FUEL SUBSTITUTION IMPACTS: AN ASSESSMENT MATRIX ANALYSIS

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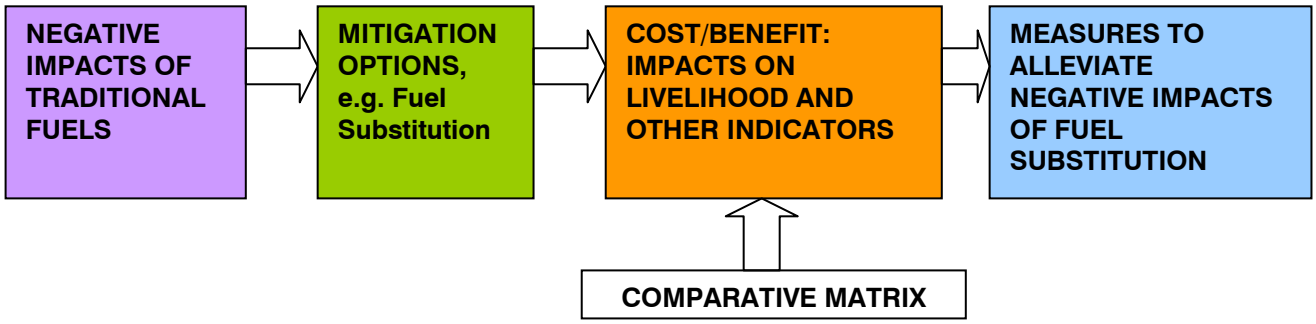
ABSTRACT

More than two billion people in developing countries rely on biomass fuels for household energy needs. These fuels include firewood, charcoal, crop residues and animal dung, the use of which is recognised to have negative impacts which range from environmental degradation to the health effects of combustion smokes and fuel handling. In the attempt to find a solution to these problems, governments, bilateral organisations and NGOs have promoted fuel substitution measures, such as the introduction of modern fuels (e.g. kerosene, LPG, electricity) often at subsidised prices; improved stove programmes; promotion of hoods and chimneys; and bans on charcoal production and transportation.

The impacts of these interventions extend, not only to the problems they are intended to solve, but to a number of other social and economic circumstances. Indicators of these impacts include local employment, dependency on foreign imports, gender and other social indicators, and health. For example, in some cases, an intervention may succeed in addressing environmental degradation, yet result in unforeseen problems in other areas of life.

A research project, funded by the UK's Department for International Development (DFID) and undertaken by a team of energy and development experts in Ethiopia, Kenya, Uganda and the UK, has analysed the effectiveness of various mitigation options aimed at reducing the impacts of traditional biomass fuels on health and the environment. Alongside the important considerations of health and environment, the research team has investigated the impacts of various interventions on a range of other cross-cutting issues, including livelihood and gender and sustainable economy. The analysis has been conducted using a purpose-made matrix that presents, in a graphical way, the positive, negative or neutral effects of each potential mitigation option on a set of key social and economic indicators.

The logic of the research methodology, undertaken by the project team is illustrated in the following flow chart:



Particular attention was paid to identifying the impacts of fuel substitution measures on the livelihoods of those engaged in the supply of traditional biomass fuels. Through a number of surveys, directed to both transporters and vendors of biomass fuels, the project team was able to determine that fuel substitution policies and the introduction of improved stoves have not been without livelihood implications for a large number of the most vulnerable categories of traditional fuel suppliers in all the three countries. The results of this part of the study are

reported in a separate document[1]. A number of recommendations for policy makers have been developed on the basis of the research.

INTRODUCTION

Reliance on traditional biomass fuels for household energy needs is a reality for over two billion people in developing countries. Although the proportion of global energy derived from biomass fuels fell from 50% in 1900 to around 13% in 2000, recent research (UNDP) gives evidence that use of biomass among the poorest in society has increased and that this trend is likely to continue in the near future. Poverty is recognised as one of the main barriers to the adoption of modern fuels. Other factors include availability and market penetration of alternative fuels, the cost of appliances that utilise modern fuels and cultural food preparation practices that require traditional fuel use.

