# What can we learn from household surveys on inequalities in cooking fuels in sub-Saharan Africa?[1]

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**ABSTRACT**

We use a new database from the Africa Infrastructure Country Diagnostic study to assess the use of cooking fuels in sub-Saharan Africa. A majority of households relies on biomass as its cooking fuel. We find that the highest rates of biomass use are found in rural areas, low income countries, and hydrocarbon importers. There are exceptions in some countries due to specific subsidies favoring a certain cooking fuel. When the rates of biomass use start to shrink, it seems that some countries specialize in kerosene while others in LPG. An analysis of expenditures shows that wood-fuel behaves as an inferior good except for the poorest households. Despite wood-fuel being the most expensive cooking fuel in some countries, it is still widely used. This suggests there is an under-supply of modern fuels. Finally, we estimate that around 50% of the annual rate of deforestation in Africa can be attributed to the use of wood-fuel as a cooking fuel.

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## 1. Literature Review and Institutional Framework

Around 2.5 billion people in the world rely on biomass such as fuel-wood, charcoal, agricultural waste, and animal dung, to meet their energy needs for cooking. Estimates made by the International Energy Agency (IEA 2006) show that, in the absence of new policies, this figure will increase to 2.6 billion in 2015 and 2.7 in 2030 due to population growth. The United Nations Millennium project has recommended halving the number of households using traditional biomass for cooking by 2015. This would involve 1.3 billion people switching to other fuels.

Biomass use can have serious adverse consequences on health, the environment, and on economic development. Concerning health, 1.3 million people die prematurely every year because of exposure to indoor air pollution from biomass - more than the annual deaths from malaria. In developing countries, only malnutrition, unprotected sex, and lack of clean water and sanitation are greater health threats (WHO 2006). As for the environment, biomass use exacerbates land degradation and regional air pollution. Use of biomass through deforestation may lead to global warming effects through loss of carbon sink, as well as higher greenhouse gas emissions than other fuels. Finally, biomass use can also have negative effects on economic development, as valuable time and effort is devoted to fuel collection instead of education or income generation activities.

As can be seen in the table below, sub-Saharan Africa (SSA) is the region of the world in which a higher percentage of population relies on biomass resources as its primary fuel for cooking. SSA is also at the top of the ranking in absolute terms, having almost one quarter of people relying on biomass to cook in the world. Some parts of Asia show a picture which is nearly as bad as the one for SSA. In rural areas, 93% of African and Asian households – leaving aside China and India - rely on biomass to cook. This figure is even higher for Indonesia. However, in urban areas SSA stands out as being clearly the worst performer, with 58% of its population relying on biomass.

**Table 1-1: People Relying on Biomass as their Primary Fuel for Cooking, 2004**

| Region | % total population (million in brackets) | % rural population (million in brackets) | % urban population (million in brackets) |
|---|---|---|---|
| **Sub-Saharan Africa** | **76** (575) | **93** (413) | **58** (162) |
| North Africa | 3 (4) | 6 (4) | 0.2 (0.2) |
| India | 69 (740) | 87 (663) | 25 (77) |
| China | 37 (480) | 55 (428) | 10 (52) |
| Indonesia | 72 (156) | 95 (110) | 45 (46) |
| Rest of Asia | 65 (489) | 93 (455) | 35 (92) |
| Brazil | 13 (23) | 53(16) | 5 (8) |
| Rest of Latin America | 23 (60) | 62 (59) | 9 (25) |
| **Total** | **52** (2,528) | **83** (2,147) | **23** (461) |

Source: World Energy Outlook, 2006

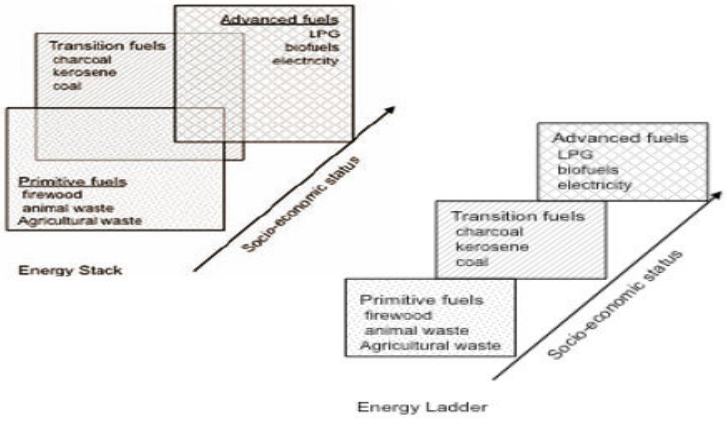
Most studies on cooking fuels usage in SSA focus either on specific cities (e.g. Ouedragou 2006 on Ouagadougou or Falcao 2000 on Maputo) or specific countries (e.g. Hosier et al 1993 on Tanzania). Other studies have considered a number of cities or countries of different continents of the developing world (e.g. Barnes 2005 or Heltberg

2003). However, little has been done on household's cooking fuels in sub-Saharan Africa from a regional perspective. Despite the local nature of many aspects of cooking fuels usage, this paper attempts to be a starting point to fill in this gap. This benchmarking exercise can help to understand which countries are performing better than others, as well as to give hints on which successful experiences could be implemented in other countries of the region.

The prevailing approach in the past to improve the use of cooking fuels in SSA was to make efforts to introduce improved stoves in order to use traditional biomass fuels more efficiently. The Programme for Basic Energy and Conservation (ProBEC) in Southern Africa - promoted by the German Cooperation - is a good example of a scaling-up initiative in the use of efficient cooking stoves. However, recently efforts have focused on switching from traditional cooking fuels to modern ones, i.e. fuels that can be used with more efficient technologies and have a limited impact in the environment – both in terms of deforestation and pollution, maintaining the health benefits associated with abandoning old practices.

The classical literature on household cooking fuels refers to the energy ladder, which divides the types of fuels in three kinds. At the bottom are the less efficient and less clean fuels. As households climb the ladder the quality of its cooking fuels improves. According to this concept, households would change to higher quality cooking fuels as their income increases, following a *transition to modern fuels*. Some studies have argued that it is more accurate to refer to an energy stack (e.g. Masera et al 2000), since the cohabitation of different types of cooking fuels in a specific household is common. Others have argued that the energy ladder is an oversimplification of reality and proposed a multiple fuel model (Barnes et al 2005). The types of fuels included in each step of the energy stack can be seen in the figure below.

**Figure 1-1: The Energy Stack**




Source: Schlag et al 2008

The *AICD Household Surveys Database* divides the types of cooking fuels in the following four categories:

1) Liquefied Petroleum Gas (LPG)
2) Kerosene
3) Wood and Charcoal[3]
4) Other

In this study, wood-fuel is at the bottom of the energy ladder, followed by kerosene, and LPG being at the top. This seems to be the best possible simplification considering the data used. However, it should be noted that according to the figure above, charcoal should rather be included in the medium fuel quality category. The "other" category potentially includes everything else going from animal and agricultural waste – at the bottom of the energy stack – to electricity and biofuels – at the top of the energy stack. The types of fuels included in this category can be a combination of different fuels. This combination will be highly variable depending on the country.

Electricity will not be explicitly analyzed in this study on purpose. As will be seen below, 3-4% of SSA households use electricity to cook. However, the electricity use is significantly different from zero in only four countries of the south of the continent, namely South Africa, Zimbabwe, Namibia, and Zambia.

The institutional framework of the sector has an influence in the way it evolves. The Energy Ministry is the government entity responsible for overseeing biomass products in most of the countries analyzed in this study. A few rely not only on the Ministry, but also on another agency. The Energy Ministry is not involved in overseeing biomass products in four countries only.

**Table 1-2: Responsible agency for overseeing biomass products**

| | |
|---|---|
| Energy Ministry | 10 |
| Special Agency/Other | 4 |
| Both | 4 |

Source: AICD Household Surveys Database (2008)

Twelve countries have a national policy on biomass, while seven do not report having one. An overwhelming majority of countries do not regulate the main biomass products (15), while only two report regulating them. In many countries there is no specific wood-fuel supply policy, while in others this is more regulated. For example, in Zambia wood-fuel producers need a license from the forestry Department and are requested to pay a levy to local authorities, and in Niger the Ministry of Agriculture gives special permissions to certain people for the exploitation of specific areas.

The data used for chapter two comes from Demographic and Health Surveys (DHS) included in the *AICD Household Surveys Database*. It includes data on the following 25 Sub-Saharan Africa (SSA) countries, representing 78% of SSA population (2005): Benin, Burkina Faso, Cameroon, Congo, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe.

[3] We will refer to this category as "wood-fuel".

The expenditure surveys included in the *AICD Household Surveys Database* are used additionally for chapter three, which includes the following 20 countries, representing 67% of the SSA population (2005): Benin, Burkina Faso, Cameroon, Cape Verde, Côte d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Madagascar, Malawi, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Senegal, South Africa, Uganda, and Zambia.

17 countries are part of both DHS and expenditure surveys, and they represent 63% of SSA population (2005). Seven countries have only information on DHS (Congo, Guinea, Lesotho, Mali, Namibia, Sudan, Tanzania, and Zimbabwe), and three countries have information only on expenditure surveys (Cabo Verde, Côte d'Ivoire, and Niger). No data is available for the Democratic Republic of Congo, a country that represents a significant share of the SSA population - almost 8%.

For most of the countries, we have used one time observation for the period 2001-2005. When the latter was not available, a previous observation from the period 1996-2000 was considered. When focusing on evolution of use on time, and for those countries with only one time observation, the evolution reflects merely the population's urban and rural growths.

The analysis is confined to primary cooking fuels. Thus, if we are told that "X% of the population uses fuel type Y for cooking", this should be understood as X% of the population uses Y as its main cooking fuel.

This paper is structured as follows. Section 2 focuses on access levels to cooking fuels, as well as the evolution and patterns of access. Section 3 analyzes the households' expenditures in cooking fuels, both in financial and energetic terms. Finally, section 4 concludes and suggests some analytical improvements for future research.

## 2. Access to cooking fuels

### a. Overview

The term *access* is understood here as *use*, as for non-grid type fuels one could argue that almost everybody has *access* to them. Using the four categories defined above, at the aggregate level of the 25 SSA countries considered, 83% of the population uses wood-fuel as its cooking fuel. This figure goes up to 93% for rural areas, and down to 58% for urban areas. Within the wood-fuel category, wood is predominantly used in rural areas, while in urban areas charcoal has a higher presence due to a better supply chain. LPG and kerosene are almost inexistent in rural areas – 1 and 3% respectively - while in urban areas, LPG is used by 8% of the population, and kerosene by almost 22%. All these figures indicate that the transition to modern fuels is at a much advanced stage in urban than in rural areas, although the urban areas' population is still far from having completed this transition. They also indicate that kerosene have a higher penetration rate than LPG. Medium-income countries (MIC) have LPG use of 8% and low-income countries (LIC) of 3%. For kerosene these figures amount to 15 and 7% respectively. If we divide the countries of our study in net hydrocarbon importers and exporters, it appears that in exporter countries 4% of the population use LPG and 15% use kerosene, whereas in importer countries 3% use LPG and 2% use kerosene.

