

Energy poverty and climate change mitigation in Ghana: An economic assessment

Jonathan Dagadu Quartey
Department of Economics, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
E-mail: jdquartey@yahoo.com

Abstract
Ghana's economy, though energy-poor, consistently grew over the past two decades, reaching 14.4% in 2011. This growth far exceeded the global average during 2011 of about 4%, from about 5.1% in 2010, making Ghana one of the fastest-growing economies in the world at that time. The Ghana Shared Growth and Development Agenda (2010–2013) projects further growth to a per capita income of USD 3000 by 2020, which is more than double the current per capita income. Since traditional biomass accounts for over 60% of total energy consumption in Ghana, attaining this target through a business-as-usual household energy approach assumes insensitivity of economic growth to energy poverty, a deceptively harmless development issue. Diversification of energy supply and demand should, however, be inevitable in the wake of climate change shocks and low-carbon development requirements. This paper assesses climate change-induced energy behaviour of households in Ghana, who contribute 32% of total energy sector emissions of greenhouse gases. It also assesses climate change-induced welfare change for households in a low carbon-development scenario as against business as usual. The net welfare effect for the scenario to switch from fuelwood to mitigate climate change was negative. The results indicate that Ghana is in an energy poverty trap, providing mixed effects for climate change mitigation. To effectively mitigate climate change under energy poverty, Ghana should promote the cultivation of energy forest plantations, introduce and use improved charcoal stoves and improved charcoal production kilns. These could lead to greater efficiency in the energy sector and create jobs for rural communities involved in the plantations for sustained growth, while at the same time delivering benefits from mitigation funding.
Keywords: Climate change mitigation, economic welfare, energy poverty, fuelwood, Ghana

1. Introduction

Wood-based biomass is the dominant source of energy for sub-Saharan Africa, and fuelwood consumption per capita in Africa is higher than any other continent. In Ghana, the bulk of energy consumption is based on fuelwood, and 90% is obtained directly from natural forests. The demand for fuelwood is thus a major driver of forest degradation and the release of greenhouse gas (GHG) emissions (UNEP Risoe 2013). Reducing the demand for fuelwood as a low carbon development (LCD) measure is, therefore, an important strategy to reduce drivers of deforestation and forest degradation to mitigate climate change, while generating financial flows from forest carbon activities under the Clean Development Mechanism, REDD+ (Reducing Emissions from Deforestation and Forest Degradation), and Nationally Appropriate Mitigation Activities (NAMAs). Ghana's energy sector shows signs of high susceptibility to climate change (World Bank 2009), an indication that achieving its targeted middle-income status of US$3000 per capita income by 2020 (NDPC 2010) would require a reorganization of generation, processing and use of energy resources due to climate change shocks. In line with projections for attaining and sustaining middle income status by 2020, total energy requirements have been growing from about seven million tonnes of oil equivalent in 2004 and are expected to reach 22 million tonnes of oil equivalent by 2020 (Ghana Energy Commission 2006). Current trends in energy use show that this energy requirement is to a large extent met through traditional biomass sources, accounting for about 63% of total energy consumption (NDPC 2010). Ghana has one of the strongest economies of sub-Saharan Africa, due to its wealth in natural resources, coupled with political stability.

However, the exploitation of resources through subsistence agriculture and cutting fuelwood has resulted in significant deforestation and degradation of the country's forests (UNEP Risoe, 2013). Gillis (1988) also found that one of the two principal sources of deforestation in Ghana was fuelwood harvesting, driven by rural and urban poverty. Energy poverty can be defined as 'the absence of sufficient choice that allows access to adequate energy services, affordable, reliable, effective and sustainable in environmental terms to support the economic and human development' (Reddy 2000). It concerns people that have low income, low energy consumption and no access, or limited access, to modern energy fuel (petroleum products and electricity). Approximately 1.6 billion people do not have access to modern energy fuels globally (Chevalter & Ouedraogo 2009). The high dependence on fuelwood therefore shows the prevalence of energy poverty in Ghana, since such a trend appears highly unsustainable for continued economic growth, particularly in the wake of recent and projected climate change shocks and persistently high levels of deforestation. Also, the threat to climate change mitigation is expected to be high under such circumstances. Ghana's greenhouse gas (GHG) emissions represent about 0.05%

of the total global emissions and rank 108 in the world. This represented a total per capita emission of nearly 1tCO2e as at 2006. At the continental level, Ghana ranks equally with Senegal and Mali as the 21st most GHG-emitting country in Africa (Ghana EPA 2010). Though GHG emission levels appear relatively low compared to other major developing economies, Ghana's Environmental Protection Agency (2010) cautions that the emission trends clearly indicate a strong peaking potential in the near-to-medium-term horizon, as the economy continues to grow. Also, the EU Emissions Trading Scheme, one of the world's largest carbon markets, considers Ghana to be one of Africa's largest potential emitting countries (Hanrahan & Morton 2012). Thus, the development of new frontiers dominated by agriculture, forestry and the oil and gas industry are expected to pose further challenges for climate change mitigation efforts in Ghana. This paper therefore assesses the limiting consequences of energy poverty on climate change mitigation and development in Ghana. It begins by briefly reviewing the link between energy poverty and development. It then discusses energy poverty as a cause and effect of climate change and hence the need for low-carbon development in Ghana. The paper finally assesses the economic welfare implications of a switch from fuelwood use by households in Ghana and concludes by summarizing the implications of its findings.

2. Energy poverty and development

Even though modern energy has been accepted as necessary for economic growth and development, several reasons can be given to explain why it took so long to identify energy poverty as a major developmental challenge. For a long time the real impact of energy poverty was not assessed because of several misleading indicators. This was further reinforced by the largely non-market nature of most of the biomass used for energy purposes, being essentially environmental commodities and as such taken for granted. One main misleading indicator was that energy poverty-endemic countries did not seem to show serious signs of de-development through energy poverty. Some of these countries, like Ghana, had for the past two decades recorded commendable gross domestic product (GDP) growth rates and had actually been commended as doing well by the standards of development partners. Ghana's impressive GDP record over the past two decades were achieved while traditional biomass accounted for over 60% of total energy consumption and over 80% of energy for cooking. Table 1 shows the relationships among key macroeconomic variables and fuelwood consumed in Ghana since 2002.

Table 1: Some macroeconomic variables and fuel wood consumed in Ghana for 2002 – 2012.