Indoor use of biomass fuels on open fires or on low-efficiency stoves leads to several health problems. The majority of those exposed to indoor air pollution are women, who normally are responsible for cooking, and young children with them. While the majority of people at risk of exposure live in rural areas of developing countries, this is becoming a problem affecting poor urban dwellers as well, a trend that is likely to increase with progressive urbanisation. It is also worth noting that the impacts of domestic biomass fuel use extend beyond indoor air pollution and affect the household economy, women's time and activities, gender roles and relationships as well as safety and hygiene.

In addition, many bilateral organisations, NGOs and governments have shown concern over the impacts of biomass use for energy on the environment. These mainly relate to forest degradation and natural resource depletion, with effects that include loss of habitat for wildlife, soil erosion, diminished soil fertility and climate change impacts. Fuel substitution measures, including the introduction of subsidised modern fuels, and promotion of improved stoves and ventilation, have thus been promoted as a solution to the wide range of problems arising from the use of biomass fuels.

IMPACTS OF TRADITIONAL BIOMASS FUELS

As indicated above, the problems associated with the use of biomass fuels have mainly been in the areas of health, environment and social impacts, particularly gender. These are explained in greater detail below.

Health impacts: There is consistent evidence that exposure to biomass smoke increases the risk of a range of serious diseases in both children and adults. Incomplete combustion of biomass fuels generates smoke containing many substances, amongst which particulate matters, carbon monoxide, nitrous oxide, formaldehyde and organic matters are the most common. Health effects are determined by two main parameters:

- the *pollution level* which varies during the day depending on the use (burning or smouldering), type of stove and fuel, and the effectiveness of any ventilation system or chimney;
- the *exposure level* to a polluted environment, i.e. the time people spend in a polluted environment.

It is the increased exposure to PM_{10}[2] emissions resulting from partial or inefficient burning of biofuels using traditional methods in poorly ventilated kitchens, that is responsible for the increased frequency of ARI (Acute Respiratory Infections) and ALRI (Acute Lower Respiratory

[1] Name of document

[2] Particulates smaller than 10 μm in diameter

Infections which include bronchitis, pneumonia and bronco-pneumonia) among women and men of all ages in developing countries. Children below five years are the most susceptible to acute respiratory infections (in 2001 pneumonia was the single most important cause of death worldwide among children below five years), while people over 50 years generally show chronic conditions. Asthma and tuberculosis are also believed to be exacerbated by biomass fuel smoke. People in developing countries are commonly exposed to very high levels of pollution for 4-7 hours daily over their lifetime. In mountainous areas and during winter, where indoor heating is required, exposure may occur for even longer hours.

Other health hazards are also associated with cooking over open fires. For instance, ground level access to cooking pots and burning biofuels can cause severe burns, especially for babies and toddlers, as well as for the person cooking. Exposure to smoke can result in eye infections and low birth weight can be a consequence of exposure to carbon monoxide during pregnancy.

Fig. 1 A woman carrying branches for fuel along Entoto Hill in Addis Ababa, Ethiopia. Backloads of up to 50 kg are not uncommon and may cause bad injuries.

In addition, collecting biofuels can be a strenuous activity for women and girls who often end up carrying heavy loads for long distances. This is more common in the rural areas, especially in environmentally degraded areas, and among the people who supply biomass fuels to urban areas (Fig.1).

Environmental impacts: Biomass fuel for household energy use is often stated as a cause of environmental degradation. However, it is now recognised that the use of firewood is *not* one of the major causes of forest clearance, since most of it is collected rather than cut. More important causes of degradation and forest clearance include:

- weak policy formulation and enforcement;
- increasing needs for agricultural and pasture land, especially for cash crops;
- industrial use of timber for construction and other purposes;
- exploitation of mining resources;

- de-gazetting of state-owned forest land;
- unsustainable production of charcoal (for commercial and industrial purposes);
- population pressures

Nonetheless, it has been observed that collection of traditional fuels and charcoal production may have a considerable impact in certain locations. When sudden and uncontrolled concentrations of people occur, such as in refugee camps or slum areas around cities, the sudden rise in demand for fuel puts unsustainable pressure on the local environment. This also partly relates to the fact that, in recent years, social and economic changes associated with urbanisation have led to a significant shift from fuelwood use to charcoal (for instance the charcoal share in Africa grew from 15% in 1980 to 18% in 1994 at the expense of firewood and the trend is confirmed [*Amous*]). A typical example of the consequences of this trend is the localised depletion of forestry resources in the areas of Masindi and Nakasongolo in Uganda. These districts are the traditional source of the hardwood acacia used for producing the majority of the charcoal sold in Kampala. It is also important to remember that the transformation from firewood to charcoal is always connected with high energy losses, particularly if the carbonisation process takes place in traditional hearth kilns, characterised by very poor efficiency performances.

