indoor smoke from solid fuels is one of the leading causes of avoidable deaths and ill-health worldwide (WHO, 2012). The use of solid fuels also entails a waste of productive time and energy, as traditional fuels usually have to be collected and transported to the home. The local and global environment may also be degraded, as the demand for biomass encourages deforestation, the use of animal waste degrades soil quality and, to the extent that it is used unsustainably, burning biomass contributes to global warming. Burning solid fuels also contribute to local and regional air pollution, notably smog.

Of all the modern fuels available today, LP Gas, which consists mostly of propane and butane, is particularly well suited to domestic cooking and heating uses because of its clean-burning attributes and practical advantages over both solid fuels and kerosene – the other main type of cooking fuel in developing countries. In particular, it is more convenient, safer and cleaner. It is also highly portable and has a high calorific value by volume and mass. Switching from solid fuels – and from kerosene – to LP Gas can, therefore, bringing considerable health, developmental and environmental benefits.

In recognition of that critical role that access to LP Gas and other forms of modern energy services plays in helping developing countries alleviate poverty and achieve their development objectives, including the Millennium Development Goals, the United Nations General Assembly declared 2012 the *International Year of Sustainable Energy for All* and the Secretary-General is undertaking action to support the Year through a global initiative to stimulate action by governments, international development agencies, non-governmental organisations (NGOs) and the private sector.[2] Within the framework of this initiative, the World LP Gas Association (WLPGA) launched in 2012 the *Cooking for Life initiative* – a global campaign that by 2030 aims to convert to LP Gas one billion people whose health and safety are threatened daily from cooking with solid fuels and whose prospects of a better life are being held back by lack of access to modern cooking fuels.[3] The campaign convenes governments, public health officials, the energy industry and global NGOs to seek practical ways of expand access to LP Gas.

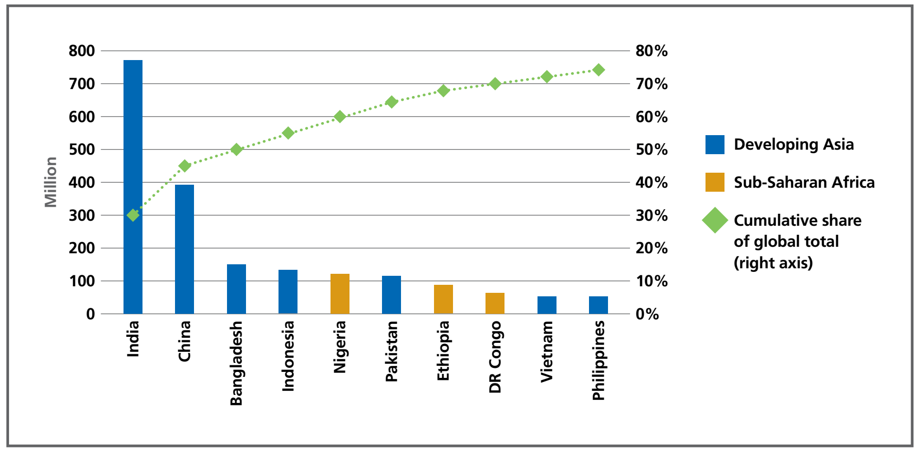
This paper – one of several papers commissioned by the WLPGA as part of the *Cooking for Life* initiative – assesses the socioeconomic benefits of switching from traditional biomass and other fuels to LP Gas for cooking in developing countries based on a review of the findings of recent research and analytical work in this area. It first sets out the nature of the transition from traditional to modern fuels for cooking by households. It then considers in detail the types of impact that fuel switching can have and reviews the evidence on the magnitude of the various impacts – both costs and benefits. The paper concludes with some discussion of the implications for policy.

The transition to LP Gas and other modern fuels

Despite important strides in economic development and rising prosperity in recent years, solid fuels still dominate residential energy use in less developed countries, accounting for just over half of all the energy used by households there (IEA, 2012).[4] Cooking is the principal use of solid fuels, especially in the southern hemisphere where ambient temperatures are higher and space and water heating needs lower. Traditional biomass and waste account for roughly 90% of total solid fuel use for cooking in those countries, with 2.6 billion people relying almost exclusively on biomass – more than half of them in India, China and Bangladesh (Figure 1). Another 300-400 million people, most of them in China and India, use coal for cooking.

Figure 1: Countries with the largest population relying on traditional biomass for cooking, 2010

Source: IEA (2012)



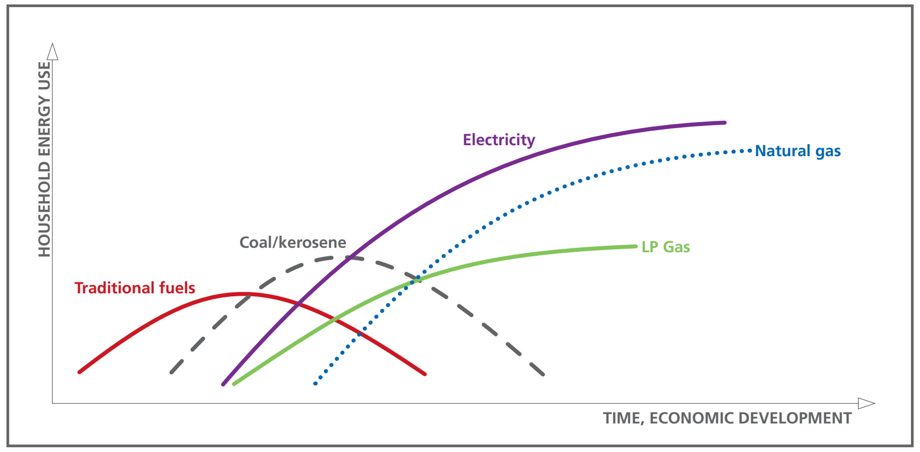
Unsurprisingly, traditional biomass is most commonly used in rural areas, where access to affordable modern forms of energy is most restricted. Yet biomass, often transformed into charcoal, remains the dominant fuel in many cities in the poorest countries. The people in households that use solid fuels make up 56% of the entire population of the less developed countries or about 40% of the world's population (WHO/UNDP, 2009). In addition to their lack of access to modern energy, their access to improved cooking stoves is also very limited: a mere 27% off those who rely on solid fuels – about 800 million people – are estimated to use such stoves.

A long-term transition away from solid fuels and towards modern forms of energy for cooking, including kerosene, LP Gas, natural gas, biogas and electricity, has been underway for decades with rising incomes and improved access to modern commercial energy services across the developing world. In some cases, supportive government action, including direct fuel subsidies, have helped to accelerate this process. At the initial stage in this process, there is a shift from woodfuel, straw and dung to charcoal and intermediate modern fuels such as kerosene and coal, as well as the deployment of more efficient biomass-stoves. As incomes rise further, the use of advanced modern fuels such as LP Gas, natural gas (where available in urban areas) and electricity expands. Growing concerns over the environmental impact of energy use are also helping to drive a shift towards renewable energy technologies, such as biogas and wind and solar power for local power generation, although they remain in most cases more expensive than fossil-fuel-based technologies.