Years	Per Capital GDP in US$	Population	Nominal GDP in million US$	Real GDP Growth rate	Fuel wood Consumed (million tonnes)
2002	310.86	19.9	6184.81	4.5	15.05
2003	372.54	20.41	7604.6	5.3	15.6
2004	423.84	20.94	8876.67	5.8	15.85
2005	497.39	21.49	10687.9	5.9	17.3
2006	923.1	22.03	20331.5	6.4	17.31
2007	1091.07	22.58	24631.9	6.5	17.94
2008	1218.85	23.14	28204.7	8.4	18.9
2009	1095.67	23.1	25962.7	4.7	19.9
2010	1235.97	24.24	29960.8	6.6	19.91
2011	1384.34	24.8	34329.2	14.4	22.93
2012	1478.1	24.34	37460.6	7.1	31.9

Sources: GSS (2012), NDPC (2010), Energy Commission (2007)

The growth rate of 14.4% in 2011 made Ghana one of the fastest-growing economies in the world in that year (ISSER 2012). Figure 1 indicates an overall positive correlation between fuelwood use in Ghana and GDP growth rates. This trend is also confirmed by data from the Food and Agriculture Organisation in the United Nation's *State of the world's forests* report of 2009.

The Ghana Shared Growth and Development Agenda (GSGDA), projects a per capital income of US$ 3000 by

2020, without targeting the over-dependence on fuelwood in the economy. This confirms the treatment of the fuelwood variable for the period 2012-2020 as operating on a business-as-usual basis as the case has been since time immemorial. It is also worth noting that Ghana's energy outlook for 2012 did not discuss fuelwood. The fact is that if in the midst of overdependence on biomass the economy was making substantial progress then there would be no incentive for change, particularly if change was going to mean more government expenditure from already scarce monetary and material resources. Thus, energy poor countries like Ghana for a long time did not realise the direct economic welfare effects of their energy poverty due to growth in GDP, which most of these countries and their assessors considered the most important indicator of progress. This probably contributed to these countries not making a big issue of energy poverty as they had of income poverty.

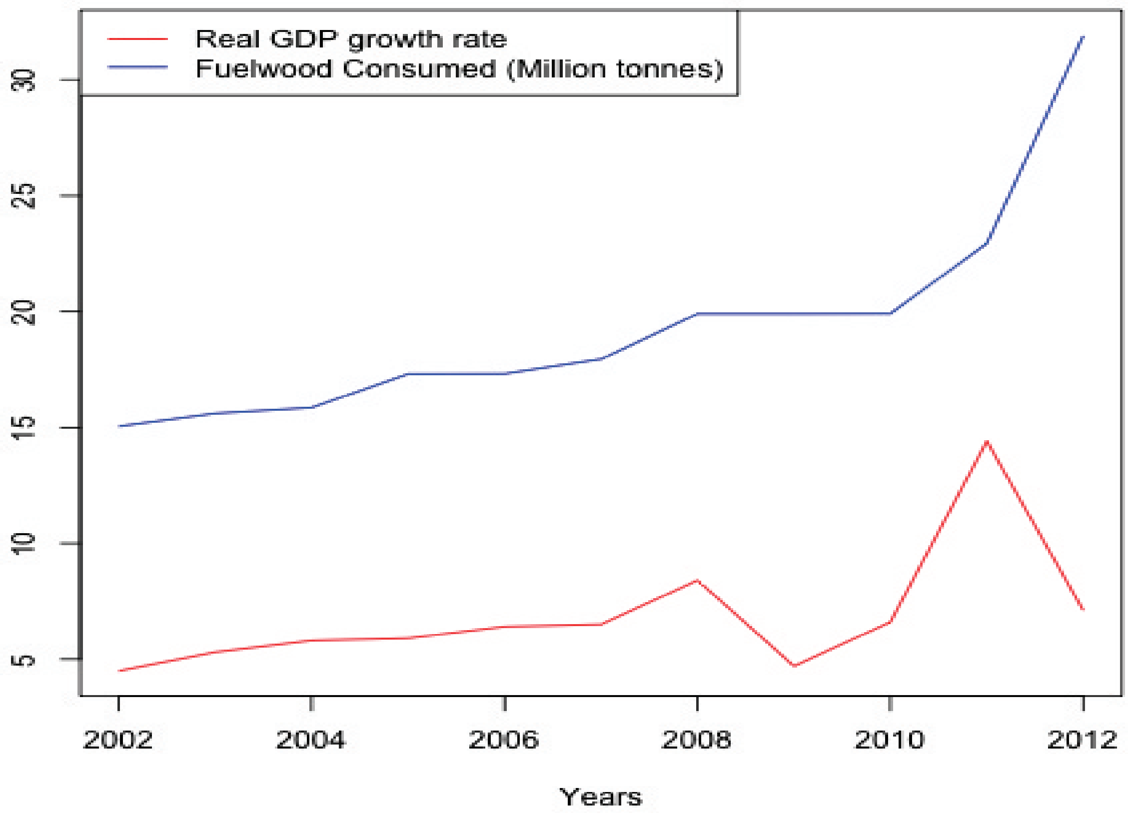

Figure 1: Relationship between real GDP growth rate and fuelwood consumed in Ghana for 2002–2012. *Source: Based on Table 1*

Another misleading indicator has been the overly open-ended definition of energy 'access' which is the sole baseline for determining energy poverty. The United Nations Development Programme/World Health Organisation (UNDP/WHO) define energy access as 'access to various forms of modern energy' comprising access to electricity, modern fuels, mechanical power and improved cooking stoves (Legros *et al.* 2009). Although the UNDP/WHO further recognise the need to include measures related to quality, quantity, appliances and equipment, services provided, socioeconomic profiles of users and affordability, these elaborate measures were left to the discretion of each country. If in a country electricity was extended from the national grid to a community which afterwards realised that it could have electricity only two days in a week on aggregate through energy rationing, this surely falls below energy access. However, no developing country left to determine energy access will consider this scenario as lack of access. Thus through various arrangements like the above, global reports about energy access have been seen to be encouraging. What the case now shows is that the overly open definition is producing negative feedback. While efforts to provide access to modern energy should be commended, the baseline must be clearly established such that a commendable effort is not mistaken for 'access', to the eventual detriment of the welfare of the energy poor. The omission of energy poverty as one of the world's leading developmental issues until 2012 was one of the greatest oversights in the history of development.

3. Energy poverty and carbon dioxide emissions

One way to assess the implications of fuelwood use for the global environment is to estimate the associated