A further environmental impact is associated with the collection and use of animal dung as fuel. Estimates [*Jeffery et al.*] report that around 400 million tonnes of cattle dung are burned annually in Asia and Africa, which leads to the loss of important nutrients, and in turn causes the reduction of crop yields of up to 20 million tonnes of potential grain output annually.

Social impacts: Traditional fuel use has disproportionate effects on women, and contributes further to the social inequalities that are caused by an uneven distribution of fuel-collection, cooking, and childcare responsibilities between men and women within the household. In the context of household biomass energy use, women in developing countries are:

- more exposed to indoor air pollution, and other biomass-related cooking hazards than men;
- more involved than men in collecting fuelwood and dung in rural areas – for both personal use and for livelihood purposes. This has the dual effects of i) spending time that could otherwise be dedicated to other social or income-generating activities; and ii) being more likely to suffer from the muscular and skeletal problems associated with carrying heavy loads of wood.
- forced to find fuel saving strategies that are generally bad for health and nutrition when faced with fuelwood shortage (e.g. reduction of cooking time, change of type of food, reduction of water boiling or house heating etc).

ALTERNATIVE OPTIONS TO TRADITIONAL BIOMASS FUEL USE - INTERVENTIONS

Concerns over environmental impacts of traditional fuels and fears of fuel shortage were the causes that initially brought about the considerable emphasis on fuel efficiency in the 1970s. Programmes have focused on technological solutions for fuel savings, and there have been hundreds of improved stove programmes that have been implemented in over 50 countries, with varying degrees of success.

Although indoor air pollution was a secondary concern, improved stoves have proved to be effective in limiting the exposure to indoor smoke (average particulate emissions can be reduced by up to 65%). The main beneficiaries of these measures have been the users of

biofuels. However, no major improvement to the environment has been reported, the main reason being that households tend to take advantage of the fuel saving benefit of improved stoves by cooking more food for the same amount of fuel (ESD; 2000).

Subsidised promotion of modern fuels, such as kerosene, LPG, electricity, and associated appliances are examples of alternative options that have been implemented as part of energy and social policy programmes in many developing countries. Nonetheless, access to modern fuels and improved stoves is not always available to all classes of people. Rural areas often lack the infrastructures and delivery systems to allow wide access to modern sources of household energy, whereas, in urban areas, although most products are available for commercialisation on a large scale, it is often the lack of ready capital or conditions of extreme poverty (like in Kibera, the slum area of Nairobi) that prevents people from shifting to improved stoves or modern sources of energy. As a general practice, biofuels tend to coexist in combination with other fuels to serve different purposes. For example, where available, electricity is often used to boil water, whilst charcoal is used for slow cooking of food and kerosene or LPG for fast re-heating, etc.

Another aspect that should not be underestimated as a barrier to the take-up of modern fuels is the cultural aspect of cooking particular dishes. These may require a ceremony or a procedure involving specific fuels and appliances (e.g. preparing coffee in Ethiopia or cooking *matooke* in Uganda) and, in these cases, the use of modern energy sources is often inappropriate.

In Ethiopia and Kenya, and for a short while Uganda as well, regulatory measures have been implemented as a means to reduce the pressure of charcoal making on the environment. Ad hoc presidential bans, that are not enforced by other legislation or policy, formally forbid the production of charcoal, but not the use of it, thus making the whole charcoal business a complicated sector to understand in both countries. Transporting charcoal is illegal, and most of the charcoal lorries that enter Addis Ababa or Nairobi have to travel at night to avoid police. However, selling charcoal is a perfectly legitimate business, though perceived as a second class activity. Rather than preventing or even reducing the production of charcoal, the non-enforceable ban creates the conditions for uncontrolled and unsustainable charcoal burning practices, thus worsening the effects on the forestry resources that it was intended to conserve.