LP Gas represents a phase in the transition to advanced modern fuels, replacing traditional fuels, coal and (at a later stage) kerosene (Figure 2). In most countries, this transition is largely complete at per capita household incomes of more than US$ 4,000, though some richer households may persist in using solid fuels or kerosene (Kojima, 2011). Where natural gas becomes available through the establishment of local distribution networks as the economy matures, LP Gas may itself be displaced to a large degree by natural gas. However, LP Gas often remains the main fuel for residential cooking (and heating) in areas remote from the natural gas grid and may be preferred by some households even where natural gas is available. In most developing countries, the distribution of natural gas to residential customers is unlikely to become widespread for many years, if ever. The initial stage of switching from traditional fuels or kerosene to LP Gas in developing countries typically involves the use of a cylinder attached to a simple burner. As familiarity with LP Gas grows and incomes rise, the user may install a modern cooker inside the home, possibly with the gas supplied by rubber pipe from a cylinder placed outdoors or in a separate room.

Figure 2: Household energy use life cycle

Source: WLPGA/World Bank (2002)



The transition to modern fuels is a gradual and uneven process. A complete shift to the patterns of energy use seen in the industrialised countries cannot be achieved overnight. Many households in relatively rich developing countries continue to use large quantities of biomass, especially in rural areas because modern fuels are not available or are too expensive. In the poorest developing countries, widening access to modern fuels is limited by extreme poverty, which keeps these countries in a vicious circle of under-development. Rising incomes will tend to expand access to LP Gas. Yet among the household that today continue to rely on solid fuels are many who are financially capable of paying the US$ 15 to 20 a month needed to purchase LP Gas. Many factors in addition to income and the price of LP Gas determine use of the fuel: availability, reliability of supply, prices of other fuels, acquisition costs of LP Gas cylinders and stoves, fears about safety, unfamiliarity with cooking with LP Gas, lack of knowledge about the harm caused by smoke from solid fuels burned in traditional stoves, and cultural preferences. (Kojima, 2011; WLPGA, 2005). The transition to LP Gas can be smoothed and sustained by policies and programmes aimed at improving affordability and accessibility (see the last section).

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Types of socioeconomic impacts

Switching by households from solid and other fuels to LP Gas for cooking can have significant and far-reaching consequences for the lives of the people in the households in which the switch occurs, which has knock-on effects for the local community, economic activity and the environment. When switching takes place on a large scale, these socioeconomic effects are felt far beyond the local community, economy and environment. Making the switch is not without cost and some of the effects of switching may be negative, but the benefits are, in most cases, even bigger, yielding important net social and economic gains that go well beyond the household making the switch.

The socioeconomic impacts of fuel switching can be categorised as costs or benefits. Most of the costs relate to the initial cost of acquiring the equipment to be able to cook with LP Gas namely the stove, the cylinder, the pipe and valve, and any related installation costs, as well as the cost of the fuel itself. In addition, there may be significant costs related to a programme aimed at expanding the use of LP Gas for cooking, which are generally borne by the government or a donor – for example, the cost of advertising, dissemination of information, education and financing/credit programmes. Maintenance costs are generally minimal. There may also be a global environmental cost related to the emissions of greenhouse gases from burning LP Gas; however, in reality, switching to LP Gas is likely to lead to fewer emissions on a net basis, to the extent that it reduces the unsustainable use of traditional biomass (i.e. biomass that it is not replaced once it has been harvested) and the use of coal, which is much more carbon-intensive than LP Gas (see below).

There are number of different social and economic benefits that result from switching from solid fuels to LP Gas, which accrue directly to the households that switch as well as the local, regional and global community. The most important are as follows:

- Health-related benefits, including improved quality of life as a result of less human suffering, reduced health-related expenditure as a result of less illness and the value of productivity gains resulting from less illness and fewer deaths.

- Time savings from reduced drudgery from collecting and preparing biomass for use, usually by women and children and from more efficient and rapid cooking and heating, increasing the time available for other social and economic activities.

- Fuel savings from using a more efficient stove.

- The avoided economic cost of environmental degradation caused by the use of solid fuels, including reduced deforestation and increased agricultural productivity where agricultural residues and dung are used as fertilizer rather than fuel, as well as reduced emissions of greenhouse gases and black carbon.

- Other less tangible benefits, such as increased personal esteem, prestige and comfort levels that result from a cleaner, tidier and more modern home environment.

Health-related benefits[5]

There is a wealth of evidence that exposure to pollutants produced by burning traditional biomass and coal indoors in open fires or stoves for cooking – notably carbon monoxide and particulate matter (soot) – can cause serious health problems and death. According to the Global Burden of Disease (GBD) 2010 study, the biggest survey of global health ever undertaken, the results of which were released in a series of articles in the Lancet Medical journal in December 2012, four million people a year die prematurely from illness attributable directly and indirectly to indoor air pollution due to solid fuel use – virtually all of them in poor developing countries.[6] Of those deaths, 500,000 are caused by the effects of second-hand cooking smoke that wafts up the chimney and out the doors and other openings of the home. Of the total number of deaths, 500,000 are attributed to child pneumonia; lung cancer, cardiovascular disease, pneumonia and chronic obstructive pulmonary disease account for most adult deaths. More men than women are killed by indoor air pollution, despite the fact that women are more exposed to smoke from cooking. This is because men have much higher background rates of the major diseases. Household air pollution is now the single most important environmental cause of premature death worldwide, accounting for almost 7% of all deaths globally. The estimate of premature deaths from indoor air pollution is twice as high as that produced by the previous study carried out by WHO in 2008, largely because there are better estimates of the impact of pollution on heart and lung disease.

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Indoor pollution from the smoke caused by the incomplete combustion of solid fuels also leads to non-fatal ill-health, which can be measured in Years Lived with Disability (YLD). Adding together YLD and Years of Life Lost (YLL) yields Disability Adjusted Life Years (DALYs). GBD 2010 estimates that 107 million DALYs were lost in 2010 due to indoor air pollution, mainly the result of lower respiratory illness in children. Young children are especially at risk from indoor pollution as they tend to stay close to their mothers, who are generally responsible for cooking for the entire household. Because the DALY measure captures the many years of life lost due to deaths from child pneumonia, it shows an even stronger impact of solid fuel use on health in the poorest countries, where pneumonia is a major cause of death in children under 5 years of age (WHO/UNDP, 2009).

Gathering and hauling large quantities of wood fuel can also harm health. In most rural households, women and children who are responsible for collecting firewood. Wood collectors are vulnerable targets for attack by criminals and wild animals, and are vulnerable to falls; carrying heavy head-loads of up to 40 kg over many years can be physically damaging (IEA, 2006).