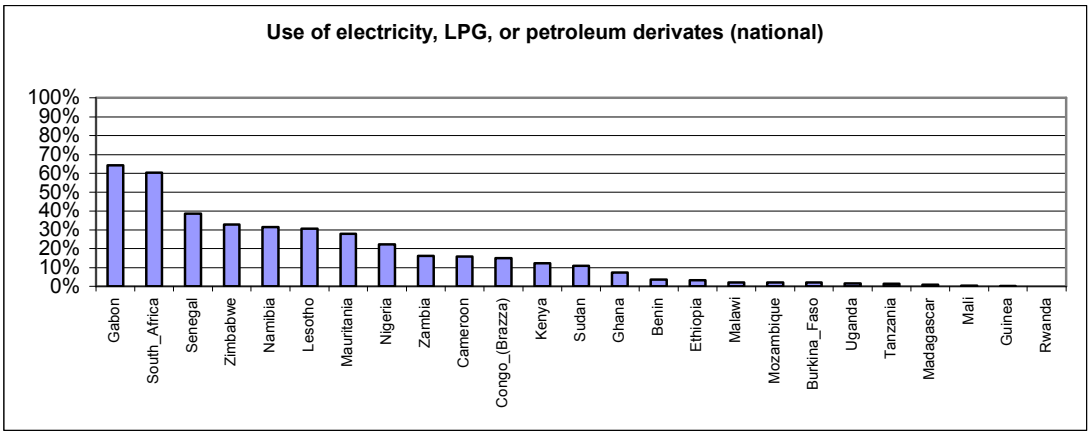
**Table 2-1: Use of household fuels use**

| | Region | | | Income Level | | Hydrocarbons assets | |
|---|---|---|---|---|---|---|---|
| Cooking fuel | National | Rural | Urban | LIC | MIC | Importers | Exporters |
| LPG | 3,4% | 1,0% | 8,1% | 2,8% | 8,1% | 2,8% | 4,2% |
| Kerosene | 8,0% | 2,9% | 21,7% | 7,1% | 14,8% | 2,4% | 15,3% |
| Wood-fuel | 82,6% | 93,2% | 57,9% | 86,8% | 52,2% | 89,9% | 73,2% |
| Other | 2,1% | 2,1% | 2,0% | 2,1% | 2,2% | 2,9% | 1,0% |

Source: AICD Household Surveys Database (2008)

The following graph shows the percentage of population having access to the top of the energy ladder, the latter being defined as an aggregation of kerosene, LPG, and electricity. Only Gabon and South Africa rely overwhelming on these types of fuels with more than 60% of its population using them. Senegal, Zimbabwe, Namibia, Lesotho, Mauritania, and Nigeria follow in the 20 to 40% bracket. Five countries follow in the 10 to 20% interval, while the remaining 12 countries- out of 25- are below the 10% threshold, with Rwanda having the lowest figure, a mere 0.06%

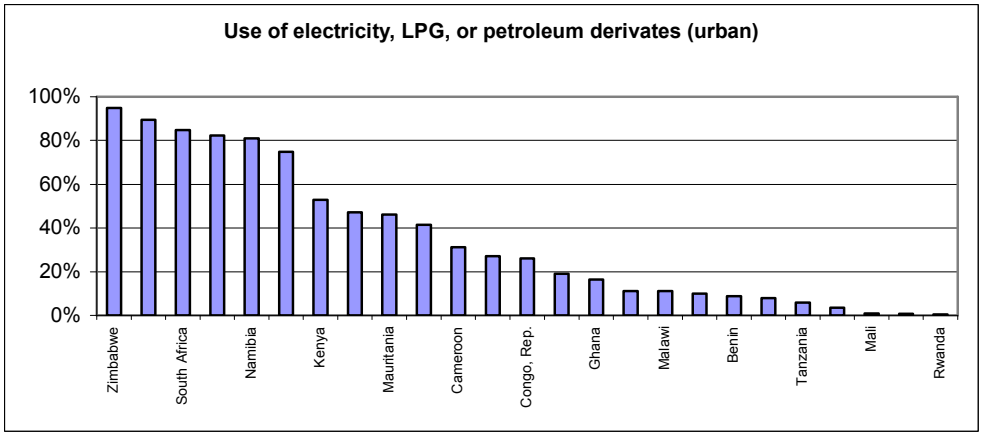
**Figure 2-1: National use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

Concerning access to the top of the energy ladder, the urban and rural pictures are extremely different. In the urban case, Zimbabwe, Lesotho, South Africa, Gabon, and Namibia are at the top with a combined access higher than 80%. It is worth noting that except for Gabon, the rest of these countries are from Southern Africa. This group is followed by Senegal around 75%, and by 7 countries in the 20 to 55% bracket. The remaining 12 countries have urban access rates lower than 20%.

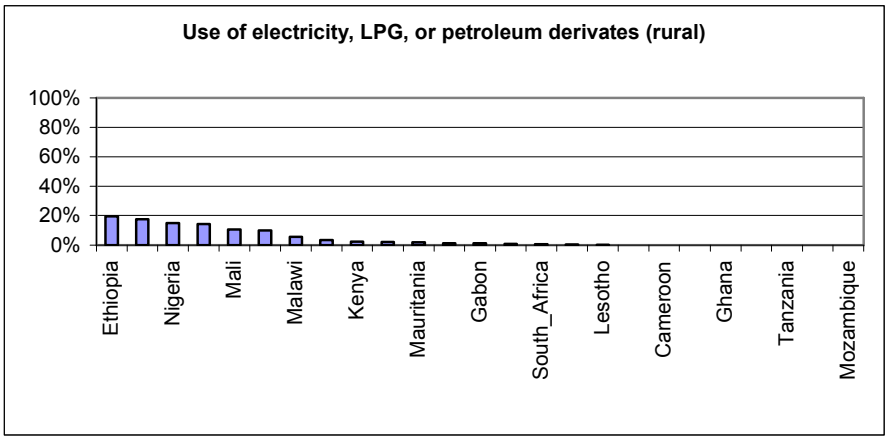
**Figure 2-2: Urban use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

For rural access, all countries are below 20%. Five countries are in the 10-20% interval (Ethiopia, Zimbabwe, Nigeria, Uganda, and Mali), eight between 1 and 10%, and the remaining twelve countries have access levels to the fuels at the top of the energy ladder below 1%.

**Figure 2-3: Rural use of fuels at the top of the *energy ladder***

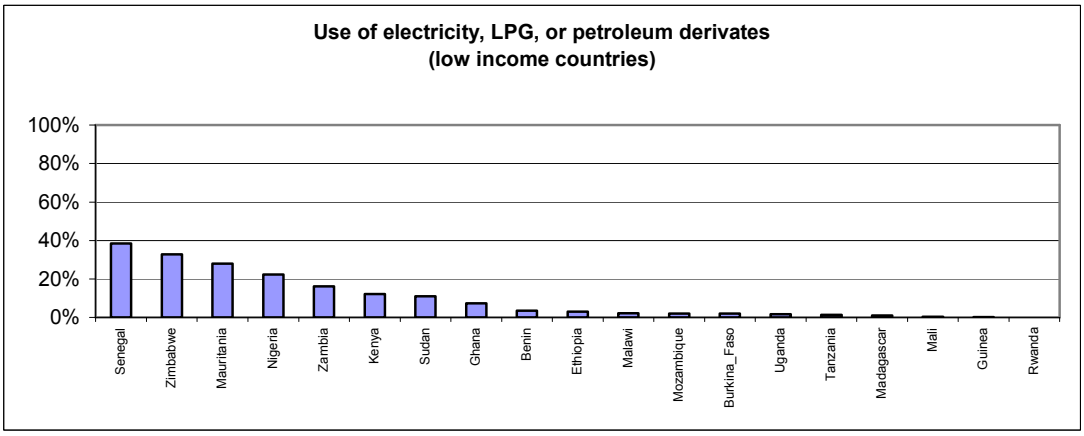



Source: AICD Household Surveys Database (2008)

For most of the countries, a low access to LPG and kerosene is complemented by a very high penetration rate of wood-fuel. However, there are some particular cases that will be developed with more detail below (e.g. dung and agricultural residues use in Ethiopia).

The following two figures indicate that income is one of the main drivers of access to high quality cooking fuels. Out of the 19 low income countries of our sample, only Senegal, Zimbabwe, Mauritania, Nigeria, and Zambia have rates above 15%.Three countries are in the 5-15% interval (Kenya, Sudan, and Ghana), while the remaining twelve countries are below 5%.

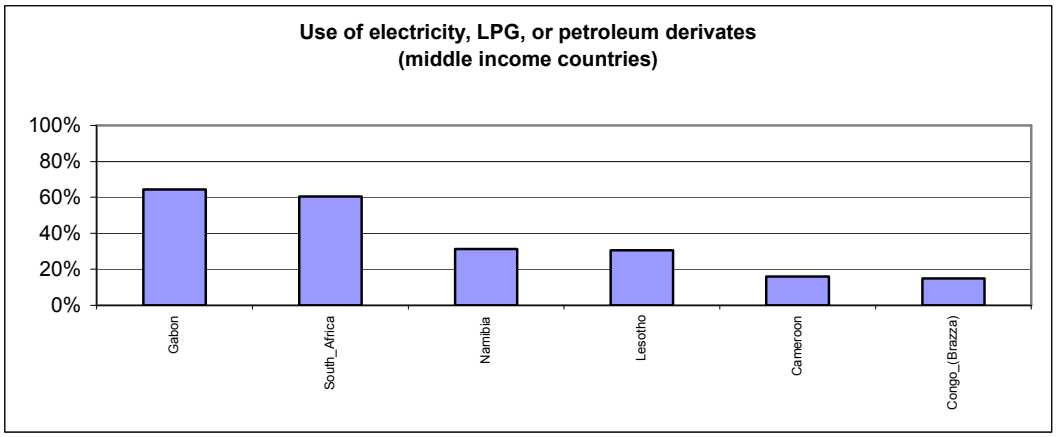
**Figure 2-4: Low Income Countries use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

However, for middle income countries the picture changes. Gabon and South Africa perform extremely well with access rates to high quality cooking fuels above 60%, Namibia and Lesotho are above 30%, and Cameroon and Congo around 15%.

**Figure 2-5: Middle Income Countries use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

No causality can be deducted from the positive correlation between access to modern fuels and income. It could be that being richer makes it more affordable to use modern fuels, but it could also be that having access to modern fuels makes households richer- e.g. by spending less time collecting wood-fuel or by having better health conditions. To study the causality effect, we would need both to use data over time and to control for other variables of the wider economy.

The price of cooking fuels will surely affect the access. Since we do not have data on prices – which vary substantially from country to country due to subsidies and taxes – we will instead focus on country's endowments of hydrocarbons. Indeed we are implicitly assuming that a larger endowment is associated with lower prices, which will not always be the case: in Ethiopia, for example, the kerosene is subsidized in peri-urban areas around Addis Ababa to fight desertification. Having discussed the limitations, let us now study if the hydrocarbon resources of countries affect the access to LPG and kerosene. A proxy for this is to divide the countries of our sample into hydrocarbon exporters and importers. It must be stressed that this table represents the *net* result. For example, Senegal in 2005 exported close to 300 thousand tonnes of oil equivalent of petroleum products, but overall it was a *net* hydrocarbons importer.

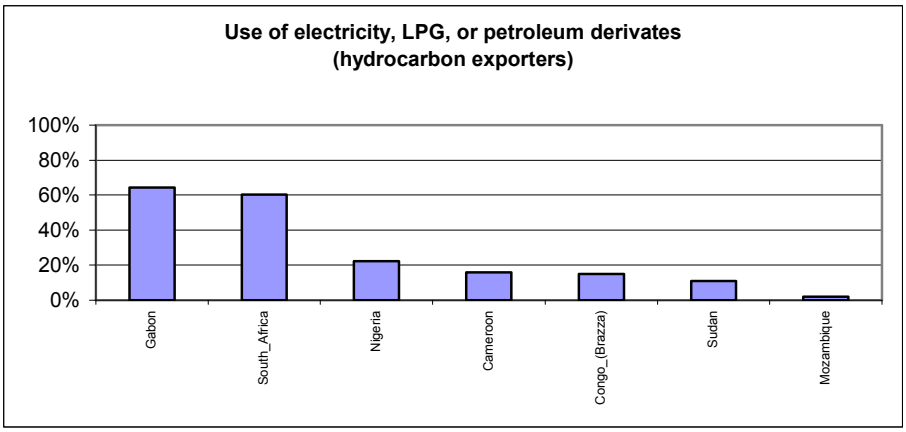
**Table 2-2: Net Hydrocarbon Exporters/Importers**

| Hydrocarbon Exporters | Hydrocarbon Importers |
|---|---|
| Cameroon, Congo (Brazzaville), Gabon, Mozambique, Nigeria, Sudan, South Africa | Benin, Burkina Faso, Etiopía, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Namibia, Senegal, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe |

Source: IEA 2005 (selected indicators & energy balances) & CIA World Factbook

The following two graphs confirm that hydrocarbon exporters perform clearly better than importers. The group of seven hydrocarbon exporters includes half of the middle income countries of our sample (3).

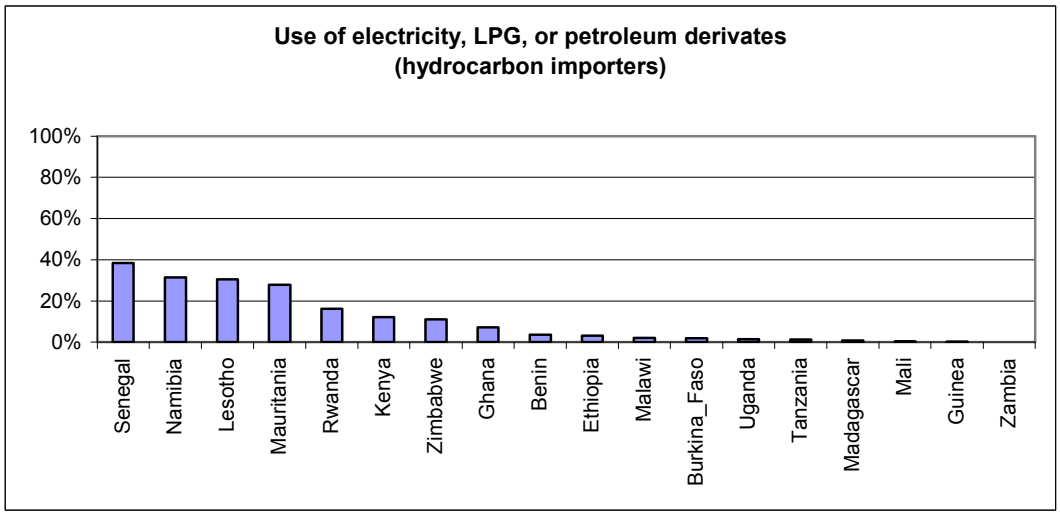
**Figure 2-6: Hydrocarbon Exporters use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

For hydrocarbon importers we see that the access rates are clearly lower than for exporters. Senegal and Mauritania appear to be interesting exceptions. They perform well although they are both low income countries and hydrocarbon net importers.