In considering some of the key measures that have been implemented in order to try and mitigate the health and environmental negative impacts of traditional biofuels, the project team has classified interventions under five categories (as shown in Table 1):

1. setup and appliances
2. user behaviour
3. fuel
4. supply management
5. regulatory

Table 1: Potential interventions for reducing negative health and environmental impacts of traditional biomass fuels in developing countries

SETUP AND APPLIANCES	USER BEHAVIOUR	FUEL	SUPPLY MANAGEMENT	REGULATORY
1. Improved ventilation 2. Chimneys and hoods 3. Outdoor cooking hut 4. Improved stoves 5. Improved stove with flue attached	1. Fuel drying & appliance maintenance	1. Briquettes and pellets[3] 2. Kerosene 3. LPG 4. Biogas[4] 5. Electricity	1. Sustainable forestry 2. Sustainable charcoal production[5]	1. Charcoal production and transportation ban

As mentioned earlier in this paper, the project team has undertaken an analysis of the various interventions in order to assess their impacts on a range of indicators that extend beyond those that are limited simply to environment and health, and that take into account other social and economic impacts.

IMPACTS OF MITIGATION OPTIONS ON SELECTED LIVELIHOOD AND DEVELOPMENT INDICATORS

The project team limited the research to Addis Ababa, Nairobi and Kampala because the substitution of traditional biomass fuels with modern energy sources is happening at a faster rate in urban areas than in rural areas (e.g. rural electrification is taking place at a very slow rate and delivery infrastructures for modern fuels and appliances does not reach far in rural areas in most developing countries). This has allowed the team to focus on the traditional fuel trade dynamics and the impacts of fuel substitution more effectively.

The research has identified the costs and benefits of fuel substitution and other possible mitigation options on a selection of livelihood and development indicators, focusing on four cross-cutting themes:

1. health
2. environment
3. sustainable economy
4. social equity

[3] Briquettes obtained from charcoal dust, agricultural residues, sawdust etc.
[4] Locally produced and utilised
[5] Charcoal production using sustainably grown wood resources and efficient kilns (to improve carbonisation efficiency)

To help identify impacts, a number of indicators were selected within each cross-cutting theme in order to focus attention on the various aspects that might be affected by fuel substitution and other interventions. The indicators selected are outlined in Table 2.

Table 2: Livelihood and development indicators

	INDICATORS	EXPLANATION
HEALTH	1. Respiratory impacts	1. Includes ARI, ALRI and other respiratory diseases
	2. Other health hazards	2. Includes accidental burns, fires, eye infections, accidental fuel ingestion etc.
	3. Transport related	3. Includes backache, bone fractures and other injuries deriving from transporting heavy loads
	4. Handling/vending related	4. Includes diseases due to charcoal dust exposure, dung handling infections, etc.
ENVIRONMENT	5. Forestry cover	5. Natural forest coverage in the country
	6. Soil quality	6. Includes soil characteristics such as fertility, nutrients leaching, erosion etc.
	7. Local air quality	7. Refers to presence of air pollutants in the local environment
	8. Water quality	8. Refers to presence of water pollutants, both organic and inorganic, including silt, BOD etc.
ECONOMY	9. Forex	9. Balance of foreign currency in country
	10. Official government revenues[6]	10. Refers to government revenues from sales of fuels
	11. Security of energy supply	11. Refers to availability of indigenous sources of energy, dependability from fossil fuel imports etc.
	12. Employment	12. Refers to number of people involved in providing the alternative intervention options
	13. Income generation	13. Refers to income generated at household level
SOCIAL	14. Gender equity	14. Refers to gender related issues of time availability, drudgery, role in the household, employment opportunities etc.
	15. Other livelihood benefits	15. Refers to availability of different options for lighting, cooking, livelihood enhancing solutions etc.

The results of the analysis have been graphically represented in a matrix (Figure 2) that indicates how the various alternatives to traditional biomass fuels impact on the indicators. As it is virtually impossible to measure in absolute terms the level of impact on each indicator, the team compared the performance of alternative mitigation options to a business as usual (BAU) situation.