It follows that switching from the solid fuels that harm human health to cleaner cooking fuels such as LP Gas would bring significant health-related benefits. LP Gas produces virtually no particulate matter and, relative to most other non-renewable fuels, low emissions of carbon monoxide. There are negligible emissions of toxic gases that can cause serious health problems if breathed in close to the point of combustion, which makes LP Gas highly suitable as a household cooking fuel. In social terms, these benefits would take the form of improved quality of life as a result of less human suffering. In economic terms, they include the reduction in health-related spending expenditure and the value of the productivity gains that result from less illness and fewer deaths.

There are also significant potential health benefits from switching from kerosene to LP Gas. These stem both from the emissions associated with using fuel indoors and the safety hazards from accidental explosions, fires and poisoning. Although kerosene is often advocated as a cleaner alternative to solid fuels, kerosene-using devices emit substantial amounts of fine particulates, carbon monoxide, nitrogen oxides and sulphur dioxide (see, for example, Ruiz *et al*., 2010). Recent studies of kerosene used for indoor cooking or lighting provide some evidence that emissions may impair lung function and increase infectious illness (including tuberculosis), asthma and cancer risks (Lam *et al*., 2012). According to the US Environmental Protection Agency, carbon monoxide poisoning is the most widespread threat to health.[7] Kerosene can also be dangerous when handled improperly or when faulty equipment is used. Because the fuel in a kerosene stove is not sealed, it may leak and ignite when the stove is accidentally knocked over when in use. Accidents with overturned lamps or stoves, explosions of stoves due to over-filling and spilled fuel are commonplace, in some cases causing severe burns and death; often, the problem is made worse by contamination of kerosene with gasoline, which is intrinsically more flammable (Shepherd and Perez, 2007). In South Africa, an estimated US$ 26 million is spent annually for care of burns from kerosene cookstove incidents.[8] Kerosene-related accidents are one of the principal causes of destruction of property by fire in urban areas in developing countries.

Poisoning from accidental ingestion of kerosene, which is often stored and transported in plastic water bottles, by children is also a widespread problem in some developing countries. In South Africa alone, there are an estimated 100,000 cases of poisoning by accidental ingestion of kerosene, mostly by small children, resulting in 16,000 hospitalisations and 200 deaths annually; an estimated 6.5% of non-electrified households have experienced incidents of kerosene poisoning of children (WLPGA/World Bank, 2002). On an equal use basis, the fire-safety and indoor pollution problems associated with LP Gas use are estimated to be only a tenth of those related to kerosene; in addition, there are no cases of poisoning with LP Gas.

Time savings

There can also be significant socioeconomic benefits from the time saved in not using traditional biomass by switching to LP Gas and other modern fuels. The principal time saving comes from eliminating the drudgery of collecting and preparing biomass for use as a cooking fuel (usually by women and children). LP Gas, which has far higher energy density than biomass, can be collected or delivered quickly to the home. Comprehensive data on the time spent collecting fuel are unsurprisingly sparce, but several national studies have shown that it can be very high in the poorest countries with the greatest dependence on traditional biomass. Time savings typically average between one and two hours per day but can be much more (Bruce *et al*., 2011; Dutta, 2005). One study estimates that villagers spend between 2-6 hours and travel from 4-8 km per day per household to collect, on an average, 10 kg of wood (Bloom and Zaidi, 2002). A 2006 World Bank study found that, in Guinea, the average time spent collecting fuel was 1.5 hours for the population as a whole and 2.1 hours in rural areas (Blackden *ed*., 2006). A field-study in Western Kenya showed that women often spend two to five hours each day on collecting firewood (IFAD/FAO 2003). In rural India, women spend about 40 minutes per day collecting fuel (Barnes and Sen, 2004). In Tanzania, the average distance travelled to collect wood fuel is over 10 kilometres (IEA, 2006). Deforestation may have increased the average time spent in recent years in many countries.

Time may also be saved in cooking with LP Gas, though it does depend on the type of traditional-fuel cook stove that is being replaced. According to the most recent study of 18 different types of cook stove in widespread use in developing countries, several biomass stoves are able to bring 5 litres of water to the boil more quickly than LP Gas (Aprovecho Research Center, 2011). However, only one stove with a chimney is quicker, with most of them – including the kerosene stove – far slower (Figure 3). An earlier study found that the savings in cooking time using LP Gas compared with traditional fuels are much larger in real life, averaging 1.82 hours per day in Uganda (Habermehl, 2007).

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Switching to LP Gas eliminates the need to spend time collecting and preparing traditional biomass and reduces cooking time, resulting in a significant increase in time available for other social and economic activities, on condition that LP Gas cylinders are available locally and can be collected or delivered quickly. Children freed from the need to spend time collecting biomass may spend more time in school, while women may spend more time looking after and educating their children. Women may also put the additional time to directly productive use, engaging in income-generating commercial activities. In rural areas, these activities are likely to be related to agriculture. The types of activities that urban women are likely to engage in will depend on the socio-cultural and economic environment; in many poor countries, the economic role of women is restricted by attitudes towards the appropriate types of activity that women ought to engage in (Lambrou and Piana, 2006). The extra income generated creates a virtuous cycle of increased spending on modern energy services, improved health, increased provision of education, increased productivity and economic and social development.

Switching from kerosene to LP Gas can also yield time savings. Washing the pots and pans used in cooking is faster when using LP Gas, as it does not blacken the pots as kerosene does. In addition, less time is spent (and less cost incurred) in cleaning and repainting the kitchen as a result of the soot produced by kerosene (Chikwendu, 2011).

Fuel savings

As well as the time saved in cooking with LP Gas, there are potential financial and economic benefits from the lower cost of providing effective energy for cooking, to the extent that the higher efficiency outweighs the higher cost of the fuel on a gross calorific value basis. With the exception of the parabolic solar cooker, LP Gas was by the most efficient of all the cook stoves tested in the 2011 Aprovecho study (Figure 4).