**Figure 2-7: Hydrocarbon Importers use of fuels at the top of the *energy ladder***




Source: AICD Household Surveys Database (2008)

The following table summarizes the average access rate to the top of the energy ladder for the 25 SSA countries of this study. It appears clearly that the divides between urban and rural areas, LICs and MICs, and hydrocarbon importers and exporters all seem to affect access to *modern fuels*.

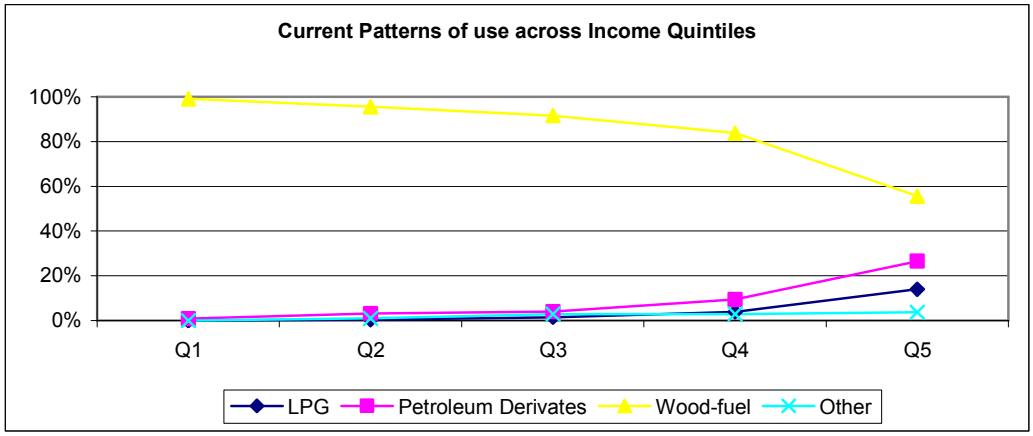
**Table 2-3: Access to the top of the energy ladder: aggregate figures**

| National | Urban | Rural | LIC | MIC | Hydroc. M | Hydroc. X |
|---|---|---|---|---|---|---|
| 15.1% | 40.1% | 3.9% | 10.9% | 45.6% | 6.0% | 25.6% |

Source: AICD Household Surveys Database (2008)

We will now look at the access to different types of cooking fuels across income quintiles. Households have been ranked by per household income values, and the different countries have been aggregated using a weighted average. We ignored the fact that data for each country may not be from exactly the same year. The first quintiles rely overwhelming on wood-fuel (figure 2-8). More than 80% of the 4th quintile population uses wood-fuel, and this figure is still at 55% for the wealthiest quintile. LPG and kerosene are insignificant for the first three quintiles. They reach 13% for the 4th quintile. For the richest quintile, LPG is around 14% and kerosene 27%. This graph shows that the positive association between income and access to modern fuels is not as intense as one could expect. In other words, there is still a long way to go in the cooking fuels energy transition in SSA.

**Figure 2-8: Current patterns of use across income quintiles**

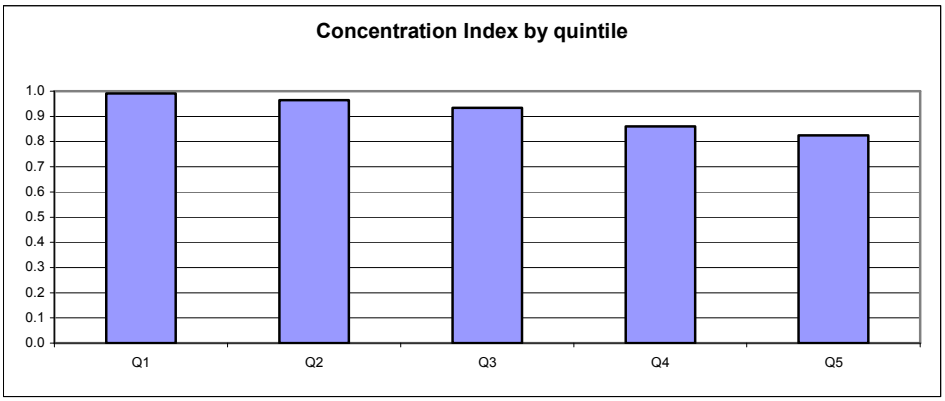



Source: AICD Household Surveys Database (2008)

Not all households in each quintile use the same fuel for cooking. A concentration index can be computed, as an index of the differences between households in primary cooking fuel usage in each quintile[4]. As can be observed in figure 2-9, this index decreases as income increases, amounting to 1 for the poorest quintile – all have the same main fuel, i.e. wood-fuel – and less than 0.8 for the richest quintile. Similar results arise when looking at the urban versus rural division: the concentration index in rural areas is 0.93, while it diminishes to 0.79 for urban areas, reflecting that there are greater inequalities in urban than in rural areas.

[4] The concentration index is computed as the square root of the sum of the shares squared, for each quintile.

**Figure 2-9: Concentration Index of cooking fuel types across quintiles**




Source: Authors calculations, based on AICD Household Surveys Database (2008)

Below is a ranking for each category of fuel, in which we indicate the percentage of the population using that category as their main cooking fuel. As was seen before, Gabon performs extremely well in access to LPG – followed by Senegal and Mauritania. South Africa and Nigeria are way ahead the rest of the countries in the degree of penetration of kerosene. In the "other" category, Guinea is close to 20%, and Ethiopia and Lesotho have also a significant degree of penetration of this category. The equivalent tables for urban and rural areas can be found in Annex 1.

**Table 2-4: Dispersion of primary fuel use across countries (National)**

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Gabon | 62.25% | Nigeria | 21.34% | Rwanda | 99.39% | Guinea | 19.96% |
| Senegal | 38.47% | South_Africa | 20.76% | Madagascar | 98.31% | Ethiopia | 7.72% |
| Mauritania | 27.98% | Lesotho | 10.28% | Tanzania | 98.07% | Lesotho | 7.34% |
| Lesotho | 18.77% | Kenya | 9.01% | Malawi | 97.81% | Mali | 3.82% |
| Cameroon | 11.26% | Zimbabwe | 7.65% | Burkina_Faso | 97.47% | Namibia | 2.71% |
| Sudan | 10.98% | Cameroon | 4.62% | Uganda | 97.39% | Senegal | 2.62% |
| Congo_(Brazza) | 8.39% | Congo_(Brazza) | 3.99% | Mozambique | 96.92% | South_Africa | 2.22% |
| Namibia | 7.19% | Ethiopia | 2.99% | Mali | 95.90% | Congo_(Brazza) | 1.91% |
| Ghana | 6.84% | Benin | 2.90% | Benin | 95.60% | Cameroon | 1.55% |
| South_Africa | 4.92% | Namibia | 2.83% | Ghana | 91.82% | Mauritania | 1.53% |
| Kenya | 3.18% | Gabon | 2.05% | Ethiopia | 88.98% | Gabon | 1.06% |
| Burkina_Faso | 1.86% | Uganda | 1.42% | Sudan | 88.30% | Nigeria | 0.91% |
| Mozambique | 1.54% | Tanzania | 1.25% | Kenya | 87.07% | Benin | 0.78% |
| Nigeria | 1.04% | Ghana | 0.40% | Zambia | 83.62% | Burkina_Faso | 0.61% |
| Madagascar | 0.84% | Mozambique | 0.38% | Congo_(Brazza) | 83.17% | Madagascar | 0.54% |
| Benin | 0.72% | Madagascar | 0.07% | Cameroon | 82.57% | Ghana | 0.49% |
| Mali | 0.26% | Burkina_Faso | 0.05% | Guinea | 79.82% | Rwanda | 0.48% |
| Zimbabwe | 0.20% | Malawi | 0.04% | Nigeria | 76.56% | Kenya | 0.47% |
| Ethiopia | 0.14% | Rwanda | 0.03% | Mauritania | 70.50% | Tanzania | 0.44% |
| Uganda | 0.12% | Guinea | 0.02% | Zimbabwe | 66.91% | Zimbabwe | 0.35% |
| Guinea | 0.08% | Mali | 0.01% | Namibia | 65.91% | Mozambique | 0.32% |
| Tanzania | 0.04% | Mauritania | 0.00% | Lesotho | 62.10% | Uganda | 0.32% |
| Malawi | 0.03% | Senegal | 0.00% | Senegal | 58.72% | Zambia | 0.24% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rwanda | 0.03% | Zambia | 0.00% | South_Africa | 37.45% | Malawi | 0.15% |
| Zambia | 0.03% | Sudan | 0.00% | Gabon | 34.09% | Sudan | 0.00% |

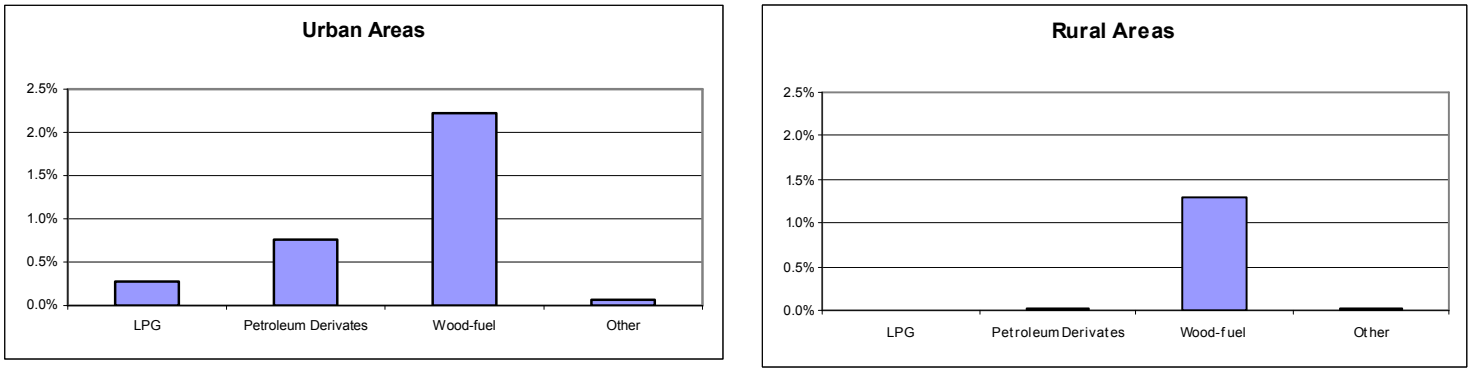
Source: AICD Household Surveys Database (2008)

It has been seen that the access *levels* are positively associated with income (e.g. MICs such as South Africa and Lesotho), and with production of hydrocarbons (e.g. Gabon, Cameroon, Congo, Nigeria, Mauritania). Senegal is an interesting exception which will be commented later on. What about the *growth rates* of access to modern fuels?

**b. Evolution**

Now that the access to cooking fuels has been analyzed, the question arises on how the evolution has been in the last years. Figure 2-10 gives, for each fuel category, the annualized change in use, expressed as a percentage of the sample population gaining access yearly for the period 2001-2005. When looking at these values, one should take into account that the average population growth rate in the countries considered was 2.37%. In rural areas, the annualized change in use is significant only for wood-fuel, with a value above 1.2%. In urban areas this value is nearly doubled to more than 2.2%. In urban areas, the annualized change in use is 0.8% for kerosene and 0.3% for LPG. In other words, the rural increase of population has been offset only by wood-fuel – helped by the rural-urban migration phenomenon - while the picture in urban areas is more nuanced, although wood-fuel remains the main source as well.

**Figure 2-10: Annualized change in use expressed as % of sample population gaining access every year in the period 2001-2005**




Source: AICD Household Surveys Database (2008)

Table 2-5 presents a ranking of the annualized change in use at the country level. As was mentioned above, the population growth rate of each country should be subtracted if one wants to know whether the increase in cooking fuels use offsets or not the population growth.