GHG emissions. Though combusting wood emits carbon dioxide (CO_2) into the atmosphere, regrowth of wood captures CO_2 from the atmosphere, showing that fuelwood use is CO_2 emissions-neutral. Arnold *et al.* (2003) explain that this assertion holds in two ways. First, with fuelwood from forest and non-forested lands the same amount of CO_2 emitted by wood combustion is recaptured from the atmosphere by regrowth of wood. Second, leftovers from non-sustainable logging and land conversion, if not used as fuel would simply decompose by natural processes, and lead to the same amount of carbon emitted into the atmosphere if the woody material were to be combusted. If fuelwood were not utilised, some alternative energy source like fossil fuels and in a few cases hydropower would be required and used with accompanying CO_2 emissions. This, however, does not imply that energy poverty is CO_2 emissions-neutral. As a result of decreased access to fuelwood, the incomes of fuelwood users, their livelihoods and forest conservation can be adversely affected (Arnold *et al.* 2003), making low-carbon development activities relevant towards energy poverty reduction and vice versa. The adverse impact on poor subsistence users arising from reduced access to fuelwood is mainly a rural issue and predominantly relates to fuelwood, as charcoal is not a subsistence fuel (Arnold *et al.* 2003). In urban areas, diminished access to supplies can negatively affect many poor households. However, this relates largely to purchased rather than gathered supplies. In most rural areas on the other hand, gathered supplies of fuelwood still constitute the main source of domestic energy for rural households (Barnes & Floor 1996) and hence these users are more vulnerable to changes that affect their ability to access fuelwood. Where access to fuelwood supplies is reduced for some reason, this implies a welfare loss for those affected. How serious this is depends on each household's ability to adapt to the new situation (Arnold *et al.* 2003). Most of the fuelwood trade among the energy poor is on a small scale, accessible to the urban poor and is a major source of income. Townson (1995) found that in the forest zone of southern Ghana, approximately 258 000 people were involved in the fuelwood trade from 38% of the households in the region. However, many instances are recorded where fuelwood-gathering and -trading activities are associated with land clearance and the formation of farms, and therefore this declines as the farmers involved move beyond that phase in the farm cycle (Townson 1995; Wunder 1996).

3.1 Forest depletion

The application of location theory in explaining spatial patterns of agriculture and other land uses indicates that woodfuel demand in large and growing urban areas is likely to lead to large-scale tree removal in periurban zones, spreading progressively further out into a given city's hinterland as the population increases (Arnold *et al.* 2003). The analysis in an Energy Sector Management Assistance Programme study (Barnes *et al.* 2001) of data from 46 cities shows a pattern of forest depletion that is initially heavy near urban areas but this slows down as cities get larger and wealthier (Arnold *et al*. 2003). The periurban areas in which fuelwood production is likely to be concentrated in the early stages of urban growth are likely to be areas that are also under pressure from clearance of agriculture. Therefore the patterns of deforestation could be explained just as much by this as the growing urban demand for fuelwood which may not be depleting wood stocks beyond what would have been cleared anyway (Arnold *et al*. 2003). However, growing population pressure on dwindling forest resources near energy poor communities definitely raises the risk of forest degradation on a daily basis. The annual rate of change in the forested areas of Ghana over the period 1990–2010 has been negative, with a deforestation rate of –1.99%. The deforestation rate increased between 2005 and 2010, reaching 2.19% (FAO 2011). Forest and grassland conversion through deforestation activities has been the major cause for the declining CO_2 removal capacity (sinks) and increased emissions in the forestry sector of Ghana (UNEP Risoe 2013).

4. Climate change and energy behaviour in Ghana

A major piece of evidence of Ghana's energy sector's susceptibility to climate change has been the effect of highly variable precipitation patterns on hydropower production. In recent times over 65% of electricity generation in the country has come from hydropower and 33% from petroleum-fired thermal generation (Ghana Energy Commission 2006), with a contribution of less than 1% from small-scale solar systems. The drought of the early eighties (1980 to 1983), and also recent times, not only affected export earnings through crop losses but also caused large-scale human suffering and called into question the nation's continued dependence on large hydroelectric power systems. As a result, the development of petroleum fired thermal plants is now viewed as an energy security necessity in Ghana. The current rate of electrification presents the challenge of providing energy in a suitable form to a large population, primarily rural but increasingly urban, while at the same time minimizing greenhouse gas emissions (low-carbon development) to contribute to global climate change mitigation efforts. System losses in electricity distribution are about 25%, with wastage in the end-use of electricity also estimated at about 30% (Ghana Energy Commission 2006). Losses in energy supply and inefficient use of energy contribute to the high levels of energy consumption.

Higher ambient temperature levels due to climate change are a contributing factor to the increased transmission losses. Under a changed climate, lower precipitation, enhanced evaporation, and more frequent droughts will diminish water availability in the Lake Volta reservoir. In addition, the Akosombo Dam, which typically provides about 70% of the country's electricity needs, produces only 30% during periods of low water levels in the dam, which poses serious implications for industrialisation and private sector development. These periods of drought result in high CO_2 emission levels as Ghana resorts to thermal systems for electricity. The residential sector was the second-largest contributor to total energy emissions between 1990 and 2006, contributing 32% of the total energy sector emissions (Ghana Energy Commission 2006). This is due to the increasing population and subsequent increase in consumption of biomass to meet domestic energy needs. Thus mitigation strategies for the energy sector will have to be closely linked with measures taken in the forestry sector. Broadhead *et al.* (2009) suggest that achieving climate change mitigation through forestry requires that forests are managed in ways that fundamentally reduce carbon emissions. The simplest way to mitigate climate change in this case would be to reduce all the uses of the forest that make it lose its reservoir and sink capacities unsustainably. Mitigation practices include maintaining or increasing forest land area, reduced deforestation, increased forestation and reforestation, reduced degradation, wildfire management, and increased use of wood products from sustainably managed forests. For society to benefit fully, forests must be managed for both mitigation and adaptation purposes. To effectively mitigate climate change in the context of energy poverty, Ghana would need to promote the cultivation of forest plantations, introduce and use improved charcoal stoves and improved charcoal production kilns. These could lead to greater efficiency in the energy sector and massively create jobs for rural communities involved in the plantations for sustained growth while at the same time delivering benefits from mitigation funding.

5. Energy poverty and climate change in Ghana

Household energy consumption in Ghana is primarily for lighting and cooking. About 67% (24 890 GWh/yr) of total energy consumption in the household is used for cooking (Ministry of Energy 2008). The UNDP (2011) estimates that 90% of households in Ghana rely on traditional biomass (fuelwood and charcoal). It further estimates that every person in Ghana currently uses around 1 cubic metre or 640 kilograms of fuelwood per annum. The statistics indicate a strong attachment to fuelwood by households in Ghana, which must have contributed strongly to the activities responsible for the rate of economic growth recorded so far. The repercussions of such a fuelwood consumption pattern on forest resources are immense. High deforestation and forest degradation have resulted in a loss of biomass in Ghana and depleted the capacity for carbon sequestration as a means of combating climate change through the natural forests. Sustainable economic growth, however, requires a growth policy that also mitigates climate change. Users of natural resource goods like fuelwood often find it difficult to adjust to potential reductions in their availability, because of the lack of affordable substitutes. Thus even though in Ghana fuelwood use should have been sensitive to availability, there is currently little tendency to switch to other sources of energy for cooking, even in the wake of climate change shocks. Land is directly affected by temperature increases and drought, floods leading to erosion, loss of fertility, and crop and resource damage. Vegetation, particularly forests, is thus affected, accounting for shortages in the availability of fuelwood or at least increasing the difficulty of accessing it. Biomass is a climate-sensitive renewable source of energy. This makes it more vulnerable to climate variability than other renewable sources of energy like solar and wind.