Figure 3: Time to bring 5 litres of water to the boil by type of cook stove

Source: Aprovecho Research Center (2011)

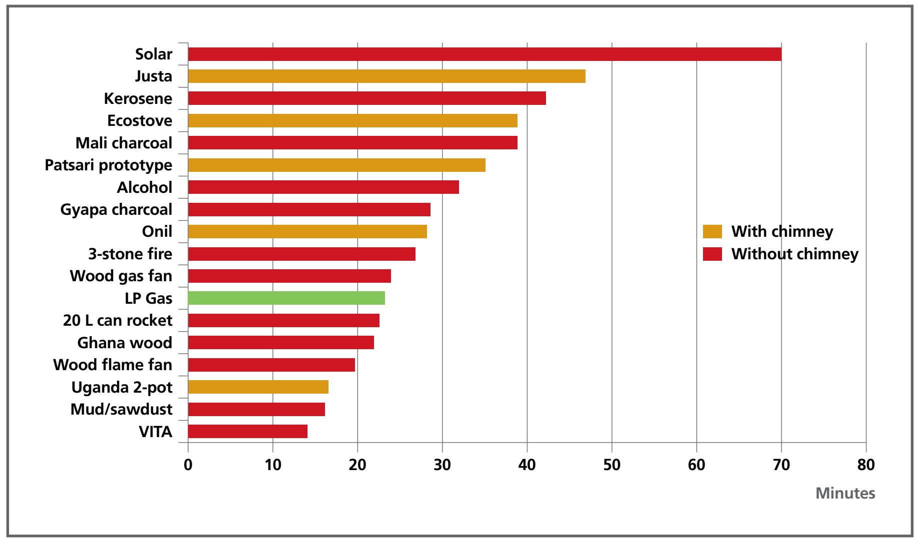
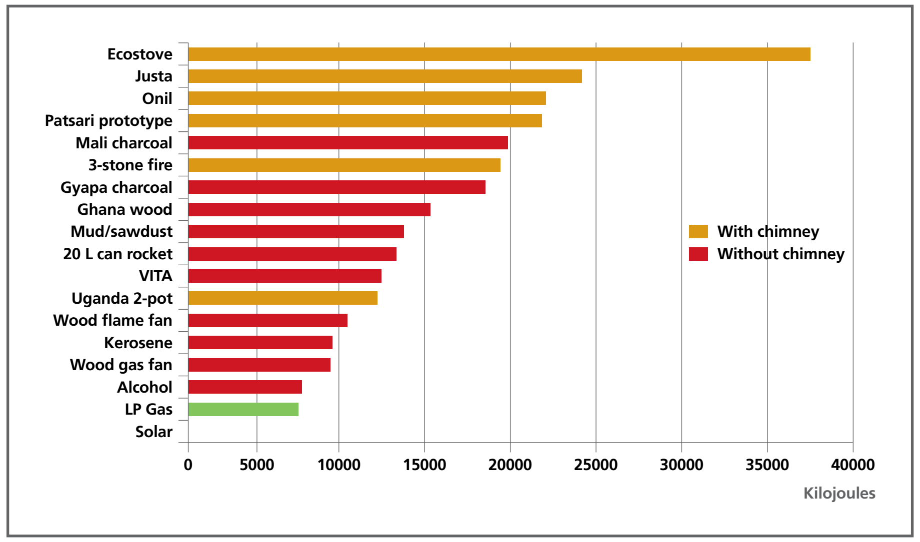


Figure 4: Energy required to bring 5 litres of water to the boil and simmer it for 45 minutes by type of cook stove

Source: Aprovecho Research Center (2011)



Coal-based stoves, even where the efficiency is as good as that of an LP Gas stove, give off around

50% more CO2;

allowing for differences in stove efficiency, emissions are often twice as high.

How big or small the fuel savings in monetary terms are in practice depends on the relative efficiency of the cook stoves and the prices of LP Gas and traditional fuels (if they are bought commercially, which is usually the case with charcoal). If LP Gas is subsidised, the overall financial savings enjoyed by households may be significant, though there may be a net economic cost of switching (i.e. the cost of the subsidies to the national economy may be bigger).

Avoided cost of environmental degradation

The use traditional fuels and coal give rise to major environmental impacts, which are generally broader and larger than those associated with the use of LP Gas. These environmental impacts, which can be local/regional or global, carry a social and economic cost.

Local environmental benefits accrue from a switch away from biomass to cleaner fuels, as well as from the deployment of improved and more fuel-efficient stoves. The most important benefits are as follows:

- **Reduced deforestation:** Less use of traditional biomass means that fewer trees need to be cut down in an unsustainable fashion to meet demand for firewood or charcoal. Deforestation due to unsustainable firewood use can lead to soil erosion, desertification, and, in hilly areas, landslides.[9]
- **Improved agricultural productivity:** Animal dung and agricultural residues are often used as low-grade cooking fuel rather than natural soil fertilizer in poor countries. Removing these sources of nutrients interrupts the normal composting process and, in the absence of any chemical fertilizers, degrades the quality of the soil, ultimately reducing farm productivity (though some of the ash produced by the combustion of biomass may be used as fertilizer, such that not all of the nutrients are lost). Reducing the use of such fuels, therefore, helps to reduce the need to buy chemical fertilizers, boost productivity and enhance food security (WHO, 2006).

Global environmental benefits occur when greenhouse-gas emissions are reduced. The extent to which this occurs as a result of switching from solid fuels depends on the types of fuels that are replaced and the efficiency of the cook stoves in which they are used. Most biomass cook stoves are very inefficient (see above), because of the incomplete burning of the fuel and poor heat transmission, leading to excessive emissions of carbon dioxide (CO_2) and other greenhouse gases such as methane and nitrogen oxides, and black carbon. When biomass is produced in a sustainable manner, the CO_2 emitted in combustion are entirely offset by the CO_2 absorbed by the biomass grown to replace it. However, in reality, much of the biomass used in poor developing countries is not replaced, so net emissions are positive. Coal-based stoves, even where the efficiency is as good as that of an LP Gas stove, give off around 50% more CO_2; allowing for differences in stove efficiency, emissions are often twice as high. In addition, in the case of charcoal, emissions arise not only from its eventual use as a cooking fuel in the household, but also from the initial preparation of charcoal, a process which generates high levels of methane and other products of incomplete combustion (Hutton *et al*., 2006).

Other benefits of switching from solid fuels

Switching to cleaner fuels for cooking and heating brings other less tangible benefits that contribute to a better quality of life. A cleaner house due to less smoke, the prestige of owning a modern stove and its convenience are often considered important factors by users and can result in a perceived rise in their self-perception and status in the community (WHO, 2008). Household assets and amenities offer a general reflection of a household's quality of life. The transition to modern energy, of which the shift to LP Gas for cooking forms an important component, can facilitate development through improvement in many different areas that are important for quality of life (Barnes *et al*., 2010).

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Measuring costs and benefits

Measuring the impact of policy interventions to encouraging switching to modern fuels is far from straightforward, as all the different short term and longer term consequences, including investment costs, knock-on effects and feedbacks, need to be taken into account. Yet it is essential that interventions be based on a credible economic evaluation of the costs and benefits to ensure that the choice and scale of intervention is optimised.

Methodological approaches

Measuring the impact of policy interventions to encouraging switching to modern fuels is far from straightforward, as all the different short term and longer term consequences, including investment costs, knock-on effects and feedbacks, need to be taken into account. Yet it is essential that interventions be based on a credible economic evaluation of the costs and benefits to ensure that the choice and scale of intervention is optimised.