[6] Assessment of the impacts on this indicator is strictly country specific. The level of official government revenues is dependent on each country's taxation policy, subsidies etc.

In the context of the research the BAU scenario is the use of biomass fuels (woodfuel, charcoal, dung, branches and leaves etc.) in a traditional manner, e.g. on a three stone fire. Impacts have been evaluated using a simple positive, negative and colour scale where:

+	denotes a positive impact of the mitigation option compared to the BAU;
-	denotes a negative impact of the mitigation option compared to the BAU;
0	denotes no changes in impact compared to traditional fuel use.

Where uncertainty exists over the cost/benefit of an intervention with regard to one of the indicators, a question mark ? has been used with an explanatory note to justify the choice.

Some intervention options may have different impacts on the same indicator according to the particular aspect and/or application considered. For example, the impact of LPG use on respiratory diseases is usually very positive, but if not well maintained, LPG stoves can release considerable amounts of carbon monoxide. In such cases, the double impact is represented in the same cell and an explanation given. - +

The project team completed a summary matrix for each country. While most of the impacts are comparable across the region, some have proved to be country related, such as the impacts of introducing certain modern fuels. In addition, the analysis of impacts resulting from regulatory measures' is not applicable to Uganda. Table 3 summarises some of the most important impacts of mitigation options on health, environment, economy and social indicators. A more detailed account of the impacts on the various indicators is available in a separate document[7].

With reference to electricity, it should be noted that impacts on health and social development have been relatively easy to assess. However, in order to assess impacts on the environment and the general economy, it was found that electricity was too general a term given that most of the impacts depend on the source/fuel used to generate power. In order to complete the impact assessment thoroughly, a whole sub-group of electricity generation options, including different renewable sources and fossil fuels should be considered. In the context of this research, the effort is not justified.

Fig. 3 Depot of charcoal and firewood in Kampala, Uganda. It is not uncommon to encounter several vendors placed very close to each other. Open and unregulated market causes competition, one of the main causes of vulnerability for biomass dealers in Uganda.

[7] Poverty Impacts of Fuel Substitution on Biomass Fuel Suppliers – Examining Mitigation Options in the Context of Cross-Cutting Issues

Fig. 2 Impact assessment matrix

	IMPACTS														
	HEALTH				ENVIRONMENT				SUSTAINABLE ECONOMY					SOCIAL	
INTERVENTIONS	Respiratory impacts[5]	Other health hazards[6]	Transport related	Handling related	Forestry cover	Soil quality	Local air quality	Water quality	Forex	Official gov't revenues	Security of energy supply	Employment	Income generation	Gender equity[7]	Other livelihood benefits
Setup/appliances															
Improved ventilation	+	+ 0	0	0	0	0	0	0	0	0	0	0	0	+	+
Chimneys and hoods[1]	+	+	0	0	0	0	0	0	0	0	0	+	?	+	+
Outdoor cooking hut	+ -	+ 0	0	0	0	0	0	0	0	0	0	0	0	+	+
Improved stove	+	+	0	0	+	0	+	0	0	0	+	+	+	+	+
Improved stove with flue attached	+	+	0	0	+	0	+	0	0	0	+	+	+	+	+
User behaviour															
Fuel drying & appliance maintenance	+	+ 0	0	0	?	0	+	0	0	0	0	+	0	0	0
Fuel															
Briquettes and pellets[2]	0	0	+	+	+	+ -	+	0	+	0	+	+	+	+	0
Kerosene	+	?	0	0	+	+	?	+	-	-	?	-	?	+	?
LPG	+	+ -	0	0	+	+	+	+	-	-	?	-	?	+	?
Biogas[3]	+	+ -	+	+	+	+ -	+	+	+	+	+	?	+	+	?
Electricity[4]	+	+ -	+	+	+	?	+	?	?	+	?	-	+	+	?
Supply management															
Sustainable woodlot	0	0	0	0	+	+	0	+	+	+	+	+	?	0	0
Sustainable charcoal	0	0	0	0	+	+	0	+	+	+	+	+	?	0	0
Regulatory															
Charcoal production ban	?	?	0	?	?	?	0	0	-	-	-	-	-	0	?
Combined interventions															
Improved stove & sustainable woodlot	+	+	0	0	+	+	+	+	+	+	+	+	+	+	+