The inelasticity of fuelwood use in relation to the cost of acquisition will mean a loss of welfare as the cost of acquiring fuelwood continues to increase for the average Ghanaian household through climate change shocks. This means breaking out of energy poverty could become more difficult than ever for Ghana unless very determined measures are employed to mitigate climate change through the forestry sector.

6. Importance of low-carbon development to Ghana

The evidence of climate change vulnerability indicated above has rendered Ghana's development more complicated than ever before. It is expected that GHG emissions can be reduced at a much lower cost than the cost of energy poverty caused by business-as usual actions. This requires a change in the way development policies are made, to include low-carbon development (LCD) strategies towards climate change mitigation. Specifically, a LCD plan which must be the starting point for LCD implementation is important to Ghana because it will: provide an effective tool to examine realistic climate change mitigation options; help policy makers identify low-carbon growth scenarios and opportunities; and facilitate informed decision- making in LCD. Afforestation and reforestation (A/R) of degraded forest lands and mangrove restoration present significant potential for climate change mitigation in Ghana, while generating financial flows from forest carbon activities under the CDM, REDD+, and possibly NAMA projects. However, A/R CDM activities have remained underdeveloped compared to other CDM sectors, mainly as a result of the complexity of the A/R CDM procedure and the limited market demand for A/R CDM credits. Nonetheless, Africa holds a significant share in the global CDM forestry sector by hosting 30% of all A/R CDM activities, which represents 8% of CDM activities in Africa (UNEP Risoe 2013), altogether reflecting the continent's potential for abatement in the land use, land-use change and forestry (LULUCF sector. Despite efforts to enhance forest biomass, activities in agriculture and forest sectors are showing increasing trends in emissions. Avoiding just deforestation in Ghana has the potential to contribute approximately 38 million tons in CO2 emission reductions every year. Reversing the trend, and adding reforestation to these estimates would increase this number even more (UNEP Risoe 2013). The cumulative total cost of climate change adaptation from 2012 to 2050 is estimated to be $2.7 billion with real GDP projected to decline from negative 5.4% per annum (Global dry) to negative 2.1% per annum (Ghana wet) by 2050 (Ghana EPA 2010). Thus, mitigation strategies in the forestry sector will to a large extent lead to a reduction in the cost of adaptation and ultimately address energy poverty. It is always true that forest conservation actions to mitigate climate change will reduce the cost of adaptation. For instance, in the case of soil erosion prevention due to floods, even if others decide not to cooperate, we would still be better off having implemented forest mitigation measures than not. Thus forest resource based mitigation will always be beneficial, no matter what the outcomes of climate change-related actions of various actors. For the household sector, the primary option for LCD is energy efficiency, making the sector a potential source of LCD in Ghana. The following areas can be potential LCD points for action in households in Ghana:

- switching to energy-saving light bulbs;
- replacing inefficient appliances with more energy efficient appliances;
- designing houses in such a way as to lower the need for cooling; and
- a cooking fuel switch from biomass to a low-carbon alternative.

It is worth noting that, among the action points identified, only cooking fuel-switching is directly related to energy poverty, making it the preferred example in the forestry sector based economic welfare analysis in the following sections. Fuelwood constitutes about 80% of the energy demand for cooking in Ghana. In rural areas the demand for fuelwood can be as high as 90% in some cases. These allow for reductions in the fuelwood needed for energy consumption, thereby having both positive economic welfare and GHG reduction effects (UNEP Risoe 2013). The Ghana Energy Commission (2006) estimated the average life cycle cost per annum for using fuelwood in Ghana to be USD 53.00. Ghana Statistical Service (GSS) (2008) data shows that 80% of households in Ghana use fuelwood, which translates to about 4.4 million households. This brings the household expenditure on fuelwood to USD 233.20 million per annum (ie. USD 53 × 4.4 million households). Since the expenditure expresses the revealed monetary value of the demand for fuelwood, if all the fuelwood is collected very close to consumers' homes, then the USD 233.2 million is the monetary value which fuelwood users place on the commodity per annum. However, average life cycle cost estimations depend mainly on market prices, which, to a large extent do not capture the real values of largely non-marketed environmental goods like fuelwood in Ghana (A travel cost model approach has been used to derive an alternative value for fuelwood in Ghana, and is provided as an appendix to this paper.). This value is also a measure of the benefit they will lose per annum if they cannot have access to fuelwood. Thus any policy which seeks to move fuelwood users from fuelwood use must be in the position to compensate them with this amount of money to ensure their welfare does not decrease.

7. Household switching from fuelwood

In considering a switch from fuelwood to more modern and efficient energy forms for the Ghanaian economy, two key sectors will be crucial – the informal and commercial/service sectors and households. The discussion is therefore based on these two sectors because they constitute over 95% of the users of fuelwood for energy in Ghana. All the official data in this section were obtained from Ghana Energy Commission (2006) publications, the only body mandated by the Government of Ghana to produce such data for official purposes. For the household sector, cost considerations and availability seem to be the most prominent issues in a shift from firewood to charcoal and then to other cooking fuels such as LPG, kerosene and electricity. Costs involved in the various cooking modes as computed by the Ghana Energy Commission are indicated in Table 2.

Table 2: Costs of using various cooking devices in Ghana

Device	**Initial Investment cost US Dollars**	**Total cost per year US Dollars**
Three stone – mud firewood stove	0	44 – 62
Traditional charcoal stove	1.5 – 3	67 – 80
Improved '*Ahibenso*' charcoal stove	10	37 – 43
LPG (1-2 burner) cooker	30 – 50	83 – 98
Electric (one-two burner) cooker	20 – 50	81 – 93
Kerosene (1-2 burner) cooker	17 – 25	138 – 161

Source: Ghana Energy Commission (2006)