Economic evaluation differs from a pure financial insofar as the former seeks to take account of non-financial impacts that may be difficult to estimate in monetary terms. Financial analysis involves assessing income, expenditure, cash flows, profit and the balance sheet at the end of a period. On the other hand, economic aims to measure the impact of an intervention on the overall economy (at the local, national, regional or global level), and considers all the uses of resources and their consequences. The results of economic evaluation can be used in a variety of ways, including for project analysis, for government policymaking, to assess the social impacts of interventions and for use by an implementing agency, such as a hospital, company or non-governmental organization (Hutton and Rehfuess, 2006).

There are two main types of economic evaluation: cost–effectiveness analysis (CEA) and cost–benefit analysis (CBA). The principal difference between them is the units in which the outcome of the intervention is measured and the scope of the analysis: CEA, which is commonly used to measure health impacts, measures the benefits of interventions to reduce indoor pollution in units such as the numbers of DALY or YLL averted.[10] It can, therefore be used to identify how much requires to be spent on an intervention to obtain a given unit of health gain. However, in focusing solely on the health impacts, CEA does not evaluate the societal benefit of interventions. In contrast, CBA determines the monetary value of all intervention costs and benefits to society as a whole, and hence whether the investment in the intervention yields a net gain in economic terms (i.e. whether the economic benefits of an intervention exceed its economic costs). A positive net benefit indicates that an intervention is socially and economically worthwhile. This approach allows all of the available alternative interventions to be ranked to identify those interventions that have the highest return and bring the greatest benefit to the target population. Because of the capacity of CBA to take into account a wide range of benefits, this method is usually considered more appropriate for economic evaluation of household energy interventions.

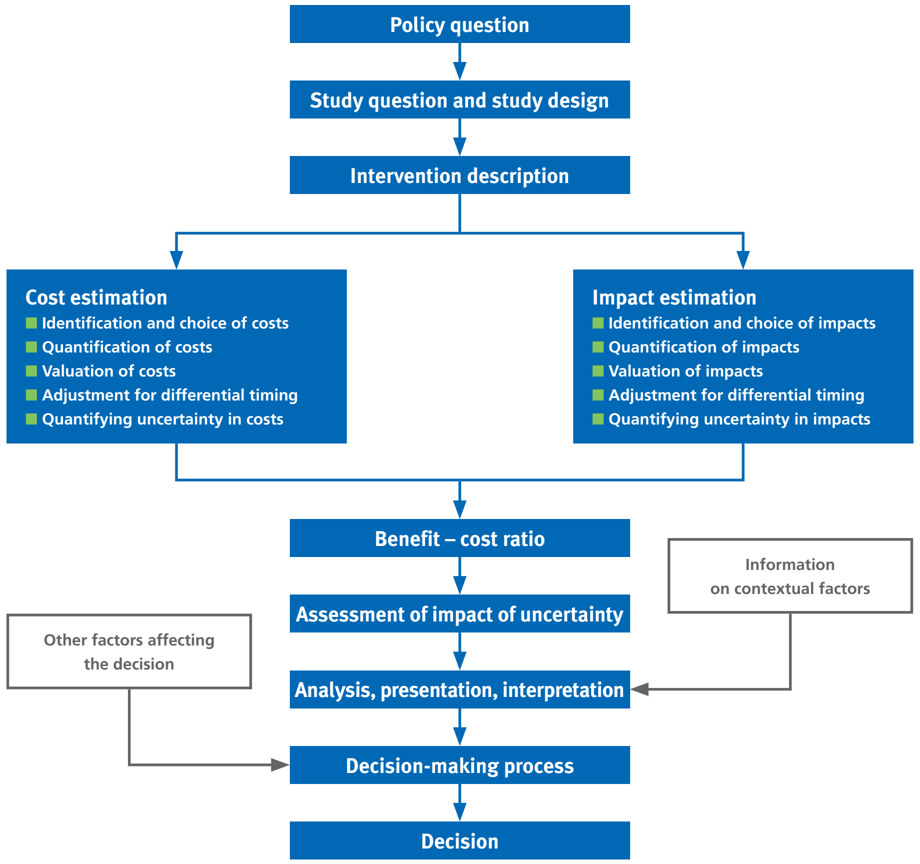
The primary output of CBA is the benefit–cost ratio (BCR), which shows the factor by which economic benefits exceed the economic costs. However, other results may also be of interest to decision-makers, such as the break-even point (how quickly the investment will be paid back), the economic internal rate of return (the discount rate at which the future expected stream of benefits equals the future expected stream of costs) and the net present value (the net economic gain that can be expected from the intervention in currency units at the start of project, discounting future costs and benefits). Intermediate results, such as cost estimates or data on various outcomes, may also 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 (Hutton and Rehfuess, 2006).

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. These have been refined and adapted since then to cover interventions aimed specifically at addressing health concerns related to indoor pollution. In 2006, the WHO prepared detailed guidance on how to carry out CBA for household energy interventions (Hutton and Rehfuess, 2006), which it has applied to evaluating interventions at the regional level – the results of which are summarised below. The WHO guidelines propose a step-by-step approach to CBA, starting with the precise formulation of the policy question to be addressed – for example, how best can the adverse health impacts of indoor pollution from solid fuels be reduced – and ending with the implementation of the policy decision (Figure 5).

CBA and CEA can be applied if primary data is available on the various impacts described above. In practice, gathering such data can be challenging. Questionnaires and participatory techniques can be used to assess and understand socioeconomic impacts. Qualitative questionnaires assess people's perceptions of impact, while quantitative questionnaires determine measurable impacts, such as time use or expenditure. Participatory methods, such as focus group discussions and ranking exercises, can be a powerful tool for assessing social and economic impacts.

Figure 5: Approach to cost-benefit analysis of interventions to reduce the health impacts of indoor pollution

Source: Hutton and Rehfuess (2006)



Empirical results of recent studies

Despite the seriousness and pervasiveness of indoor pollution caused by the use of solid fuels, only a small number of quantitative studies of the socioeconomic impact of household energy interventions in developing countries have been published in recent years. The most extensive study – and the only one with global coverage – was carried out by the WHO in 2006, covering urban and rural populations at the global level and for 11 developing and middle-income regions and based on eight different scenarios of interventions to switch from solid fuels; the results are summarised in WHO (2006) and are described in detail in Hutton *et al*. (2006). Among the eight scenarios analysed, three involved switching to LP Gas – two of which assumed that 50% of households using solid fuels in 2005 switch by 2015 (including a pro-poor scenario in which households using the most polluting and least efficient solid fuels switch first) and one that assumed that all households switch fuels. The second is clearly not feasible, but was used to provide an indication of the hypothetical potential gains.