**Table 2-5: Annualized Change in Use, National level**

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Gabon | 1.01% | Nigeria | 0.47% | Uganda | 3.36% | Guinea | 0.44% |
| Senegal | 0.92% | South_Africa | 0.23% | Burkina_Faso | 3.11% | Ethiopia | 0.15% |
| Mauritania | 0.83% | Kenya | 0.20% | Benin | 3.06% | Mali | 0.11% |
| Congo_(Brazza) | 0.25% | Congo_(Brazza) | 0.12% | Mali | 2.87% | Senegal | 0.06% |
| Sudan | 0.21% | Benin | 0.09% | Madagascar | 2.70% | Congo_(Brazza) | 0.06% |
| Cameroon | 0.21% | Cameroon | 0.09% | Congo_(Brazza) | 2.49% | Mauritania | 0.05% |
| Ghana | 0.15% | Ethiopia | 0.06% | Malawi | 2.16% | Namibia | 0.03% |
| Namibia | 0.09% | Uganda | 0.05% | Mauritania | 2.10% | Cameroon | 0.03% |
| Kenya | 0.07% | Zimbabwe | 0.05% | Ghana | 1.95% | South_Africa | 0.03% |
| Burkina_Faso | 0.06% | Namibia | 0.04% | Kenya | 1.92% | Benin | 0.02% |
| South_Africa | 0.06% | Gabon | 0.03% | Mozambique | 1.90% | Nigeria | 0.02% |
| Mozambique | 0.03% | Tanzania | 0.02% | Tanzania | 1.89% | Burkina_Faso | 0.02% |
| Madagascar | 0.02% | Ghana | 0.01% | Rwanda | 1.86% | Gabon | 0.02% |
| Benin | 0.02% | Mozambique | 0.01% | Ethiopia | 1.78% | Madagascar | 0.01% |
| Nigeria | 0.02% | Madagascar | 0.00% | Guinea | 1.74% | Uganda | 0.01% |
| Mali | 0.01% | Burkina_Faso | 0.00% | Nigeria | 1.70% | Ghana | 0.01% |
| Uganda | 0.00% | Malawi | 0.00% | Sudan | 1.69% | Kenya | 0.01% |
| Ethiopia | 0.00% | Rwanda | 0.00% | Cameroon | 1.53% | Rwanda | 0.01% |
| Guinea | 0.00% | Mali | 0.00% | Zambia | 1.41% | Tanzania | 0.01% |
| Zimbabwe | 0.00% | Guinea | 0.00% | Senegal | 1.40% | Mozambique | 0.01% |
| Tanzania | 0.00% | Mauritania | 0.00% | Namibia | 0.84% | Zambia | 0.00% |
| Malawi | 0.00% | Senegal | 0.00% | Gabon | 0.55% | Malawi | 0.00% |
| Rwanda | 0.00% | Zambia | 0.00% | South_Africa | 0.42% | Zimbabwe | 0.00% |
| Zambia | 0.00% | Sudan | 0.00% | Zimbabwe | 0.41% | Sudan | 0.00% |
| Lesotho | 0.00% | Lesotho | 0.00% | Lesotho | -0.01% | Lesotho | 0.00% |

Source: AICD Household Surveys Database (2008)

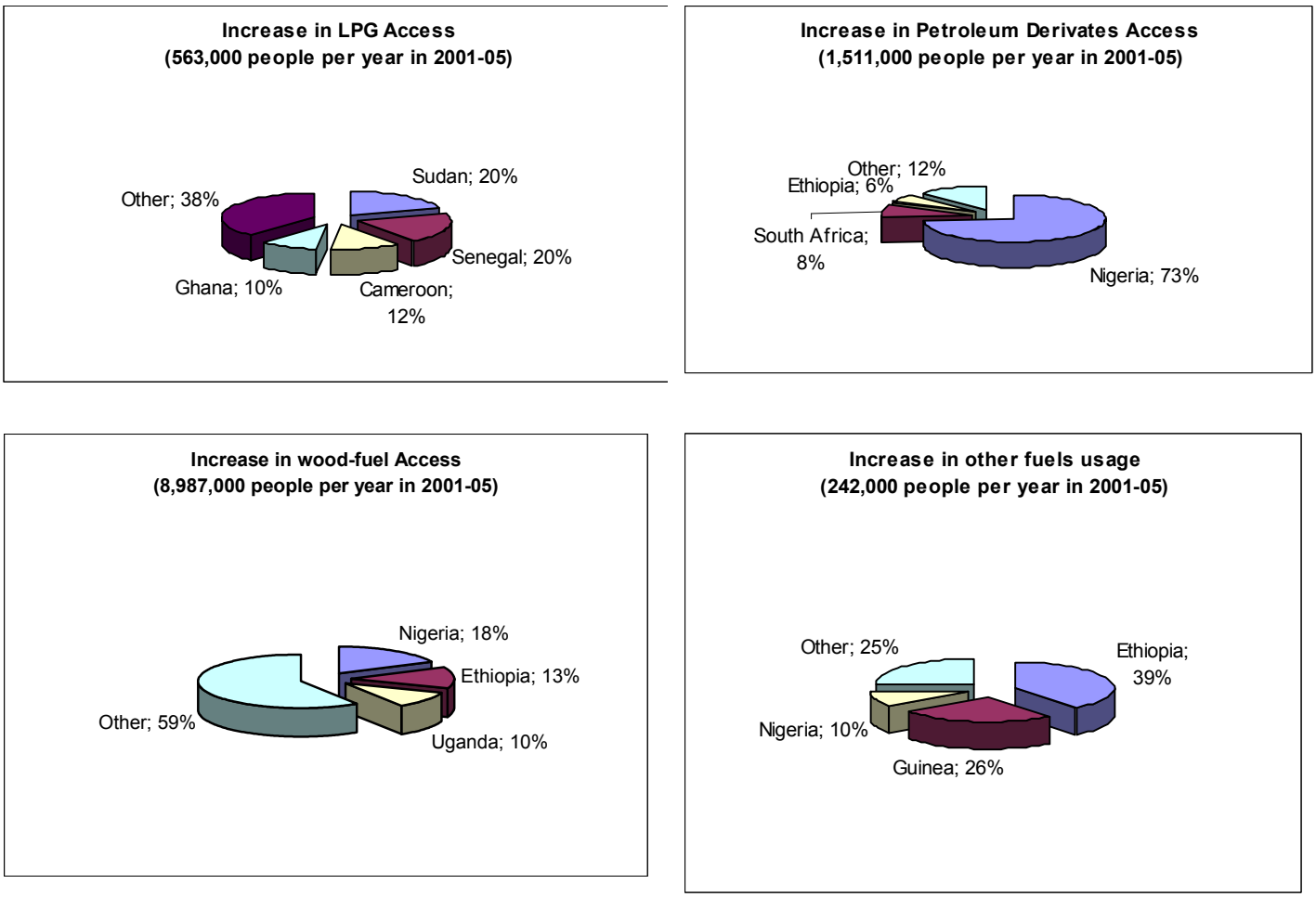
Gabon, Senegal, and Mauritania are the countries that have witnessed a higher improvement in their LPG degree of penetration. The same can be said for Nigeria with kerosene, as well as for Guinea for the "other fuels" category. In Annex 2 the equivalent tables for urban and rural areas can be found.

An interesting question is to analyze the country contribution to the annual changes in population gaining access to each type of fuel. It should be considered here that the population size of the country matters: a big country (e.g. Nigeria) with a slight improvement in a category will more easily be included here than a small country with a significant improvement in relative terms (e.g. Lesotho).

As can be seen in the chart below, the contribution to LPG increase is quite diversified, with Sudan and Senegal contributing by 20% each, followed by Cameroon and Ghana around 10%. For kerosene, 73% of the gain in access comes from Nigeria. This can be due both to the fact that Nigeria is an oil producer country, as well as by the fact that it is one of the biggest countries in Sub-Saharan Africa in terms of population. In the case of wood-fuel, Nigeria is also the country with a highest share of contribution to its increase with 18%, followed by Ethiopia with 13% and Uganda with 10%. However, as can be

seen, 59% of this increase is split across the remaining countries, which indicates that the increase in wood-fuel is the most diversified. This can be related to the overwhelming reliance of SSA in wood-fuel as its main cooking fuel. Finally, in the category of "other fuels", Ethiopia represents 39% of the increase, Guinea 26%, and Nigeria 10%. In the case of Ethiopia, a majority of the other fuels category is highly likely to correspond to dung and agricultural crops (Hedon 2007).

**Figure 2-11: Country contribution to regional change in use expressed as % of sample population gaining access every year in the period 2001-2005**




Source: AICD Household Surveys Database (2008)

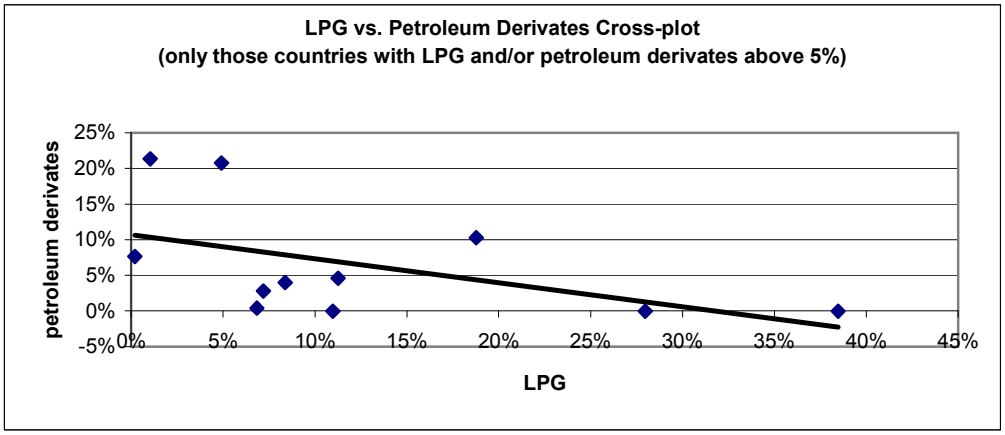
It is worth noting that the absolute number of people represented by each of the figures above differs depending on the type of fuel: the wood-fuel one represents almost 9 million people, the kerosene one 1.5 million, the LPG one more than 0.5 million, and the other fuels category less than 250,000 people.

**c. Patterns**

Among the modern fuels, it appears that while some countries seem to specialize in LPG (e.g. Gabon, Senegal, Mauritania) others seem to specialize in kerosene (e.g. Nigeria, South Africa). Lesotho seems to be the only country that has high penetration of both fuels.

A cross-plot of all the countries of our sample of LPG versus kerosene shows a very smooth downward slope. This graph may be distorted by the many countries that have LPG and kerosene penetration rates that are extremely low. To solve this problem, Figure 1-12 eliminates those countries that have both LPG and kerosene penetration rates below 5%. Now we find a correlation in which a decrease of 1% in kerosene access is associated with an increase of around 3.5% in LPG access - with an $R^2$ of 0.25. Although it is hard to extract clear conclusions, it seems that there is a negative correlation between increasing the penetration rate to LPG and to kerosene.

**Figure 2-12: LPG versus Kerosene cross-plot**
**(only those countries with either LPG or kerosene above 5%)**




Source: AICD Household Surveys Database (2008)

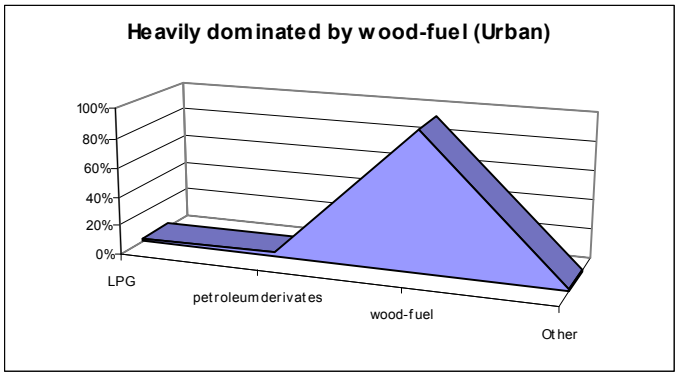
The apparent story is not so much one of an energy ladder - first kerosene, then LPG - but one of a bifurcation from wood-fuel to either LPG or kerosene. We now define three country typologies:

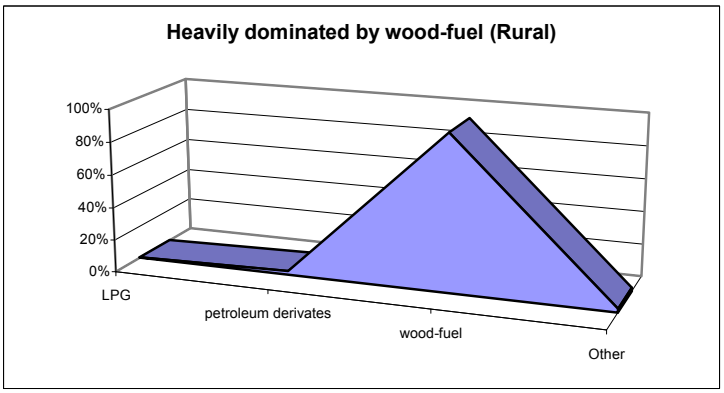
(i) heavily dominated by wood-fuel.
(ii) significant development of kerosene, i.e. penetration rate of at least 10%.
(iii) significant development of LPG, i.e. penetration rate of at least 10%.