Even though there is no initial capital investment in making a three-stone or mud firewood stove, particularly in rural areas, it is more expensive to use when compared with improved charcoal stove in the case where firewood is purchased. Otherwise, the three-stone or mud firewood stove is the least expensive cooking device and has the lowest life-cycle cost as well. For health reasons, however, it will be wise to encourage a switch from firewood stove to charcoal stove usage, but that involves an initial capital investment of about USD 10.00. On the environmental front, charcoal usage consumes more wood than firewood does, and is not an attractive option for CDM and other large climate change-related financial facilities. Charcoal usage leads to higher GHG (methane) emissions because it takes between four and six units of wood to make a unit of charcoal, whilst firewood is used directly from the field. A switch from fuelwood usage to kerosene for cooking is the most expensive option in terms of annual expenses. Secondly, kerosene is a fossil fuel and so the shift is not environmentally attractive. A switch from fuelwood to electricity for cooking presents the cleanest option in terms of indoor pollution. However, it is not climate change-neutral if the electricity is a product of thermal-based generation. Carbon dioxide emission from fuelwood is neutral in terms of global warming whilst emissions from fossils are non-biogenic. There is also the issue of availability, since national electricity access is still less than 55% in real terms (UNEP Risoe 2013). The most advocated option is the switch from fuelwood to liquefied petroleum gas (LPG), since the latter is quite 'environmentally' friendly. LPG is a cleaner fuel in terms of indoor pollution, with far less emissions of particulate matter, acidic and other pollutants. Other renewable sources of energy are not viable yet due to cost and technical reasons, and hence are not discussed. The LPG required to substitute for fuelwood in a LCD scenario will be 750 000–1.9 million tonnes by 2012–2015; and 950 000–2.8 million tonnes by 2020 (Ghana Energy Commission 2006). This additional LPG demand is likely to put a lot of pressure on the crude oil refining capacity of the country, unless the LPG shortfall is imported. This can create an opportunity to increase the refinery capacity of the country and boost gas cylinder manufacturing in the country. Introducing LPG to rural users will, however, require an efficient distribution network and back-up support to control potential gas accidents associated with it and occasional shortages due to distances from retailing centers. Mobile LPG retailers exist but have higher premium than stationary retailers. For rural areas (where the effect may be greatest), it will be a significant extra payment to make, unless rural supplies are targeted and subsidised. The switch from fuelwood use to LPG for residential cooking and heating has probably been the boldest step taken so far to mitigate climate change in the energy sector of Ghana. Such a policy had the capacity to reduce deforestation and forest degradation. It also led to the creative and increased use of LPG as fuel in the road sector. Many commercial drivers rapidly converted their gasoline-based commercial passenger vehicles to LPG, realising it was more cost effective. However, the adoption of LPG for commercial vehicle use has of late created some shortages for household users and has tended to defeat the purpose of promoting LPG use. Net benefit comparisons are made for the switch from fuelwood to LPG as a demonstration of the net welfare effect of an energy poverty-based LCD initiative in Ghana, in the next section.

8. Welfare analysis: Net benefit comparisons for LCD

Even though the switch from fuelwood has been analysed for various energy sources in the previous section, the switch from fuelwood to LPG is considered the most feasible alternative (Ghana Energy Commission 2006) due to cost and technical issues. It is, however, worth assessing whether the net benefit of LPG use as a LCD measure surpasses that of fuelwood (business-as-usual) in Ghana. Ghana's LPG programme was initiated in 1990 to promote the use of LPG as a substitute for charcoal and firewood in order to slow down the rate of deforestation caused partly by the production and use of wood fuels (Damptey & Mensah 2008). The programme has, however, been derailed to a large extent as a result of cost, organisational and structural deficiencies. Nonetheless, the net benefit implications are relevant to inform policy on the possible way out, which can ensure continued growth in the face of climate change challenges. The use of fuelwood does not come with any installation cost, since the tripods used are moulded out of common clay found in abundant quantities in Ghana. The total cost of use per year, as computed by the Ghana Energy Commission (2006), in cases where fuelwood is bought as shown in Table 2, is a maximum of USD 62 per annum. LPG (with a one-two burner cooker) however has a maximum initial installation cost of USD 50 and then a cost of use of USD 98, making a total of USD 148. Thus the cost difference in switching from fuelwood to LPG is about 239% of the cost of using fuelwood. This will be higher in cases where fuelwood is collected near consumers' homes and not bought. Since the expenditure on fuelwood in the business-as-usual case derived earlier is USD 233.2 million per annum, the expenditure on LPG will be 239% of USD 233.2, which is equal to USD 557.35 million per annum. This means for LCD action to provide the same benefit as fuelwood in a business-as-usual case a subsidy of USD 324.15 will be required annually to ensure households use LPG instead of fuelwood in Ghana. This subsidy will excessively add to the already heavy government subsidy burden in the energy sector, which the government is trying to offload to consumers to improve efficient use of available energy resources. The current subsidy for LPG of USD 110 million from the government of Ghana (IMANI Ghana 2011) is for all users of LPG. Based on use patterns, it has been estimated that USD 80 million of this subsidy goes to urban and peri-urban users, whose use of it is of less LCD value than for those who will need to switch from fuelwood (IMANI Ghana 2011). Thus, only about USD 30 million of the subsidy goes to supplement LPG for a supply that meets only about 45% of the domestic need. To meet the full domestic need, the remaining LPG must be imported, considering the current operational challenges of refinery activities in Ghana. This comes with a huge cost to growth, with the potential of creating a worse situation of export dependency. Currently the greatest problem with LPG use even by the affluent in Ghana is the lack of availability. The uncertainty that has come to be associated with LPG shortages in Ghana has not been a good sign for the switch from fuelwood to LPG. Clearly the net benefit of switching to LPG from fuelwood is negative given the current income and energy situation in Ghana. This implies a switch imposed on the status quo will lead to a decrease in welfare. Ghana appears trapped in a fuelwood energy trap and therefore energy poverty in the short-to-medium term. The only alternative left is to continue to use biomass; this compounds the issue of GHG emissions through persistent deforestation and degradation of forest resources, posing a serious threat to climate change mitigation.

9. Conclusion

Forest and grassland conversion through deforestation activities has been the major cause for the declining CO_2 removal capacity (sinks) and increased emissions in the forestry sector of Ghana. The drought of the early eighties (1980 to 1983), and also in recent times, not only affected export earnings through crop losses but also caused large-scale human suffering and called into question Ghana's continued dependence on large hydroelectric power systems. As a result, the development of petroleum-fired thermal plants is now viewed as an energy security necessity in Ghana. This trend, which will increase due to climate change, remains one of the threats to LCD in Ghana's energy sector. Mitigation strategies for the energy sector will have to be closely linked with the forestry sector. This makes policy coordination essential between the forestry and energy sectors of Ghana's economy, to prevent deforestation while simultaneously supporting better energy security. There is currently no competitive alternative to fuelwood as the most important household fuel in Ghana. A subsidy worth three times the current subsidy will be needed to ensure fuelwood users switch to LPG and remain as well off as they were before the switch, so as to mitigate climate change. Such a measure will also serve the purpose of getting the country out of energy poverty. However, Ghana's practical situation shows it is not prepared enough to eradicate energy poverty. This means the high dependence on fuelwood by households is bound to continue. Growth policy projects an increase in fuelwood use as incomes and population increase. This trend makes the Ghanaian energy sector very vulnerable to climate change shocks, a major contributor to forest degradation, an increasing contributor to GHG emissions, and eventually a source of decreasing welfare. Promoting cultivation of energy forest plantations, introduction and use of improved charcoal stoves and improved charcoal production kilns could lead to greater efficiency in the energy sector and create massive jobs for rural communities involved in the plantations for sustained growth while at the same time delivering benefits from climate change mitigation funding.

Acknowledgements:

An earlier version of this paper was presented in the Development and Mitigation Forum, Cape Town 2014. The author would like to thank the organizers of the forum for funding his participation and especially Emily Tyler, Meagan Jooste and their team for editorial work on the first draft.

References

Armah, B. (2003), Economic analysis of the energy sector. Energy Commission of Ghana publication. Accra, Ghana.