The study involved calculating the benefit–cost ratio as the annual average economic benefits of the intervention divided by the annual average economic net costs of the intervention, discounted over the ten-year period. Net intervention costs are calculated as absolute intervention costs minus cost savings as a result of fuel-efficiency gains. Economic benefits include reduced health expenditure due to less illness, the value of productivity gains due to less illness and death, time savings due to less time spent on both fuel collection and cooking, and reduced environmental damage at the local and global levels. Local environmental effects are assessed as fewer trees cut down, while the global environmental effects include fewer emissions of CO_2 and methane. Some benefits were not modelled, such as the health effects where the current evidence for indoor air pollution as a cause is inconclusive, improved food safety, better quality of the home environment and additional environmental impacts such as improved soil fertility and reduced emissions of other greenhouse gases.

The results show very favourable benefit–cost ratios for switching to LP Gas, as well as for the deployment of improved stoves. The benefits outweigh the costs, in most cases by a large factor, in all scenarios and regions, with the exception of the urban areas of Americas region with high mortality and the southeast Asia region with low mortality in the pro-poor scenario; on average worldwide, the benefits are around seven times greater than the costs in the two scenarios in which 50% of people using solid fuels switch to using LP Gas and are 34 times greater in the 100% switching scenario (Table 1). In many cases , the fuel savings for households are bigger than the upfront cost of switching (the purchase of the stove and cylinder) such that the net cost and, therefore, the benefit-cost ratio are both negative. In the scenario in which 50% of people using solid fuels switch to using LP Gas, total economic benefits amount to roughly US$ 90 billion per year compared with net intervention costs of only US$ 13 billion. Time savings account for 49% of the gross economic benefits, health-related productivity for 44.5%, environmental benefits for 7% and health-care savings for just 0.2%, though the breakdown varies markedly across regions (Figure 6). In the pro-poor scenario, the economic benefits are even higher, at US$ 102 billion, with a net intervention cost of just US$ 15 billion.

For all three scenarios, the net intervention costs were found to be higher for rural populations, as the urban population already purchases a higher proportion of their fuel, thus giving rise to a bigger cost saving when switching to LP Gas. But the economic benefits were also significantly higher in most cases in rural areas, especially with respect to time savings due to the higher proportion of the rural population that collects rather than purchases their fuels. In all three scenarios, roughly half of the benefits in absolute terms accrue to the western Pacific region (mostly in urban areas), with Africa and southeast Asia accounting for most of the remaining benefits. In contrast to the western Pacific, the benefits are bigger in rural areas in almost all other regions.

Inevitably, any analysis of this type is bound to be subject to considerable uncertainty, notably with regard to the underlying assumptions adopted. Sensitivity analysis was performed to evaluate the impact of changes in assumptions on results and conclusions. Although the benefit-cost ratios proved to be highly sensitive to changes in the underlying assumptions, the results were found to be robust within the range of optimistic and pessimistic alternatives tested.

On average worldwide, the benefits are around

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In the scenario in which 50% of people using solid fuels switch to using LP Gas, total economic benefits amount to roughly

US$ 90 billion

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Table 1: Benefit-cost ratios for WHO LP Gas intervention scenarios ($ return per $ invested)

Source: Hutton *et al*. (2006)

	50% of population reliant on traditional fuels switch to LP Gas				100% of population reliant on traditional fuels switch to LP Gas	
	Baseline		Pro-poor*		Baseline	
WHO region	Urban	Rural	Urban	Rural	Urban	Rural
Africa – D	26.5	3.7	3.3	3.2	Neg	4.4
Africa – E	Neg	6.2	12.7	6.9	Neg	10.5
Americas – B	14.3	3.8	6.9	3.7	Neg	4.7
Americas – D	Neg	1.8	0.9	3.6	Neg	2.0
E Mediterranean – B	4.9	4.2	4.9	4.3	5.0	4.2
E Mediterranean – D	Neg	2.2	16.1	2.1	Neg	2.7
Europe – B	Neg	3.0	Neg	2.9	Neg	4.1
Europe – C	Neg	3.4	Neg	3.1	Neg	6.3
SE Asia – B	Neg	2.7	0.2	3.4	Neg	3.2
SE Asia – D	2.6	1.5	1.4	1.8	Neg	1.6
W Pacific – B	27.0	21.2	68.5	14.6	Neg	Neg
World**	**22.3**	**3.2**	**15.1**	**3.7**	**Neg**	**4.0**
World (average)**	**6.9**		**6.7**		**33.7**	

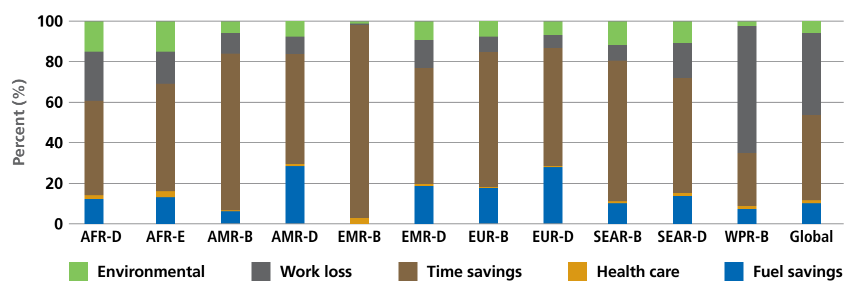
*Switching is targeted at hosueholds using the most polluting and least efficient solid fuels (first dung and crop residues, second firewood, third charcoal and finally coal).

**Excluding regions with very low mortality among both adults and children (A).

Note: Neg = negative (i.e. the intervention cost savings exceed the intervention costs). Mortality strata: A = very low child & adult; B = low child & adult; C = low child, high adult; D = high child & adult; E = high child, very high adult.

Figure 6: Contribution to gross economic benefits from switching of 50% of households to LP Gas by region

Source: Hutton *et al.* (2006)



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

Only a handful of local or programmatic CBA studies of the socioeconomic impact of fuel switching in households have been conducted to date, only one of which covered switching to LP Gas. The most recent study evaluated the impact of actual programmes implemented in poor communities in Kenya, Nepal and Sudan between 2004 and 2007 to reduce indoor air pollution, involving different combinations of interventions – improved stoves, smoke hoods and a switch to LP Gas (Malla *et al.*, 2011). The outcomes of each programme were evaluated, providing the basis for a household-level CBA for a ten-year intervention period, which essentially followed the WHO methodology. The results suggest that interventions – especially those involving switching to LP Gas – were justified on economic grounds with estimated internal rates of return of 19% in Nepal, where smoke hoods and stove modifications were the only interventions, 429% in Kenya, where LP Gas and smoke hoods were introduced, and 62% in Sudan, where LP Gas was the only intervention (Table 2). In each case, time savings constituted by far the most important benefit followed by fuel cost savings; direct health improvements were a small component of the overall benefit. In Sudan, the benefit-cost ratio was 2.5 at a 10% discount rate, with the net present value amounting to US$ 227 per household. These results are remarkably consistent with the results of the 2006 WHO study for the eastern Mediterranean region with high mortality (where Sudan is located), which show a benefit-cost ratio in rural areas of 2.2 in the baseline scenario.