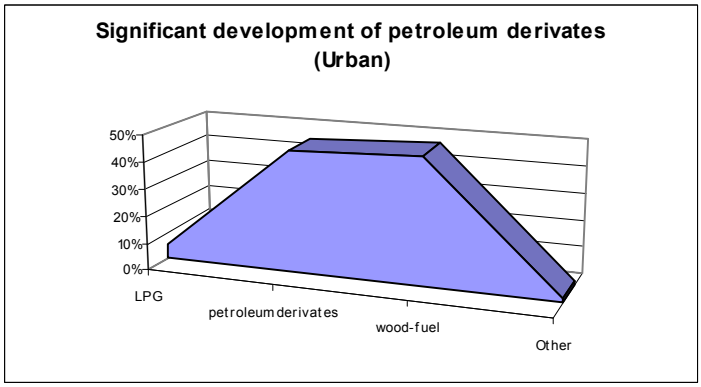
The following two groups of graphs represent the penetration rates of each technology for urban and rural areas, following the three categories classification defined above. As can be seen, the shape appearing for those countries heavily dominated by wood-fuel is similar for both urban and rural areas. This category includes 9 out of 25 countries for urban areas, and 20 countries for rural areas.

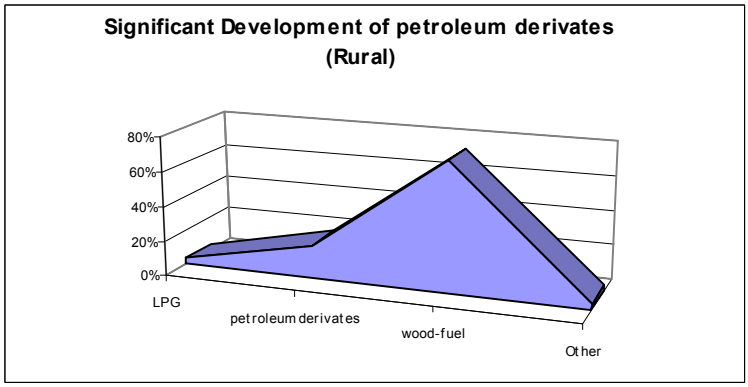
For countries with a significant development of kerosene, the comparison between urban and rural areas appears to be quite different. In urban areas the penetration rate of kerosene is above 45%, complemented by approximately the same value for wood-fuel. However, in rural areas the kerosene penetration rate is 19% while the wood-fuel one is 74%. These figures should be taken with precaution, since while the urban category is formed by 5 countries the rural category corresponds to only one country, South Africa, one of the richest countries in coal in the world – thus part of our wood-fuel category.
When comparing the urban and rural graphs of countries with significant development of LPG, a similar trend to the one for kerosene appears. The data represents 10 countries for urban areas and 4 for rural areas. While the LPG penetration rate in urban areas reaches 30% (complemented by 65% of wood-fuel), it falls to 11% for rural areas (complemented by 83% of wood-fuel).

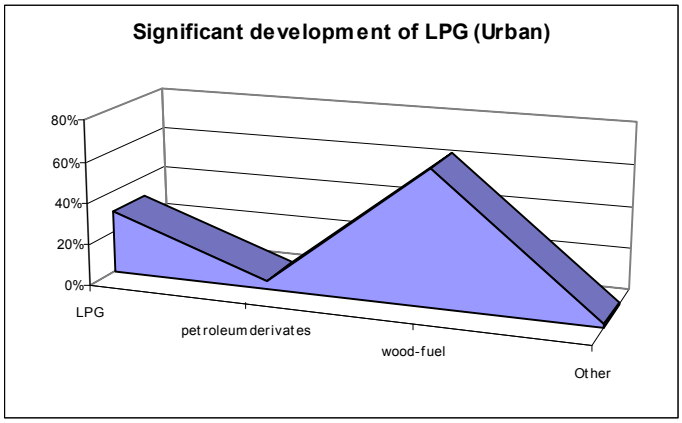
**Figure 2-13: Urban & Rural areas: classification in types of modernization in cooking fuels**

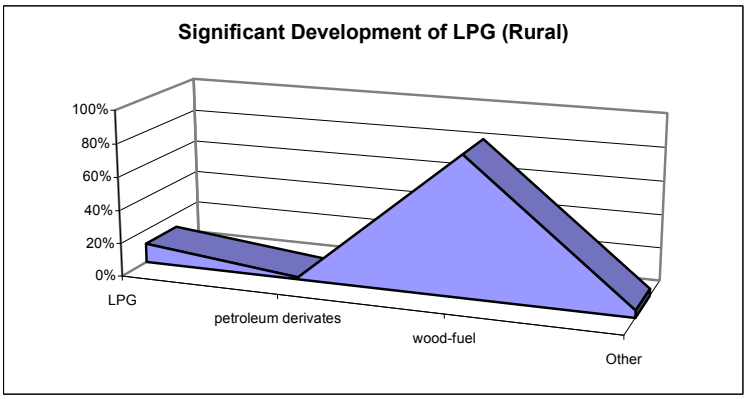





Source: AICD Household Surveys Database (2008)

It is also interesting to look at what these graphs tell us about the *bifurcation hypothesis* at the top of the energy ladder, between LPG and kerosene. Although these graphs seem to support this hypothesis, they also show that the penetration of kerosene is deeper than the one of LPG for those countries with significant development in one or the other. Kerosene is ahead of LPG by 46% versus 30% for urban areas, and by 19% versus 11% for rural areas. This means that the penetration of wood-fuel – the main complement of high quality cooking fuels such as kerosene or LPG - of those countries specializing in LPG is much deeper than the one of countries specializing with kerosene.

**d. Outlier countries**

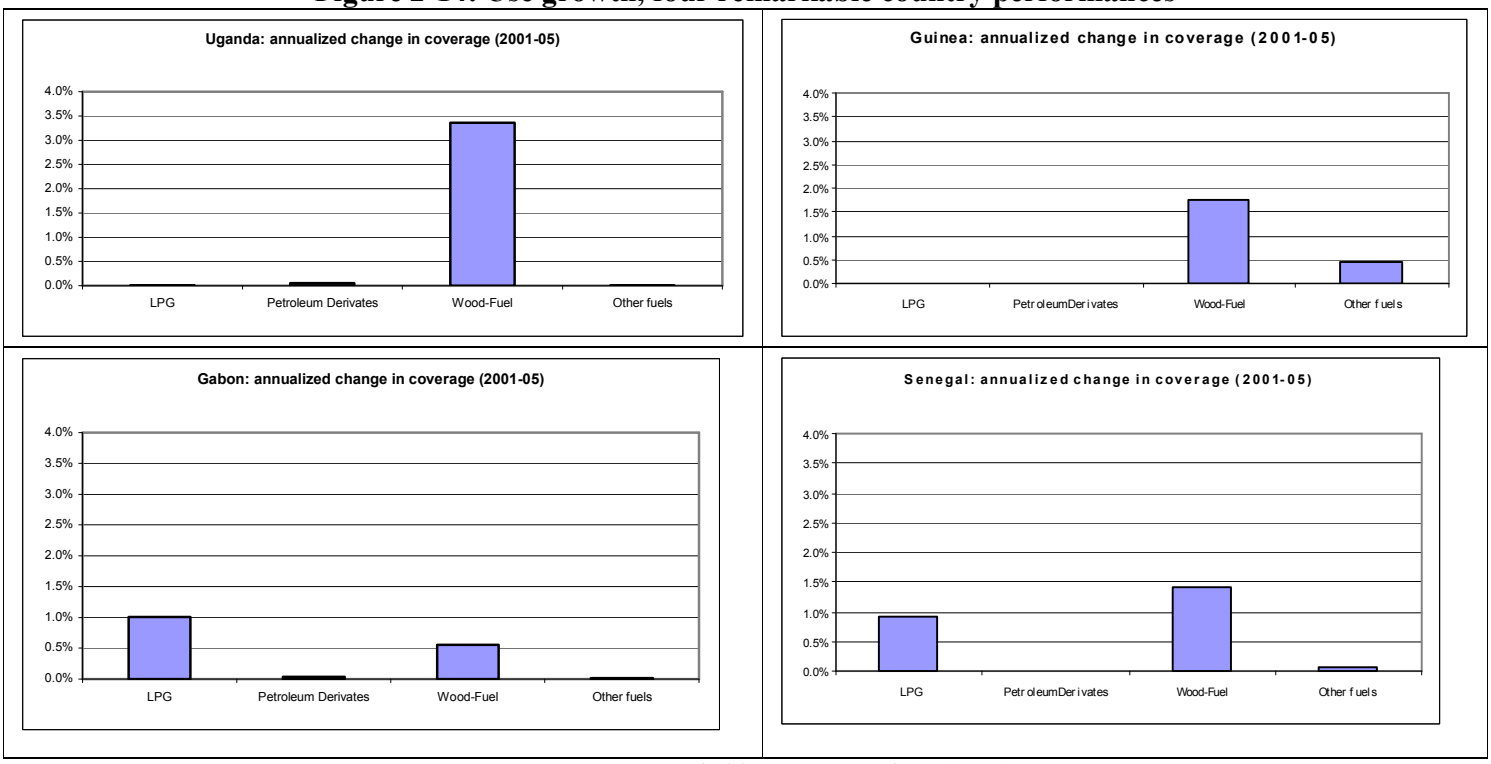
Uganda has the highest annual increase in wood-fuel, with 3.36%. Its evolution in both LPG and other fuels is close to zero. For kerosene, although it rises by only 0.05% annually, Uganda is the 8$^{th}$ in the ranking of best performance with this fuel. It should be considered that Uganda's population growth rate in the period considered is the second highest of the countries considered reaching 3.22%, which may partially explain this important increase.

The percentage of population using either kerosene or LPG in Guinea has not increased from 2001 to 2005. All the improvements have been achieved in wood-fuel and other fuels.

Gabon has the highest increase in LPG. In kerosene and other fuels it is close to zero, and in wood-fuel it is very close to the bottom of the ranking with an increase of only 0.55%.

Senegal has in common with Gabon that it performs really well in LPG with a 0.92% increase, which is due to a subsidy policy of the Government (see Box below). In kerosene and wood-fuel it is close to the bottom of the ranking, with 0% and 1.40% respectively. It is intriguing that for the other fuels category, although Senegal grew only by 0.06%, in relative terms this seems to be a good performance since it is ranked 4$^{th}$ out of the 25 countries of the study.

**Figure 2-14: Use growth, four remarkable country performances**




Source: AICD Household Surveys Database (2008)

**The LPG Subsidies in Senegal**

Senegal has penetration of modern fuels way beyond what one would expect for a LIC with no hydrocarbons, due to a subsidy policy that has been in place since decades. It should be noted that Senegal does have some LPG production (630 TJ in 2005) but it is a net hydrocarbon importer, and this LPG mainly feeds electricity plants. Other Western African countries such as Côte d'Ivoire have implemented similar policies. However, the Senegalese experience is probably the most successful.

| National | Rural | Urban | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|---|---|
| 38.5% | 10.6% | 74.6% | 0.2% | 3.1% | 34.6% | 65.1% | 89.7% |

Since the 1970's Senegal has specifically targeted subsidies at small cylinders from 6kg downwards in an attempt to target LPG household use. By offering discounts on smaller units of fuel, the government hoped to provide an adequate incentive to encourage fuel switching. The origin of this policy was an alarming rate of deforestation. This was done by taxing other petroleum products.

Due to this subsidy policy the domestic consumption of LPG in Senegal has risen from 3,000 tons in 1974 to 100,000 tons in 2000, most of which is sold in small cylinders. This represents an annual growth above 10%. The Senegal Ministry of Energy estimates the annual saving of firewood-fuel to be 70,000 tonnes and 90,000 tonnes respectively. However, these subsidies typically have benefited urban middle and high classes, as can be seen in the table above.

In 1998, the government began to reduce the subsidy by 20% per year with the goal of eliminating it altogether by 2002. Since the subsidy's elimination consumption of LPG in Senegal has continued

to expand, though at a slower pace (by 2005 the annual consumption was 140,000 tons), as the private sector has taken over the market. Due to competition between firms, LPG prices remain affordable for most households.