Arnold M., Kohlin G., Persson R. & Shepherd G. (2003), Fuelwood Revisited: What Has Changed in the Last Decade? Center for International Forestry Research (CIFOR), Indonesia.

Barnes, D.F. & Floor. W.M. (1996), "Rural energy in developing countries: a challenge for economic development". *Annual Review of Energy and Environment* 21: 497-530.

Barnes, D.F., Krutilla, K. & Hyde, W. (2002), The urban energy transition: energy, poverty and the environment in the developing world. The World Bank.

Bateman, I.J. (1993) "Valuation of the Environment, Method and Techniques: Revealed Preference Methods" in Braden, J.B. & Kolstad, C.D. (eds.) *Measuring the Demand for Environmental Quality,* Elservier Science Publishers B.V. The Netherlands.

Broadhead, J.S., Durst, P.B. & Brown, C.L. (2009), "Climate change: Will it change how we manage forests?" In Bodegom, V, Jan, A, Savenije, H and Wit, M. (eds). *Forests and climate change: Adaptation and mitigation*. ETFRN News no. 50. ETFRN & TBI, Wageningen, The Netherlands: 57-65.

Brown, W., Sorhus, C., Chou Yang, B. & Richards, J. (1983), "Using individual Observations to Estimate Recreation Demand Functions: A Caution" *American Journal of Agricultural Economics* 65: 154-157.

Cesario, F. (1976), "Value of time in recreation benefit studies" *Land Economics* 52:32-41.

Cesario, F. & Knetsch, J.L. (1976), "A recreation site demand and benefit estimation model". *Regional Studies* 10: 97–104.

Chevalter, J.M. & Ouedraogo, N.S. (2009), "Energy poverty and economic development". In Chevalter, JM (ed), *The new energy crisis: Climate, economics and geopolitics.* Palgrave Macmillan.

Chevas, J.P., Stoll, J. & Sellar, C. (1989) "On the Commodity Value of Travel Time in Recreational Activities" *Applied Economics* 21:711-722

Clawson, M. (1959), "Methods of measuring demand for the value of outdoor recreation". Reprint 10. *Resources for the Future*. Washington D.C.

Clawson, M. & Knetsch, J..L. (1966), "Economics of Outdoor Recreation", in Dixon *et al* (eds.) *Economic Analysis of Environmental Impacts*, London: Earthscan Publications Limited.

Common, M. (1988), "Individual Observations, Per Capita Observations and Zone Averages in the Specification and Estimation of Trip Generation Functions", In Hanley, N. & Spash, C.L. (eds.) *Cost-Benefit Analysis and the Environment*, Aldershot: Elgar Publishing Limited.

Damptey, P. & Mensah, A.T. (2008), "Climate change impacts on women's livelihoods". In *Ghana climate change impacts, vulnerability and adaptation assessments.* Environmental Protection Agency. Accra, Ghana: 234-262.

Food and Agricultural Organization (FAO), (2011), *State of the World's Forests*. Rome.

Garrod, G. & Willis, K.G. (1999), *Economic valuation of the environment: Methods and case studies*. Edward Elgar, Cheltenham, UK.

Ghana Energy Commission (2006), *Strategic national energy plan* (2006–2020). Annex IV of IV. Woodfuels and Renewables. Accra, Ghana.

Ghana Environmental Protection Agency (2000), Ghana's initial national communication under the United National Framework Convention on Climate Change. Accra, Ghana.

Ghana Environmental Protection Agency (2010), *National greenhouse gas inventory report for 1990–2006 Volume 1: Synthesis report.* Accra, Ghana.

Ghana Statistical Service (2000), *Population and housing census 2000.* Accra, Ghana.

Gillis, M. (1988), "West Africa: resource management policies and the tropical forest". In Repetto, R. & Gillis, M. (eds.) *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge.

Girardet, H. & Mendonca, M. (2009), *A renewable world: Energy, ecology, equality.* A report for the World Future Council. Green Books, UK.

Hanley, N. (1989) "Valuing Rural Recreation Benefits: An empirical comparison of two approaches" *Journal of Agricultural Economics* 40 (3): 361-374.

Hanley, N. and Spash, C.L. (1993) *Cost-Benefit Analysis and the Environment*. Aldershot: Elgar Publishing Limited.

IMANI, Ghana. (2011), Energy ministry's policy on LPG does not add up. *The Chronicle*. Accra, Ghana.

Institute for Statistical, Social and Economic Research (ISSER) (2012), *The State of the Ghanaian Economy in 2011*. ISSER, University of Ghana, Accra.

Johansson, P.O. (1987), *The economic theory and measurement of environmental benefits.* Cambridge University Press, Cambridge.

Legros, G., Havet, I., Bruce, N. & Bonjour, S. (2009), The Energy Access Situation in Developing Countries: A Review focusing on the Least Developed Countries and sub-saharan Africa. : UNDP/WHO, New- York.

Manrahan, E. & Morton, T. (2012), Low Carbon Development in Africa. Climatecare. Accessed at www.climatecare.org, December, 2012.

McConnell, K. & Strand, I. (1981), "Measuring the Cost of Time in Recreation Demand Analysis: An Application to Sportfishing*." American Journal of Agricultural Economics* 63: 153-156.

Ministry of Energy (2008) Information pack. In *Ghana climate change impacts, vulnerability and adaptation assessments.* Environmental Protection Agency. Accra, Ghana: 246-247.

National Development Planning Commission (2010), *Ghana shared growth and development agenda 2010-2013*. Government of Ghana. Accra, Ghana.

Reddy, A.K.N. (2000), Energy and social issues. In Goldemberg, J. (ed), *World energy assessment: Energy and the challenge of sustainability*. New York: UNDP, 39–60.

Smith, V.K. & Desvousges, W. (1986) "Measuring Water Quality Benefits", In Hanley, N. & Spash, C..L *Cost-Benefit Analysis and the Environment*, Aldershot: Elgar Publishing Limited.

Smith, V.K. & Kaoru, Y. (1990), "Signals or noise? Explaining the variation in recreational benefit estimates". *American Journal of Agricultural Economics* 72: 419-433.

Townson, I.M. (1995), Patterns of non-timber forest products enterprise activities in the forest zone of southern Ghana: Main report. Report to the ODA Forestry Research Programme, Oxford.

UNDP Ghana (2011), Success Story: Cleaner Energy Dents Poverty: Human Development in Action. Accessed atwww.undp-gha.org/news&event.php?id=196, 16 November 2011.

UNEP Risoe. (2013), *Emissions reduction profile: Ghana.* UNEP Risoe Centre, Denmark.

Willis, K. & Benson, J. (1989) "Recreation Value of Forests "*Forestry* 62(2): 93-110

Wood, S.E. & Trice, A. H. (1958) "Measurement of Recreational Benefits", *Land Economics*, 34:195-207

World Bank (2009), Ghana. Economics of adaptation to climate change. Consultation Draft. Accra, Ghana.

Wunder, S. (1996), "Deforestation and the uses of wood in the Ecuadorian Andes". *Mountain Research and Development* 16(4): 367–382.