Table 2: Cost-benefit analysis over 10 years for interventions in Kenya, Sudan and Nepal (US$ per household unless otherwise indicated)

Source: Malla *et al.* (2011)

	Kenya (LP Gas/smoke hoods)	Sudan (LP Gas)	Nepal (smoke hoods)
Costs			
Investment (total)	38.50	80.08	70.84
Maintenance (annual)	1.54	12.32	1.54
Present value*	48.00	155.8	80.3
Benefits			
Healthcare cost savings (annual)	0.03	0.41	0.08
Health-related time savings (annual)	0.10	0.29	0.23
Fuel cost savings (annual)	20.64	46.20	0.00
Fuel collection time savings (annual)	9.12	0.45	11.27
Cooking time savings (annual)	136.86	15.92	6.14
Present value*	1 025.00	382.40	109.90
Net present value*	**977.00**	**226.7**	**29.6**
Internal rate of return (%)*	**429.3**	**61.8**	**19.0**
Benefit-cost ratio*	**21.4**	**2.5**	**1.4**

At a 10% discount rate.

The net benefit of 1.1 billion people switching to LP Gas by 2030 amounts to

$60 billion

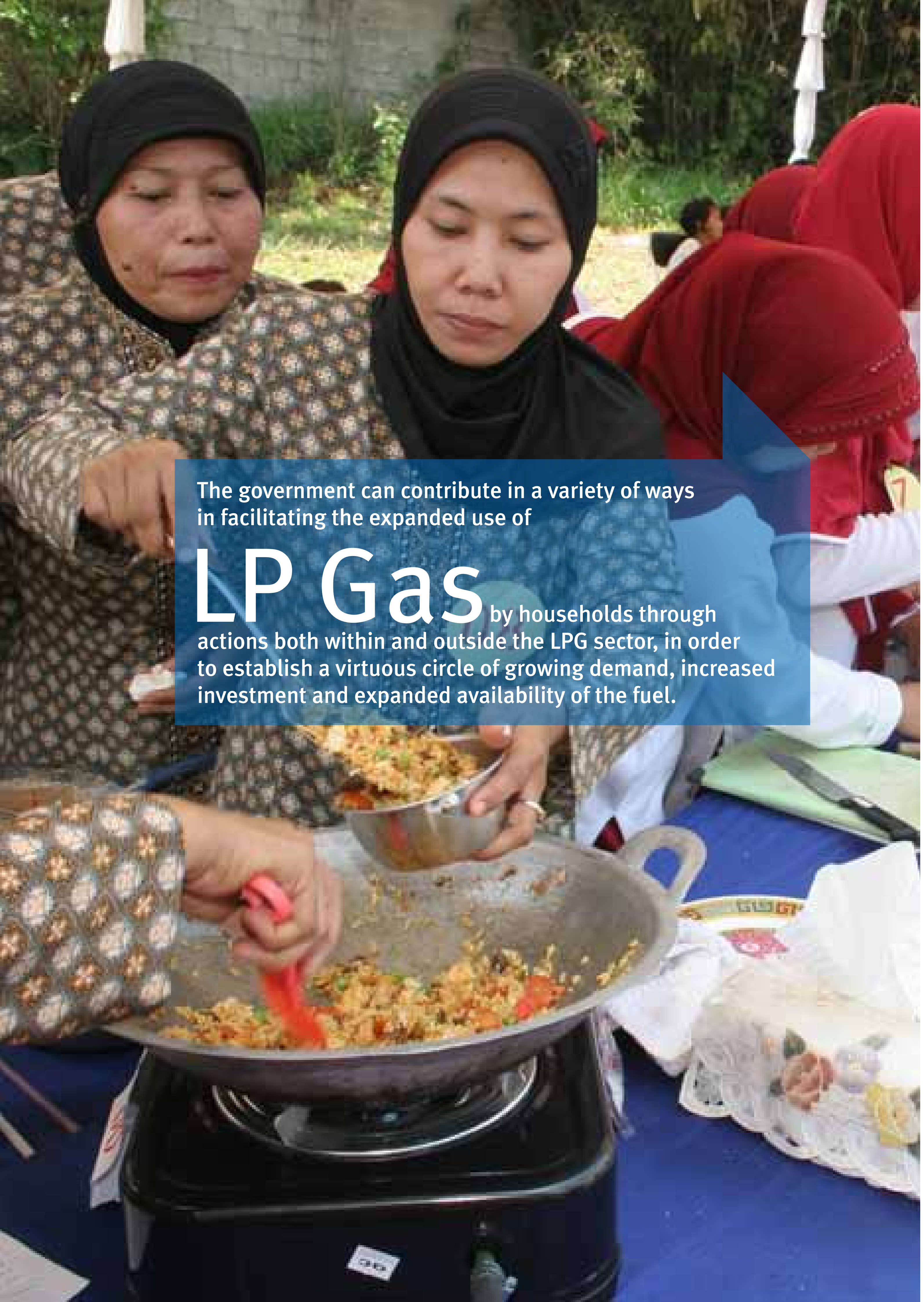
per year in 2011 dollars in net present value terms.

Two earlier studies involved CBA of household interventions, but did not include switching to LP Gas. One study examined costs and benefits for a programme promoted by the German Gesellschaft für Technische Zusammenarbeit (GTZ) in Malawi, which found a benefit-cost ratio of 5.2 with negative intervention costs thanks to large fuel savings (Habermehl, 2008). Another GTZ study in Uganda involving 190,000 households adopting rocket wood stoves and improved charcoal stoves reported a benefit-cost ratio of 25 (Habermehl, 2007). Winrock International carried out a CBA of biogas interventions for the whole of sub-Saharan Africa and country-level analyses for Uganda, Rwanda and Ethiopia (Renwick *et al.*, 2007). The interventions, which included household biogas with a subsidy of around 30%, also found favourable ratios, ranging from 1.2 to 1.3 for households and 4.5 to 6.8 for the economy as a whole (including broader societal benefits). Other studies have attempted to quantify certain aspects of household fuel switching. For example, one recent study quantifies the relative health and emissions impacts of different switching scenarios at the global level, concluding that LP Gas and kerosene stoves have unrivalled air-quality benefits while their climate impacts are lower than all but the cleanest stove using traditional fuels (Greishop *et al.*, 2011). Studies of the benefits of rural electrification, which are more numerous, also show generally highly favourable benefit-cost ratios (see, from example, World Bank, 2008).

Estimating the net benefit of a billion people switching to LP Gas by 2030

LP Gas will continue to play a central role in the quest for universal access to modern energy for cooking alongside other fuels and technologies, including advanced cook stoves for biomass and other solid fuels, electricity, natural gas in urban areas (where available) and biogas. In the IEA's Energy for All Case, in which all households gain access to modern cooking fuels by 2030, more than 40% of the households currently lacking access that switch from solid fuels choose LP Gas (IEA, 2011). This equates to around 1.1 billion people.