The government has been trying for years, if not decades, to eliminate the subsidy because of its high fiscal cost, particularly with the recent energy crisis, but is still battling. There have been recent episodes during which the refinery was seriously in debt and could not operate for a while, causing a severe fuel shortage not only in Senegal but in the neighboring countries that import from Senegal.

Source: based on Schlag et al 2008

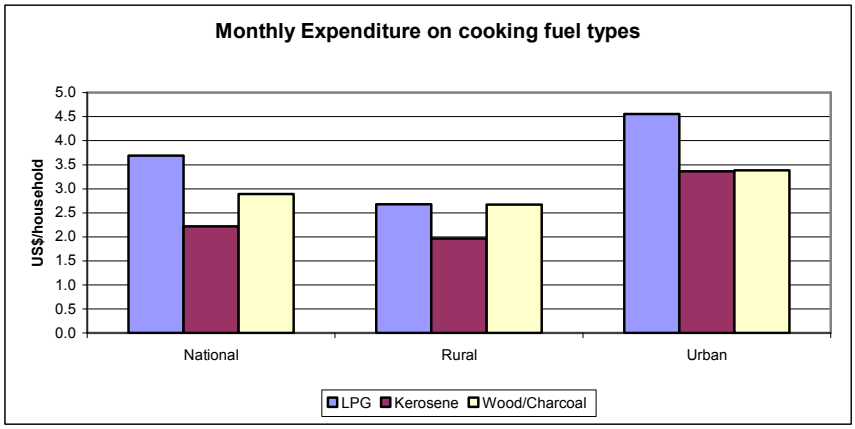
## 3. Expenditures in cooking fuels

In this chapter, 20 countries representing 67% of Sub-Saharan Africa population are analyzed. There are a number of market barriers to a clean cooking fuel transition such as technological issues, infrastructure, lack of information, socio-cultural issues and pricing of fuels (Schlag et al 2008). This chapter will focus on the latter.

### a. In financial terms

The rural versus urban stratification results interestingly indicate that LPG is the cooking fuel with more financial resources spent in. This could be expected for the urban areas, but it is surprising for the rural areas since they have a very high wood-fuel penetration rate. For rural areas, more resources are devoted to wood-fuel than to kerosene, while a similar amount is spent in each family of these fuels in urban areas.

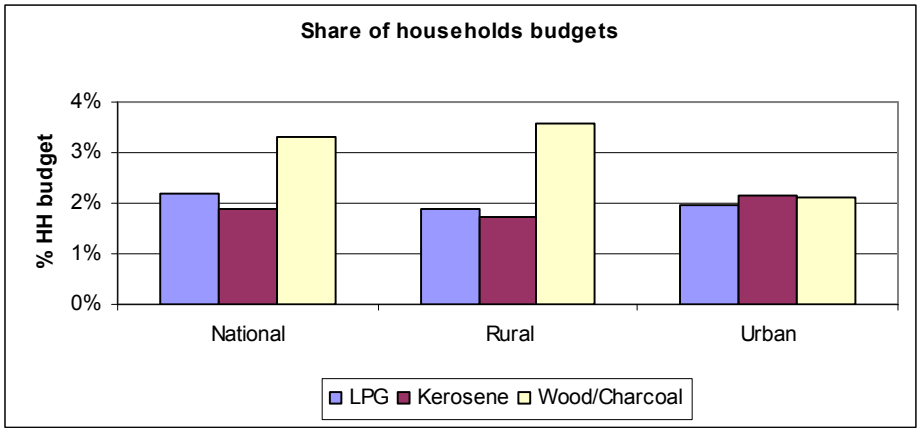
**Figure 3-1: Monthly expenditure on cooking fuel types**




Source: AICD Household Surveys Database (2008)

In relative terms the trends change. Wood-fuel is the category in which a more important effort is put, reaching almost 3.5% of monthly expenditure in rural areas and more than 2% in urban areas. This apparent contradiction is explained by the fact that most of the LPG expenditure comes from households having a higher household budget, while an important share of the wood-fuel expenditure comes from poorer households. Also, the advantage in absolute terms that LPG had in both urban and rural areas compared to kerosene is neutralized in relative terms.

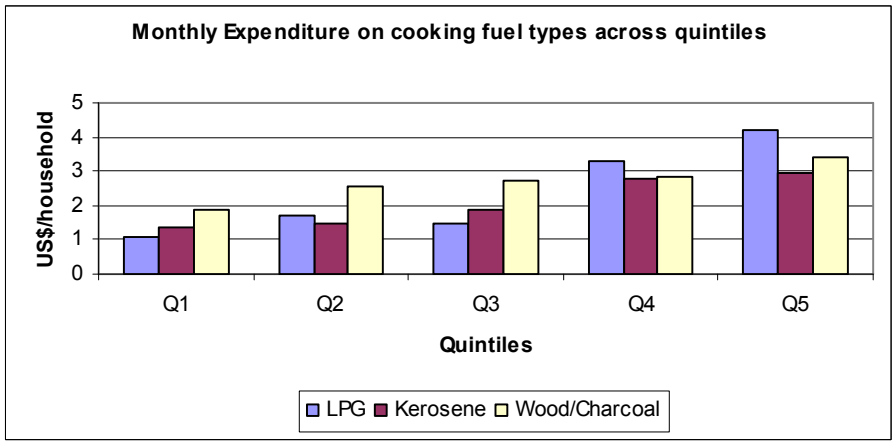
**Figure 3-2: Share of households' budgets spent on cooking fuels**




Source: AICD Household Surveys Database (2008)

It is also interesting to look at this financial burden from an equity perspective across populations. According to figure 3-3, the first three quintiles seem to follow an energy ladder pattern, i.e. LPG is the cooking fuel in which poor people put less financial effort – in absolute terms - followed by kerosene, and finally by wood-fuel. It also shows that the richer people are, the more they spend in each of the cooking fuels considered. However, for the richer two quintiles, LPG becomes the fuel in which households put more money for cooking purposes, followed by wood-fuel and eventually kerosene. This shows that wood-fuel behaves as a superior good for the lowest shares of the population only, i.e. it has a positive income elasticity of demand. However, afterwards it starts behaving as an inferior good due to the substitution effect to fuels of higher quality: from the 3rd quintile on, the effect of moving towards higher quintiles is that with higher incomes, the demand for wood-fuel decreases. High-income households may consider wood-fuel an inferior good, but low-income households may not share this view. Consequently, in poor countries, the switch from wood-fuel to other types of energy is likely to occur slowly.

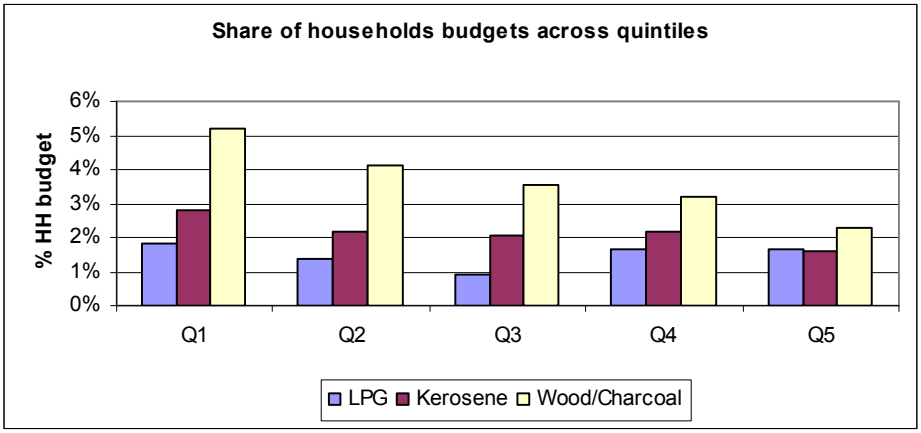
**Figure 3-3: Monthly Expenditure on cooking fuel types across quintiles**




Source: AICD Household Surveys Database (2008)

When looking at it in relative terms the trend is reversed. The poorest quintiles are those spending a higher share of their household budget in cooking fuels and the richest quintiles the smaller share. The burden of cooking fuels is thus much higher for poor than for rich people. Even if the prices differ among fuels, it could be argued that access to some kind of cooking fuel is a *basic need* for any household. In other words, the demand for some type of cooking fuel is highly inelastic. The share of each quintile's budget spent in modern fuels does not vary as much as the one of wood-fuel which clearly diminishes as income goes up.

**Figure 3-4: Share of households' budgets across quintiles**




Source: AICD Household Surveys Database (2008)

Another way to look at the pricing of cooking fuels is to think about the economic burden households have to support in order to satisfy their basic cooking needs. We assume a household consumes 320 MJ of effective energy monthly, which corresponds to 2.5 meals per person per day (Utria 2004, mentioned in Schlag et al 2008). We need to introduce prices of cooking fuels to undertake this analysis. The average prices considered in table 3-2 necessarily derive from a number of assumptions – due to data constraints - which are presented in Annex 3. Useful energy prices imply that we are already considering the technology efficiency, i.e. they are prices per unit of output, per unit of energy once it has been transformed using the corresponding technology. The assumptions are the following:

**Table 3-1: Assumptions on fuels and technologies characteristics[5]**

| Fuel | Energy Density | Technology Efficiency |
|---|---|---|
| Wood-fuel | 6.39 KWh/kg | 0.19 |
| Kerosene | 9.72 KWh/liter | 0.35 |
| LPG | 12.5 KWh/kg | 0.6 |

We are now in a position to compute *useful* energy prices:

[5] Barnes et al 2005.

**Table 3-2: Assumptions on useful energy prices[6]:**

| | | |
|---|---|---|
| Wood-fuel | 3.7 cents $/MJ | 0.73 US$/kg |
| Kerosene | 2.6 cents $/MJ | 0.91 US$/liter |
| LPG | 1.4 cents $/MJ | 0.65 US$/kg |

The percentages below represent the affordability of consuming cooking fuels to satisfy the needs of 320 MJ. The figures represent the % spent on a certain fuel if and only if that fuel was the only one used, which may not always be the case. If a household consumes a mix of two categories of cooking fuels, then the % of its budget will be in between the % corresponding to each category.

**Table 3-3: Percentage of Households Budget needed to consume 320 MJ**

| Country | LPG | Kerosene | Wood-fuel |
|---|---|---|---|
| Angola | 2% | 4% | 5% |
| Benin | 5% | 9% | 12% |
| Burkina Faso | 4% | 7% | 8% |
| Burundi | 7% | 13% | 16% |
| Cameroon | 4% | 7% | 9% |
| Chad | 1% | 2% | 3% |
| Congo | 2% | 4% | 5% |
| Cote d'Ivoire | 2% | 4% | 4% |
| DRC | 4% | 8% | 9% |
| Ethiopia | 8% | 15% | 18% |
| Gabon | 1% | 2% | 2% |
| Ghana | 3% | 5% | 6% |
| Guinea-Bissau | 3% | 6% | 7% |
| Kenya | 3% | 6% | 7% |
| Madagascar | 2% | 3% | 4% |
| Malawi | 7% | 12% | 15% |
| Mauritania | 2% | 4% | 5% |
| Mozambique | 7% | 13% | 16% |
| Niger | 4% | 7% | 8% |
| Nigeria | 5% | 10% | 12% |
| Rwanda | 5% | 8% | 10% |
| Senegal | 2% | 4% | 5% |
| Sierra Leone | 4% | 8% | 9% |
| South Africa | 1% | 2% | 2% |
| Tanzania | 8% | 14% | 17% |
| Uganda | 6% | 10% | 13% |
| Zambia | 5% | 8% | 10% |
| **AVERAGE** | **2.8%** | **5.0%** | **6.1%** |

Source: authors' calculations

[6] The wood-fuel price is extracted from AICD data (only available for some countries), while the kerosene and LPG prices are not. See Annex 3 for details on assumptions and sources to get these price figures.

This table tells us that, considering a cross-country weighted average, the cheapest option families have to satisfy their minimum cooking energy needs is to use LPG, followed by kerosene, and finally wood-fuel. There are wide variations depending on the country.

It is striking that in five countries households would need to spend 15% or more of their budget in cooking fuels if they use wood-fuel to satisfy their basic energy needs. Therefore, we can interpret that in a number of SSA countries modern fuels are under supplied, which would explain why households decide to consume more "expensive" fuels. Moreover, capital costs have not been included in this analysis. If they were, they would modify this picture, since they are higher for modern than for traditional cooking fuels.