Appendix: The travel cost model

A travel cost model was used to determine the economic value of fuelwood as an alternative to the average life cycle cost value (though other methods like the contingent valuation method and the hedonic price model could also have been used). This could subsequently be used to derive the net welfare change for households switching from fuelwood as a potential LCD policy. The use of the travel cost model yields a welfare value for fuelwood based on fuelwood collected for use – the most practical way of capturing the value of current fuelwood demand in Ghana. For LCD policy purposes, a similar study needs to be done for charcoal, which potentially has an equally devastating effect on LCD actions, particularly in urban Ghana. For a fuller appreciation of the drivers of household energy consumption, further research is suggested using the contingent valuation method, which captures total economic value unlike the travel cost approach which reveals only use value (which was the most relevant value concept for this paper). The following sections provide the travel cost model application.

A.1 The model

The travel cost model portrays a simple concept of the cost of fuelwood collection. This concept is embedded in the fact that every collector and or user of fuelwood pays a price measured by his/her travel costs (Johansson 1987).Thus a change in travel cost to collect fuelwood results in a change in economic welfare due to changing costs that the household has to bear. This principle was first used by Clawson (1959) after being proposed by Hoteling to the director of the US Park Service in 1947 (Johansson 1987). The model is widely used by government agencies in the United States and increasingly in the United Kingdom, for example, by the Forestry Commission (Willis & Benson 1989).

The travel cost model is technically and essentially an example of a conventional household production function model (Garrod & Willis 1999). These models investigate changes in the consumption of commodities that are substitutes or complements for each other. The application of this principle for evaluating preferences for fuelwood in Ghana over and above more efficient alternatives allows the use of the travel cost model. The early literature on valuation of non-market resources abounds with the use of travel cost models for recreational values, but that was a very limited use of the travel cost principle. With improved understanding of the model, recent literature has several uses of the model for valuing clean water, fuelwood, health care demand, etc. In principle, the model can be applied to any good whose consumption involves travel-related costs.

A.2 Methodological framework

The travel cost model seeks to place a value on non-marketed environmental goods by using consumption behaviour in related markets. It is a survey technique. A questionnaire is prepared and administered to a sample of visitors at a site in order to ascertain their place of residence, necessary demographic and attitudinal information; frequency of visits to sites; and trip information such as purposefulness, length and associated costs. From these data, visit costs can be calculated and related, with other relevant factors, to visit frequency so that a demand relationship may be established. In the simplest case, this demand function can then be used to estimate the value of the commodity that attracted the consumer to the site or the value of the whole site. Also, in more advanced studies, attempts can be made to develop demand equations for the differing attributes of sites and values evaluated for these individual attributes. The demand function estimated by the model is an uncompensated ordinary demand curve incorporating income effect, and the welfare measure obtained from it will be that of Marshallian consumer's surplus (Bateman 1993). However by Willig's approximation, specifically, the costs of consuming the services of the environmental asset which attracted a consumer to the site are used as a proxy for price of consuming the commodity. These consumption costs will include travel costs, entry fees, on-site expenditures and outlay on capital equipment necessary for consumption. The Model cannot estimate non-user values. An implicit assumption made in most travel cost studies is that the representative visitor's utility function is 'separable' in the activity being modelled. This means that, if the activity of interest is fishing, then the utility function is such that demand for fishing trips can be estimated independent of demand for say hunting trips (alternative leisure activities). Travel costs (C) depend for a given site 'j' on several variables.

Cij = c(DCij, TCij, Fi)

Where i=1,…,n, j=1,…,m. DCi are distance costs in cedis for each individual 'i', dependent on how far he/she has to travel to visit the site and the cost per mile of travelling. TC are time costs in cedis: these depend on how long it takes to get to the site and the value of an individual's time. F is the fee if any, which is charged for entrance to site j. Travel costs (C) are included in a trip generating function (TGF) which predicts how may visits (V) will be undertaken by any individual i to site j. Also included in the TGF for an individual would be socio-economic characteristics such as incomes, education and age level, as well as variables giving information on the type of trip. The alternative to the individual travel cost model as described above is the zonal travel cost model. This was the version employed by Wood and Trice (1958) and Clawson and Knetsch (1966). The zonal approach entails dividing the area surrounding the site to be valued into 'zones of origin'. These may be concentric rings around the site, but are more likely to be selected with regard to local government administrative districts (such as counties and states). Measuring the area under the obtained demand curve gives an estimate of consumers' surplus per visit. Travel cost models are often estimated for particular sites, such as Hanley's (1989) study of Achray Forest in Central Scotland. However, the approach can also be applied to groups of sites, for example, Willis and Benson's work on UK forests (1989). The literature reveals a few basic problems. These include the choice of Dependent Variable. Two basic options exist for choosing the dependent variable. These are (i) visits from a given zone; and (ii) visits made by a given individual. Option (ii) is usually implemented by collecting data on visits per annum for each respondent (VPA). Option (i) is frequently expressed as visits per capita V/pop. There is no consensus in the literature as to which option is preferable on theoretical grounds. Brown *et al.* (1983), for instance, advocate V/Pop, while Common (1988) advocates VPA. Hanley and Spash (1993) used the model in a study of a wildlife site in eastern England particularly valued by bird watchers. They converted distances into travel costs using a marginal cost per kilometre. Time cost both on-site and travelling were set at zero. Their regression equation which was a log- linear function showed that the travel cost variable was significant at 95% level and correctly signed (that is negative). Smith and Kaoru (1990) examined 77 US travel cost studies for which consumer's surplus per visit figures were obtainable. To give an econometric explanation of the figures obtained they related them to the treatment given to substitute sites, opportunity cost of time, type of activity, type of site and functional form. They were able to explain 43% of the variation in consumer's surplus figures and could also predict the effect of the employment of a particular functional from or treatment of travel time on consumer's surplus.

A.3 Distance costs

After data has been collected on the distance travelled by respondents to the site in question, this variable is converted into a 'cost of distance travelled' variable. This involves setting a price per mile, which requires choosing between two options:

- use of petrol costs only as an estimate of marginal cost, or
- use of 'full cost of motoring', figures to include an allowance for depreciation and insurance.

Consumer's surplus figures will depend on the choice. It is assumed that Individuals, in maximising utility, compare the marginal utility with marginal costs of consumption; this makes option (1) more attractive, since option (2) is a measure of average costs. In an Achray forest study by Hanley (1989) when full cost data was used he obtained a total consumer's surplus of GBP 402 023 per annum, while the use of petrol costs only gave GBP 160 744 (Hanley & Spash 1993).