1 Built in the structure of the house
2 From charcoal dust or agro-residues
3 Locally produced
4 Includes all electricity sources (fossil fuels and renewables)
5 Includes ARI and ALRI
6 Includes burns, eye infections, accidental fuel ingestion etc.
7 Relative to time spent cooking and drudgery

Table 3: Summary of the impacts of mitigation options on health, environment, economy and social indicators

MITIGATION OPTIONS	HEALTH	ENVIRONMENT	SUSTAINABLE ECONOMY	SOCIAL
SET UP AND APPLIANCES • Improved ventilation • Chimneys & hoods • Improved stoves • Outdoor cooking huts	Ventilation and chimneys can reduce the level of health-damaging pollutants, such as carbon monoxide, benzene, PM10s and nitrogen oxides[8]. Improved stoves have been designed to reduce pollution and burns. These interventions will not reduce the health and safety impacts resulting from transportation and handling of biomass fuels.	If used in conjunction with traditional biomass fuels, these measures will not have positive impacts on the environment. In the case of improved stoves, although they are more efficient, the effects on forests and air quality will not necessarily change. Households may continue to use similar amounts of fuel, but for a wider range of purposes, e.g. by cooking more food, or using excess fuel to boil water, etc.	At low national cost, improved stove production can boost the local economy, particularly in terms of employment. Ventilation and chimney initiatives may also provide job opportunities in terms of production and installation.	Households can benefit by using the same amount of fuel for additional purposes, thus improving quality of life at no extra costs. The health improvements have positive gender impacts, since women are usually responsible for cooking. There are also employment opportunities for women in the production of improved stoves, while employment in the biomass sector is not at risk.
FUEL SUBSTITUTION • LPG • Kerosene • Electricity	Although modern fuels result in reduced smoke and indoor air pollution, they are not without their own safety and health risks. These include accidental fuel ingestion, explosions, burns and high carbon monoxide levels, especially for LPG.	The use of LPG and kerosene can have positive impacts on forests and air quality, but there are risks to water and soil quality, associated with unsafe disposal. These risks, however, are mainly associated with bad practice. However, wider environmental impacts related to the use of fossil	Import costs are high for modern fuels. Uganda, Ethiopia and Kenya spend approximately $10m, $20m and $40m each year respectively on household kerosene alone. If subsidised, national costs are even greater. These fuels are supplied by multinational organisations, with formal distribution channels. Employment in	Wider access to modern fuels can improve quality of life for those who can afford them, and lighting from kerosene and electricity can improve opportunities for learning in the home. Gender impacts are likely to be positive for consumers, whilst for those employed in the traditional biomass fuel supply trade, the loss of livelihood may

[8] Sparknet (2002) *Public Health and Household Energy* (www.sparknet.info)

		fuels need to be taken into account (e.g. climate change, resource depletion etc). As for the environmental impacts of electricity, these are strictly dependent on how electricity was generated in the first place.	this sector is unlikely to favour the poor.	be significant, especially since most modern fuels are supplied and distributed by multinational organisations in the formal sector.
USER BEHAVIOUR • Fuel drying and appliance maintenance	The use of green or non properly dried firewood creates more smoke than the use of dry wood, and can also clog chimneys. This has clear implications on health. The same thing applies to the correct use and maintenance of appliances. Risk of burns, leakages and explosions are all minimised with improved maintenance.	As indicated above, unsafe disposal can have detrimental effects on water and soil quality.	Local employment in training and maintenance of appliances could have positive impacts on the local economy.	Health improvements from using dry fuel will have positive impacts on the main fuel users, women. Depending on the particular effects of ill-maintained appliances, women are also likely to benefit from improved practices. As an additional financial cost, maintenance is unlikely to be a priority for poorer households, and so this group may be excluded from the benefits of appliance maintenance services. However, if it might be possible for users to carry out simple maintenance themselves.
SUPPLY MANAGEMENT • Sustainable forestry	When used in a traditional way, biomass fuels will continue to result in ill-health. Unless used in conjunction with other measures, consumers and particularly women will continue	Sustainable production of biomass will slow down the rapid and uncontrolled depletion of national forest resources, whilst ensuring a sustainable supply of	Both national and local governments have the potential to benefit from a sustainable biomass sector. Revenues may be accumulated through tax	The employment in the biomass sector will be less subject to outside risks. Gender impacts may continue to be negative unless the sector is organised in a more formal