### b. In energy terms

Using data on energy content of each type of cooking fuel and prices, an analog analysis as with the financial effort can be done in energetic terms. Table 3-4 summarizes the results of this analysis:

**Table 3-4: Comparison of HH monthly energy expenditures with gross and net consumption across quintiles**

| Quintile | Energy Expenditure (US$) | Gross consumption (kWh) | Net consumption (kWh) | Efficiency Factor (net/gross) |
|---|---|---|---|---|
| 1 | 4.3 | 120 | 34 | 0.28 |
| 2 | 5.7 | 165 | 47 | 0.29 |
| 3 | 6.1 | 174 | 48 | 0.28 |
| 4 | 9.0 | 224 | 73 | 0.33 |
| 5 | 10.6 | 269 | 90 | 0.33 |

Source: authors' calculations

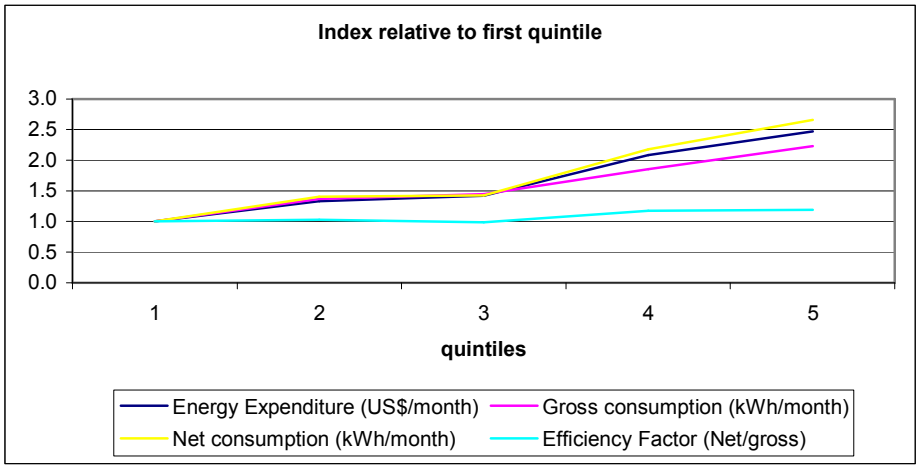
Both the gross and net energy consumption for cooking follow an upwards trend. This is not always necessarily the case for gross energy: in fact, in a study of Guatemala in the late 1990s the trend was one of a bell shape, with the quintiles in the middle having the higher gross energy consumption (Foster et al 2000). This was due to the fact that richer people tend to use more efficient technologies, and thus require a smaller amount of gross consumption to obtain a certain value of net consumption.

In SSA, however, a look at the efficiency factor shows that although the expenditure and energy consumption differ across quintiles, it is not the case that the wealthier are using clearly more efficient technologies (table 3-4). In fact, the first quintile gets an efficiency factor of 0.28, while the fifth gets one above 0.33. This effect can also be observed in figure 3-5: the index relative to the first quintile for the efficiency factor is close to a horizontal line.

As could be expected by looking at the energy expenditure across quintiles, the richer people are, the more they spend in cooking fuels. In the following graph it is seen that the wealthiest spend almost three times more in cooking fuel than the poorer. It is interesting

to note there is an important jump upwards going from the 3rd to the 4th quintile for the expenditure, and both the gross and net consumption.

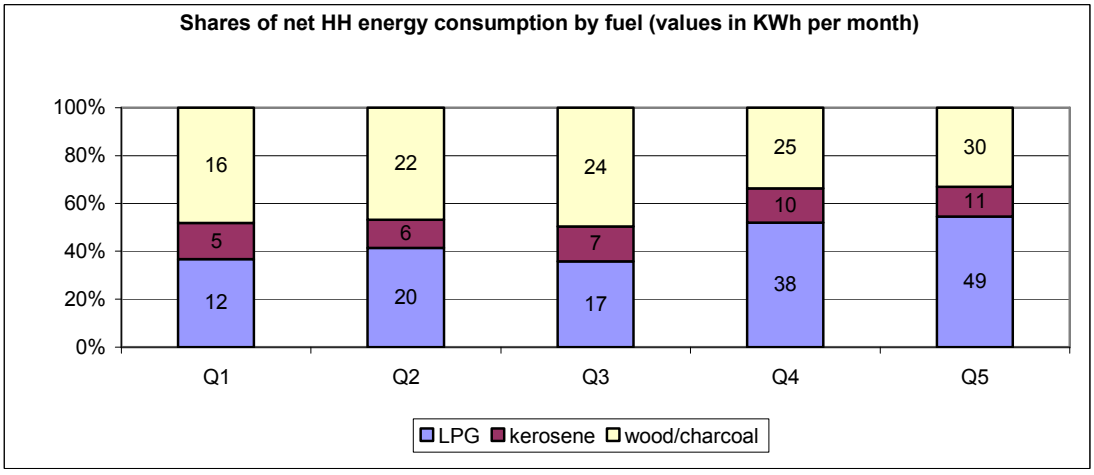
**Figure 3-5: Index relative to first quintile**




Source: authors' calculations

Figure 3-6 shows that although in absolute terms the rich consume a higher amount of net energy than the poor, the share of each type of fuel across quintiles remains extremely similar.

**Figure 3-6: Shares of net HH energy consumption by fuel**




Source: authors' calculations

A similar exercise can be undertaken focusing separately on each fuel. In the case of wood-fuel, this will allow us to focus on the environmental impact of the households' use of cooking.

If we compare the net energy consumption of the 5th (richest) quintile with the 1st (poorest) quintile's one, we get a higher ratio for more "modern fuels", namely 4.1 for LPG, 2.2 for kerosene, and 1.9 for wood-fuel. This tells us that the inequalities are much

larger in the use of LPG than in the use of wood-fuel. However, even in the latter category, the rich spend and consume nearly twice more than the poor. We can now split the analysis just made according to each type of cooking fuel:

**Table 3-5: LPG Comparison of HH monthly energy expenditures with gross and net consumption across quintiles**

| LPG Quintile | Energy Expenditure (US$) | Gross consumption (kWh) | Net consumption (kWh) | Kg |
|---|---|---|---|---|
| 1 | 1.1 | 21 | 12 | 1.7 |
| 2 | 1.7 | 33 | 20 | 2.6 |
| 3 | 1.5 | 29 | 17 | 2.3 |
| 4 | 3.3 | 64 | 38 | 5.1 |
| 5 | 4.2 | 81 | 49 | 6.5 |

Source: authors' calculations

There is an interesting jump between the 3rd (corresponding to $119 per month per household) and 4th quintiles ($ 155) in terms of LPG consumption. This jump can also be observed in the use of kerosene - see table below.

**Table 3-6: KEROSENE Comparison of HH monthly energy expenditures with gross and net consumption across quintiles**

| Kerosene Quintile | Energy Expenditure (US$) | Gross consumption (kWh) | Net consumption (kWh) | Liters |
|---|---|---|---|---|
| 1 | 1.4 | 14 | 5 | 1.5 |
| 2 | 1.5 | 16 | 6 | 1.6 |
| 3 | 1.9 | 20 | 7 | 2.0 |
| 4 | 2.8 | 30 | 10 | 3.1 |
| 5 | 3.0 | 32 | 11 | 3.3 |

Source: authors' calculations

Table 3-7 gives the equivalent data for the wood-fuel category:

**Table 3-7: WOOD-FUEL Comparison of HH monthly energy expenditures with gross and net consumption across quintiles**

| Wood-fuel Quintile | Energy Expenditure (US$) | Gross consumption (kWh) | Net consumption (kWh) | Kg |
|---|---|---|---|---|
| 1 | 1.9 | 85 | 16.2 | 13.3 |
| 2 | 2.5 | 116 | 22.1 | 18.2 |
| 3 | 2.7 | 125 | 23.8 | 19.6 |
| 4 | 2.9 | 130 | 24.7 | 20.4 |
| 5 | 3.4 | 156 | 29.6 | 24.4 |

Source: authors' calculations

### c. Environmental Impact

The fact that more than 80% of the population of the countries analyzed in this study relay on wood-fuel for cooking has indeed an impact on biomass stocks. According to the FAO, the forest area is decreasing by 0.2% per year at the global level, and by 0.6%

in Africa (FAO 2006). The reasons for this shrink vary from one region to another, and include agricultural expansion, firewood-fuel collection, wood-fuel production, timber harvesting, and development infrastructure. In this section we will focus on the effect of cooking fuels usage in the decrease of biomass stock. A number of studies report a clear link between wood-fuel extraction and deforestation based on statistical analysis from data collected (e.g. Tole 1998). We should keep in mind that we are focusing on a subgroup of the total wood-fuel extracted to use as energy, i.e. we are only interested in the wood-fuel taken for cooking purposes, thus excluding other energy uses that could be satisfied by wood-fuel such as heating.

Using FAO 2005 data on biomass stock in each country, the following table represents the % of the overall stock disappearing each year due to use as a household fuel[7]:

**Table 3-8: Percentage of biomass stock used for cooking purposes (million tonnes)**

| Country | Annual wood-fuel consumption for cooking | Biomass stock (FAO 2005) | % |
|---|---|---|---|
| Benin | 2.9 | 0 | / |
| Burkina Faso | 4.7 | 577 | 0.82% |
| Cameroon | 2.7 | 3066 | 0.09% |
| Cape Verde | 0.1 | 12 | 1.12% |
| Cote d'Ivoire | 8.5 | 4091 | 0.21% |
| Ethiopia | 5.1 | 907 | 0.56% |
| Gabon | 0.6 | 6363 | 0.01% |
| Ghana | 9.7 | 865 | 1.12% |
| Kenya | 9.8 | 610 | 1.61% |
| Madagascar | 3.0 | 5160 | 0.06% |
| Malawi | 7.5 | 260 | 2.89% |
| Mauritania | 0.7 | 10 | 6.85% |
| Mozambique | 0.4 | 3234 | 0.01% |
| Niger | 5.8 | 39 | 14.99% |
| Nigeria | 18.0 | 2653 | 0.68% |
| Rwanda | 3.2 | 93 | 3.41% |
| Senegal | 0.6 | 634 | 0.10% |
| South Africa | 7.8 | 3032 | 0.26% |
| Uganda | 8.7 | 271 | 3.20% |
| Zambia | 3.0 | 2217 | 0.14% |
| **TOTAL** | **102.8** | **34,094** | **0.30%** |

Source: authors' calculations based on AICD Household Surveys Database & FAO 2005

Globally, more than 100 million tones of wood-fuel are spent each year out of a biomass stock of 34 billion tones of wood-fuel in the countries studied, which corresponds to an annual decrease of 0.3% of biomass stock. Considering the FAO reference of 0.6% of

[7] We assume that half of the wood-fuel consumption is wood, while the other half is charcoal. For the latter, we assume that 9kg of wood are needed to produce 1kg of charcoal. This ratio is much lower in other parts of the world but increases up to 9 to 1 in SSA because the carbonization efficiency is significantly lower (IEP 2006).

annual deforestation rate in Africa, cooking fuels account for half of the deforestation rate. The situation seems particularly worrying in some countries such as Niger, Mauritania, Rwanda, and Uganda. For example, if the current trend was maintained and wood-fuel was only used as a cooking fuel – a very conservative and unrealistic assumption – Niger's biomass stock would be reduced by half in less than 5 years.

## 4. Conclusion and further research suggestions

SSA is performing worse than other regions of the developing world in terms of access to modern fuels. A vast majority of SSA households use wood-fuel as their main cooking fuel. As their patterns of cooking energy consumption evolve, countries seem to specialize either in LPG or in kerosene: this would confirm what we have called the bifurcation hypothesis. However, the penetration rate of kerosene is higher than the one of LPG, which is an argument in favor of the energy ladder view, since kerosene are considered to be below LPG in the energy ladder.

Some countries perform surprisingly well. Senegal, for example, has had an effective policy in terms of expanding access of households to the top of the energy ladder, namely to LPG. Yet this benefit should be compared with the fiscal burden this policy has caused to the government.

Wood-fuel behaves as a superior good for the lowest quintiles of the population only, i.e. it has positive income elasticity. However, in higher quintiles it behaves as an inferior good due to the substitution effect to fuels of higher quality. The burden of cooking fuels is therefore much higher for poor than for rich people.

This paper has argued that incentives should be given to households to switch to more modern fuels. However, this policy does not exclude the scaling-up of improved stoves. As the World Energy Outlook 2006 states: "two complementary approaches can improve this situation: promoting more efficient and sustainable use of traditional biomass; and encouraging people to switch to modern cooking fuels and technologies. The appropriate mix depends on local circumstances such as per-capita incomes and the availability of a sustainable biomass supply".

This exercise had two main constraints in terms of data availability. First, the classification of "types of fuels" was not optimal. And second, the lack of better data on prices makes the results obtained fragile. Concerning the categories in which the data was collected, a first problem arises in putting in the same category kerosene, gasoline, gas oil, and paraffin, which have different physical and economic characteristics. Another limitation was to have charcoal and wood in the same category, since this did not allow us to test the hypothesis that, among the vast majority of the population in SSA, who use mainly wood-fuel for cooking purposes, those living in urban areas tend to use charcoal and those in rural areas wood. Finally, not having country specific details on what the "other" category included has probably left some questions unanswered. These considerations should be taken into account when designing new household surveys, so that the analysis of this sector can also benefit from new data. Having more data on rural-urban migrations would allow seeing the net effect of the growth rates of the different types of fuels.