A.4 The value of time

In the household production function approach to recreation demand modelling, consumers combine several inputs to 'produce' recreation service flows. Principal among these inputs are visits, equipment and time. Time is expended both in travelling to a site and while recreating on the site. As a scarce commodity, time clearly has an implicit (or shadow) price. Chevas *et al.* (1989) provide recent estimates of the value of time. They distinguish between the opportunity cost measure of travel time and the 'commodity value' measure of travel and on-site time. Time has a positive commodity value if its consumption directly generates positive utility. On-site time clearly has a positive value, while travelling time may have a positive or negative value. Chevas *et al.* used a household production function approach to estimate this commodity value for recreational boating in East Texas, looking at travelling time alone. They found the commodity value of travel time to be small but positive, varying across sites and reaching a maximum of USD 0.41 an hour. After reviewing empirical evidence, Cesario (1976) valued the opportunity cost for time to be one-third of the hourly wage rate. Using a simulation process, and choosing the value which maximised the R^2, McConnel and Strand (1981) also estimated a value for time.

Comparing results from the Cesario, McConnel/Strand and full-cost (hourly wage) alternatives for 23 recreation sites in the USA, Smith and Desvouges (1986) found that the full cost and Cesario alternatives were rejected (at the 10% level) in 7 cases. However, the McConnel/Strand method fared worse in terms of the variance of its estimates (Hanley & Spash 1993).

A.5 Statistical problems

The dependent variable is both censored and truncated. 'Truncated' means that as only visitors to the site are recorded, there is no information on the determinants of the decision to visit the site. Also, visits are only recorded during the sampling period and may thus incorrectly describe the preferences of those visiting at other times of the year. 'Censored' means that less than one visit cannot possibly be observed. This implies that the dependent variable (visits) is censored at one, and that OLS estimates of demand parameters will be biased (Smith and Desvouges, 1986). The solution to truncated problems is to use a maximum likelihood (ML) estimator instead of OLS. Data shows that OLS gives larger consumer's surplus estimates than ML. The choice of the appropriate functional form can also be problematic (Hanley and Spash, 1993).

A.6 The value of fuelwood in Ghana

The travel cost model therefore provides a measure of willingness to pay for fuelwood based on travel cost data. The two basic means by which travel costs are computed are the individual travel cost and zonal travel cost. The individual travel cost computes travel cost for individuals, while the zonal travel cost computes travel cost for groups of people based on their average distance from the point where the facility to be benefited from is located. The paper's welfare measure is equivalent to the consumers' surplus obtained through the consumption of fuelwood as a household energy source (Johansson, 1987). Even though not heavily forested, the northern savanna zone of Ghana has been well known for its nationwide supply of biomass for energy. The Tamale metropolis is the largest settlement in Northern Ghana and acknowledged to be one of the fastest growing cities in West Africa, with a population of about 293 881 (Ghana Statistical Service (GSS 2000). The metropolis lies between the latitudes 9^0 18^1N and 9^0 26^1N and longitudes 1^0 15^1E and 1^0 23^1W. The choice of Tamale was deemed appropriate since the use of fuelwood there was well established and probably the largest in Ghana. Two main modes of acquiring fuelwood exist in Ghana – through collection and purchases. In most urban centers commercial and large household users purchase fuelwood from sellers at very moderate prices depending on the season and also tree species. However, most household users collect fuelwood freely from nearby wooded vegetation. Face-to-face interviews were used to elicit responses from respondents who were household heads in 2010. The number of trips to fetch fuelwood from various sites was the sum of trips of all members of the household who went to fetch fuelwood. Communities were selected by simple random sampling, while households were selected through a second stage systematic sampling. The total number of communities which used fuelwood was 179, out of which 100 communities were selected. Given a total population of households using fuelwood in the Tamale municipality as 20 407 (GSS 2000) a sample size of 392 was computed. The respondents provided the distances they covered and the times used to collect fuelwood as well as some socio-economic data. A zero price was assigned for fuelwood collected. Sellers of fuelwood would normally price the product based on where they went to collect the wood and the cost of transportation to the point of sale. The wood itself is normally freely obtained in most cases. The travel cost (TC) in this case represents the cost of collection, which is its implicit price. Travel distance costs were based on fares of locally used means of transport (called 'tro-tro'), commonly used by low income earners in Ghana, while time cost (opportunity cost of time) was one-third of the minimum wage as used by Cesario (1976). Thus the functional form of the travel cost model used was $TC = f\ (TN + TM)$ where TC is total cost of travel to collection site, TN is cost of transportation to site and TM is time cost to site.

A.7 Results of travel cost estimation

Using the zonal travel cost estimation, households were grouped according to their distances from the places of fuelwood collection: Zone 1 being the nearest with mean distance of less than 2 km, Zone 2 with mean distance of 3 km, Zone 3 with a mean distance of 6 km, Zone 4 with mean distance of 9 km and Zone 5 being the furthest with mean distance of 12 km (a detailed account of the use of the TC model can be found in Garrod & Willis (1999). Table A1 shows the computation of the TC per trip of fuelwood for each household member in Tamale. Based on the fact that it is mainly women and children who pick fuelwood, and given an average family size of 5.5 for the region, about 3 members of the average household normally go out to fetch fuelwood. This makes the TC per year 108 051.32 x 3 = GHS 324 153.96. About 80% of households predominantly rely on fuelwood for their energy needs in Ghana (GSS 2008). This brings the total number of households in Ghana using fuelwood to 4.4 million. Thus if for the households sampled the TC to fetch fuelwood per year is GHS 324 153.96 for 20 407 households, this translates to GHS 15.88 per household. Therefore, the total travel cost for the 4.4 million households would be GHS 69.87 million, which is an equivalent of USD 43.67 million per annum. Since the travel cost model estimation shows the value placed on the commodity, the USD 43.67 million represents the value placed on fuelwood by its users in Ghana per annum. This is also described as the benefit derived from consuming fuelwood by households in Ghana per annum. Thus the consumers' surplus (welfare value) of fuelwood use in Ghana is USD 43.67 million per annum. While the difference between the welfare value of fuelwood use (derived through the travel cost model) and the monetary value of fuelwood use (based on average life cycle cost) is big, the general policy direction recommended would be the same when each of them is used. The difference becomes relevant where specific household welfare measures are in contention. Since developing country problems require specific attention to household welfare issues, coupled with high prevalence of non-monetization in the distribution of environmental goods and services, it is recommended that measures which provide accurate welfare information be used rather than those that thrive on highly monetized systems.

Table A1: Computation of annual Travel Cost (TC) for fuel wood collection in the Tamale Municipality in Ghana cedis (GHS). [US$1.00 = GHS1.60]

Zone (a)	**% of Households (b)**	**Population of households (c)**	**TC per visit in GHS (d)**	**No. of Visits per year (e)**	**TC per year for population in GHS (f = d x e)**
Zone 1	19.9	4,061	0.56	25,324	14,181.44
Zone 2	53.3	10,877	0.58	65,884	38,212.72
Zone 3	20.7	4224	3.98	10,764	42,840.72
Zone 4	2.0	408	6.77	572	3,872.44
Zone 5	4.1	837	10.75	832	8,944.00
Total	100	20,407		103,376	108,051.32

Source: Author's field work, 2010.