• Sustainable charcoal production	to suffer from the adverse effects of biomass combustion.	indigenous resources for the future.	and licensing measures and local employment created.	way. The removal of the legal barriers may reduce corruption and raise the social status of this business.
REGULATORY • Charcoal production ban • Charcoal transportation ban	The ban of charcoal, unless enforced, has no particular effects on health because experience shows that people keep using it. To a certain extent it can also be argued that illegal charcoal burning practices stemming from the ban are directly linked to declining charcoal quality and consequent worsened burning performances.	Charcoal ban, unless enforced, has clear negative impacts on the environment. Instead of preventing people from producing charcoal, the ban forces them to act illegally and to produce charcoal to meet demand using unsustainable and illegal practices, often in national forests. Lack of long term vision also pushes people not to replant the trees cut down.	The impacts of charcoal ban can be very severe on the general economy of the country if the measure is not enforced. Charcoal trade is practiced despite the ban, resulting in loss of official tax revenues from production and commercialisation, loss of national income from charcoal export, loss of confidence in government's measures.	Charcoal ban has a clear negative impact on the livelihood and social status of those engaged in the business despite the ban. Police harassment, bribery, loss of income, wrong perception from the general public are some of the most obvious impacts on social welfare.

CONCLUSION

Evidence indicates that the use of biomass fuels is increasing, both in rural and urban areas and this is not set to change in the near future. In economic terms, the costs of importing and subsidising modern fuels are extremely high. On the other hand, relatively few people in urban and peri-urban areas are likely to enjoy the health benefits of modern fuels, unless considerable market development efforts are put into LPG, kerosene and electricity distribution to rural areas. The poorest, and particularly women in society will continue to suffer from the ill health associated with indoor air pollution and burdensome fuel transportation.

On the other hand, wise biomass energy management, through sustainable production and end-use efficiency, has the potential to positively influence the lives of a much wider section of society, whilst also bringing positive environmental benefits. However, this will not alleviate all the social impacts of traditional biomass supply such as the disproportionate number of women engaged in the non-vehicle transportation of fuel, and the vulnerability of those engaged in this sector.

In this regard, this project's research has identified a number of improvements that can be made within the traditional biomass fuel sector. If implemented in conjunction with sustainable biomass production, the potential exists for this to continue to be an important source of livelihood for many urban dwellers.

RECOMMENDED MEASURES TO ALLEVIATE THE NEGATIVE IMPACTS OF FUEL SUBSTITUTION AND OTHER ALTERNATIVES

The impact related analysis has shown that it is virtually impossible to tackle one of the negative effects of traditional fuels use without incurring in problems in other areas. Acknowledging the importance of an integrated policy approach is fundamental. In this perspective, a number of recommendations were developed:

In general:

- When considering future fuel substitution measures, the social and economic impacts of interventions must be considered alongside the health and environmental impacts of biomass fuels use.
- When technical and economic barriers need to be overcome to promote improved stoves and modern fuels, collaboration between agencies responsible for health, energy, environment, housing and rural development is required. That is an integrated approach to the adoption of fuel substitution measures is essential in order to ensure that impacts are not simply transferred from one area to another.
- A combination of different measures is likely to yield the most positive social, economic and environmental results for society as a whole.
- A number of strategies need to be employed that will mitigate the existing and future negative effects of fuel substitution on the many vulnerable actors engaged in traditional biomass fuel supply.
- Mitigation measures need to respond to stakeholders demands and needs and not only be policy choices.

- Long term strategy that accounts for changes such as demand increase and progressive urbanisation is required.
- If regulatory measures are adopted, it is of fundamental importance that those are enforced in order to obtain results.

Specifically:

- Improved stove programmes should be accompanied by sustainable natural resource management, if they are to achieve environmental benefits.
- Awareness of the potential health negative impacts of traditional biomass fuels together with the provision of modern infrastructures and energy services for households are key measures to mitigate the health effects.

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