What would be the value of the socioeconomic benefits of switching to LP Gas on such a scale? The results of the 2006 CBA carried out by the WHO can be used to provide an indication, even though the assumptions about the numbers switching and the timeframe are not the same. In the scenario that assumes that 50% of people relying on solid fuels in 2005 (which equates to around 1.4 billion people) switch to LP Gas by 2015, the total benefits total US$ 90 billion per year and net intervention costs US$ 13 billion per year, yielding an overall net present value benefit of US$ 77 billion per year and a benefit-cost ratio of almost seven to one. Scaling down the net benefit to 1.1 billion people and adjusting for inflation over the period since the WHO was carried out yields a net present value of just over $60 billion per year in 2011 dollars.



> The government can contribute in a variety of ways in facilitating the expanded use of **LP Gas** by households through actions both within and outside the LPG sector, in order to establish a virtuous circle of growing demand, increased investment and expanded availability of the fuel.

Implications for policy

Over time, rising incomes will tend to boost the proportion of poor people using modern fuels such as LP Gas for cooking in developing countries. Yet that process will remain unacceptably slow unless governments intervene – in part because incomes are held back by the very fact that households do not have access to modern energy. The IEA projects that the number of people without access to clean cooking facilities in 2030 will be barely lower than in 2010 in a central scenario, which assumes no change in government policy, even though their share of the world's population drops from 38% to 31% (IEA, 2012). The potential socioeconomic benefits – to households themselves, but also to the broader community – provide a strong justification for decisive policy action to accelerate switching to LP Gas and other clean fuels and facilities.

The role of government in a market economy is to establish an enabling environment for the private sector to function in a way that is consistent with socioeconomic objectives. Non-governmental organisations and international donors can assist governments by providing advice and financial resources. The compatibility of policies to boost switching to LP Gas with other policies, including structural and regulatory reforms and policies concerning health, education, infrastructure and financing, is critical to their success. At the level of implementation, how well actual programmes are integrated into broader urban and rural energy development plans will influence how effective they are in encouraging the use and availability of LP Gas. In rural areas, co-ordination with, and the participation of, local organisations can be of vital importance; co-operatives, non-governmental organisations and local community organisations can be highly effective vehicles for supporting the establishment of local systems for energy distribution and delivery, as they understand local needs and can play a key role in communicating these needs to government, donors and external development agencies (World Bank/WLPGA, 2002).

The government can contribute in a variety of ways in facilitating the expanded use of LP Gas by households through actions both within and outside the LPG sector, in order to establish a virtuous circle of growing demand, increased investment and expanded availability of the fuel. Within the sector, support can take various forms, including measures to make the general regulatory and business environment more favourable to investment in distribution infrastructure (including making it clear to investors what laws, regulations and standards apply) and programmes to make LP Gas more affordable and to provide assistance in setting up micro-credit or micro-finance programmes. Policies and regulations need to be accompanied by effective monitoring and enforcement to ensure fair competition and that efficiency gains are passed on to consumers in the form of lower prices. Outside the sector, the government needs to ensure that the transport infrastructure is built to enable the fuel to be delivered to local communities, including roads that can cope with heavy trucks and adequate port facilities. Effective policymaking calls for strong leadership on tackling household energy poverty and addressing apathy and resistance to change on the part of both public institutions and households, good inter-institutional coordination, education and training and access to resources by the authorities as well as households (Ahmed *et al*., 2005).

It makes sense to first target households whose income is sufficiently high to start using LP Gas without subsidies and who already live in areas with LP Gas marketers, because these households are best placed to switch entirely to LP Gas and sustain its use (Kojima, 2011). Most of these households are likely to be in urban or peri-urban areas. Increasing use of LP Gas in the community will tend to lead others to consider switching to the fuel too through demonstration effects.

Raising awareness of the true cost of solid fuel use and the benefits of switching to LP Gas is a critical part of the solution. This makes it all the more important that donors and governments understand the scale of the socioeconomic prize. Analysis of costs and benefits not only shows the potential efficiency of the interventions, but also who is likely to incur the costs and who enjoys the benefits of the interventions. The UN Sustainable Energy for All initiative (SE4All) has already had a big impact in raising global awareness of energy poverty and the urgent need to increase modern energy access: over 150 commitments were submitted to the SE4All initiative across its three focus areas – energy access, energy efficiency and renewables – by the time of the Rio+20 Summit and more than 50 countries across Africa, Asia, Latin America and the Small Island Developing States have now confirmed their engagement.[11] Seven of the ten largest populations without clean cooking facilities, have signed up to the SE4All initiative. In total, funding commitments earmarked specifically for modern energy access under the SE4All initiative amount to over US$ 30 billion, much of it from multilateral development banks. While highly encouraging, it is clear that this level of funding still falls well short of that required for universal access to clean cooking fuels to become a reality (IEA, 2012).

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Footnotes

[1] See Polsky and Ly (2012) for a detailed discussion of the health impacts of the use of solid fuels for cooking.

[2] www.sustainableenergyforall.org/

[3] www.worldlpgas.com/resources/cooking-for-life

[4] Defined as countries that are not members of the Organisation for Economic Cooperation and Development (OECD).

[5] A detailed discussion of the health benefits of switching to LP Gas can be found in Polsky and Ly (2102).

[6] The work was led by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, with key collaborating institutions including the University of Queensland, the Harvard School of Public Health, the Johns Hopkins Bloomberg School of Public Health, the University of Tokyo, Imperial College London and the World Health Organization. The study took more than five years to complete and involved 486 authors in 50 different countries. The results are summarises in seven separate articles published in the 13 December 2012 edition of *The Lancet* Medical Journal in the United Kingdom, each containing data on different aspects of the study (including data for different countries and world regions, men and women, and different age-groups). All the articles can be downloaded from www.thelancet.com/themed/global-burden-of-disease.

[7] www.epa.gov/iaq/co.html

[8] http://www.who.int/mediacentre/factsheets/fs365/en/index.html

[9] This issue is to be addressed in a separate paper being prepared for the WLPGA.

[10] See, for example, Mehta and Shahpar (2004). Cost–utility analysis is a subcategory of CEA that measures health outcomes in generic terms to allow comparability between health interventions addressing different health outcomes (Hutton and Rehfuess, 2006).

[11] www.sustainableenergyforall.org/actions-commitments/commitments. One such commitment is the Global LPG Partnership – a private/public partnership formed by the company Energy Transportation Group in consultation with other companies in the industry, the WLPGA, representatives of national governments and the global health community to address the policy and investment requirements necessary to create a reliable and safe LP Gas supply chain in developing country markets and strive for universal access to clean cooking solutions.

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