As for the prices, the assumptions made in Annex 3 clearly show that the results inferred from the available prices should only be seen as a benchmark. Ideally, a study in the near future based on household surveys will be able to match the prices that each household

faces for different types of fuels. A second best scenario would be to have data for each region of each country.

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## ANNEX 1: Urban and Rural Dispersion of primary fuel use across Countries

**Table 1: Dispersion of use across countries (Urban)**

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Gabon | 78.93% | Nigeria | 44.95% | Rwanda | 98.30% | Guinea | 60.05% |
| Senegal | 74.65% | Kenya | 39.56% | Mali | 97.61% | Ethiopia | 3.27% |
| Lesotho | 57.46% | Ethiopia | 24.62% | Madagascar | 96.35% | Congo_(Brazza) | 2.63% |
| Mauritania | 46.22% | Lesotho | 24.52% | Tanzania | 93.38% | Mauritania | 1.85% |
| Cameroon | 22.47% | South_Africa | 24.03% | Mozambique | 91.92% | Benin | 1.67% |
| Sudan | 18.41% | Zimbabwe | 19.56% | Benin | 89.46% | Cameroon | 1.65% |
| Namibia | 16.22% | Cameroon | 8.79% | Malawi | 88.72% | Mali | 1.51% |
| Congo_(Brazza) | 15.05% | Namibia | 7.18% | Burkina_Faso | 88.55% | South_Africa | 1.49% |
| Ghana | 14.93% | Benin | 7.10% | Uganda | 87.81% | Burkina_Faso | 1.48% |
| Kenya | 12.17% | Congo_(Brazza) | 6.64% | Ghana | 82.71% | Gabon | 1.32% |
| Burkina_Faso | 9.79% | Tanzania | 4.99% | Sudan | 80.89% | Rwanda | 1.21% |
| South_Africa | 6.80% | Uganda | 4.88% | Congo_(Brazza) | 71.28% | Lesotho | 1.10% |
| Mozambique | 4.55% | Gabon | 2.69% | Ethiopia | 69.65% | Uganda | 1.08% |
| Madagascar | 2.35% | Mozambique | 1.14% | Cameroon | 67.09% | Kenya | 1.06% |
| Nigeria | 1.85% | Ghana | 0.65% | Zambia | 58.48% | Ghana | 0.85% |
| Benin | 1.77% | Burkina_Faso | 0.18% | Nigeria | 52.05% | Senegal | 0.84% |
| Ethiopia | 1.15% | Madagascar | 0.15% | Mauritania | 51.93% | Nigeria | 0.82% |
| Uganda | 0.93% | Rwanda | 0.09% | Kenya | 46.05% | Tanzania | 0.72% |
| Mali | 0.81% | Malawi | 0.06% | Guinea | 39.28% | Mozambique | 0.31% |
| Zimbabwe | 0.45% | Mali | 0.06% | Senegal | 24.32% | Namibia | 0.28% |
| Rwanda | 0.22% | Guinea | 0.06% | Namibia | 18.73% | Madagascar | 0.26% |
| Guinea | 0.21% | Mauritania | 0.00% | Gabon | 16.38% | Malawi | 0.21% |
| Tanzania | 0.17% | Senegal | 0.00% | South_Africa | 13.68% | Zambia | 0.07% |
| Malawi | 0.14% | Zambia | 0.00% | Lesotho | 9.49% | Zimbabwe | 0.03% |
| Zambia | 0.06% | Sudan | 0.00% | Zimbabwe | 5.07% | Sudan | |

**Table 2: Dispersion of use across countries (Rural)**

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Gabon | 14.86% | South_Africa | 16.83% | Rwanda | 99.59% | Lesotho | 8.69% |
| Mauritania | 14.29% | Nigeria | 9.32% | Tanzania | 99.52% | Ethiopia | 8.33% |
| Senegal | 10.64% | Lesotho | 7.20% | Malawi | 99.52% | Mali | 4.65% |
| Lesotho | 10.39% | Zimbabwe | 2.05% | Mozambique | 99.47% | Senegal | 3.98% |
| Sudan | 5.79% | Kenya | 1.40% | Burkina_Faso | 99.39% | Namibia | 3.91% |
| Namibia | 2.72% | Congo_(Brazza) | 1.03% | Benin | 99.06% | Guinea | 3.21% |
| South_Africa | 2.66% | Uganda | 0.90% | Madagascar | 98.85% | South_Africa | 3.09% |
| Ghana | 1.07% | Namibia | 0.68% | Uganda | 98.82% | Cameroon | 1.46% |
| Kenya | 0.95% | Cameroon | 0.64% | Ghana | 98.31% | Mauritania | 1.29% |
| Congo_(Brazza) | 0.93% | Benin | 0.54% | Zambia | 97.56% | Congo_(Brazza) | 1.09% |
| Nigeria | 0.63% | Gabon | 0.23% | Cameroon | 97.33% | Nigeria | 0.96% |
| Cameroon | 0.57% | Ghana | 0.22% | Kenya | 97.28% | Madagascar | 0.62% |
| Madagascar | 0.42% | Tanzania | 0.09% | Guinea | 96.77% | Zimbabwe | 0.50% |
| Burkina_Faso | 0.15% | Ethiopia | 0.05% | Congo_(Brazza) | 96.48% | Burkina_Faso | 0.42% |
| Benin | 0.13% | Madagascar | 0.05% | Zimbabwe | 95.97% | Rwanda | 0.35% |
| Zimbabwe | 0.08% | Malawi | 0.03% | Mali | 95.29% | Tanzania | 0.35% |
| Mali | 0.06% | Burkina_Faso | 0.03% | Sudan | 93.47% | Zambia | 0.34% |
| Guinea | 0.02% | Rwanda | 0.02% | Ethiopia | 91.61% | Gabon | 0.33% |
| Malawi | 0.01% | Guinea | 0.00% | Namibia | 89.27% | Mozambique | 0.33% |
| Mozambique | 0.01% | Mozambique | 0.00% | Nigeria | 89.03% | Kenya | 0.32% |
| Zambia | 0.01% | Mali | 0.00% | Senegal | 85.18% | Benin | 0.27% |
| Ethiopia | 0.00% | Mauritania | 0.00% | Mauritania | 84.43% | Ghana | 0.23% |
| Rwanda | 0.00% | Senegal | 0.00% | Gabon | 84.42% | Uganda | 0.21% |
| Tanzania | 0.00% | Zambia | 0.00% | Lesotho | 73.51% | Malawi | 0.14% |
| Uganda | 0.00% | Sudan | 0.00% | South_Africa | 65.91% | Sudan | |

## ANNEX 2: Urban and Rural Annualized Change in Use

### Table 1: Urban Annualized Change in Use 2001-05

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Senegal | 2.14% | Nigeria | 1.83% | Rwanda | 8.13% | Guinea | 2.06% |
| Gabon | 1.95% | Kenya | 1.26% | Mali | 4.65% | Ethiopia | 0.11% |
| Mauritania | 1.47% | Ethiopia | 0.84% | Burkina_Faso | 4.64% | Rwanda | 0.10% |
| Cameroon | 0.81% | South_Africa | 0.47% | Malawi | 4.23% | Congo_(Brazza) | 0.10% |
| Sudan | 0.80% | Zimbabwe | 0.35% | Mozambique | 3.92% | Burkina_Faso | 0.08% |
| Ghana | 0.56% | Cameroon | 0.32% | Uganda | 3.74% | Mali | 0.07% |
| Lesotho | 0.55% | Benin | 0.29% | Benin | 3.63% | Benin | 0.07% |
| Congo_(Brazza) | 0.55% | Congo_(Brazza) | 0.24% | Sudan | 3.50% | Cameroon | 0.06% |
| Burkina_Faso | 0.51% | Lesotho | 0.24% | Tanzania | 3.31% | Mauritania | 0.06% |
| Namibia | 0.46% | Uganda | 0.21% | Madagascar | 3.23% | Uganda | 0.05% |
| Kenya | 0.39% | Namibia | 0.21% | Ghana | 3.12% | Kenya | 0.03% |
| Mozambique | 0.19% | Tanzania | 0.18% | Congo_(Brazza) | 2.59% | Nigeria | 0.03% |
| South_Africa | 0.13% | Gabon | 0.07% | Cameroon | 2.41% | Gabon | 0.03% |
| Madagascar | 0.08% | Mozambique | 0.05% | Ethiopia | 2.37% | Ghana | 0.03% |
| Nigeria | 0.08% | Ghana | 0.02% | Nigeria | 2.12% | South_Africa | 0.03% |
| Benin | 0.07% | Burkina_Faso | 0.01% | Mauritania | 1.65% | Tanzania | 0.03% |
| Uganda | 0.04% | Rwanda | 0.01% | Kenya | 1.47% | Senegal | 0.02% |
| Ethiopia | 0.04% | Madagascar | 0.01% | Guinea | 1.35% | Mozambique | 0.01% |
| Mali | 0.04% | Malawi | 0.00% | Zambia | 1.05% | Lesotho | 0.01% |
| Rwanda | 0.02% | Mali | 0.00% | Senegal | 0.70% | Malawi | 0.01% |
| Zimbabwe | 0.01% | Guinea | 0.00% | Namibia | 0.54% | Madagascar | 0.01% |
| Guinea | 0.01% | Mauritania | 0.00% | Gabon | 0.40% | Namibia | 0.01% |
| Malawi | 0.01% | Senegal | 0.00% | South_Africa | 0.27% | Zambia | 0.00% |
| Tanzania | 0.01% | Zambia | 0.00% | Lesotho | 0.09% | Zimbabwe | 0.00% |
| Zambia | 0.00% | Sudan | 0.00% | Zimbabwe | 0.09% | Sudan | 0.00% |

## Table 2: Rural Annualized Change in Use 2001-05

| Country | LPG | Country | Kerosene | Country | Wood-fuel | Country | Other |
|---|---|---|---|---|---|---|---|
| Mauritania | 0.41% | Nigeria | 0.06% | Uganda | 3.29% | Ethiopia | 0.14% |
| Senegal | 0.22% | Uganda | 0.03% | Burkina_Faso | 2.73% | Mali | 0.10% |
| Sudan | 0.02% | Kenya | 0.03% | Benin | 2.61% | Senegal | 0.08% |
| Congo_(Brazza) | 0.02% | Congo_(Brazza) | 0.02% | Madagascar | 2.50% | Guinea | 0.05% |
| Kenya | 0.02% | Benin | 0.01% | Mauritania | 2.40% | Mauritania | 0.04% |
| Namibia | 0.01% | Namibia | 0.00% | Mali | 2.15% | Congo_(Brazza) | 0.02% |
| Madagascar | 0.01% | Ghana | 0.00% | Congo_(Brazza) | 1.99% | Namibia | 0.02% |
| Ghana | 0.01% | Tanzania | 0.00% | Kenya | 1.90% | Madagascar | 0.02% |
| Burkina_Faso | 0.00% | Madagascar | 0.00% | Senegal | 1.74% | Burkina_Faso | 0.01% |
| Nigeria | 0.00% | Ethiopia | 0.00% | Malawi | 1.69% | Benin | 0.01% |
| Benin | 0.00% | Burkina_Faso | 0.00% | Ethiopia | 1.59% | Uganda | 0.01% |
| Mali | 0.00% | Malawi | 0.00% | Zambia | 1.59% | Kenya | 0.01% |
| Guinea | 0.00% | Rwanda | 0.00% | Guinea | 1.54% | Nigeria | 0.01% |
| Malawi | 0.00% | Guinea | 0.00% | Tanzania | 1.42% | Zambia | 0.01% |
| Zambia | 0.00% | Mozambique | 0.00% | Mozambique | 0.83% | Tanzania | 0.00% |
| Mozambique | 0.00% | Mali | 0.00% | Ghana | 0.70% | Mozambique | 0.00% |
| Ethiopia | 0.00% | Mauritania | 0.00% | Rwanda | 0.55% | Malawi | 0.00% |
| Rwanda | 0.00% | Senegal | 0.00% | Nigeria | 0.54% | Rwanda | 0.00% |
| Tanzania | 0.00% | Zambia | 0.00% | Namibia | 0.41% | Ghana | 0.00% |
| Uganda | 0.00% | Sudan | 0.00% | Sudan | 0.35% | Sudan | 0.00% |
| Zimbabwe | 0.00% | Cameroon | 0.00% | South_Africa | -0.01% | Zimbabwe | 0.00% |
| South_Africa | 0.00% | Zimbabwe | 0.00% | Zimbabwe | -0.04% | South_Africa | 0.00% |
| Cameroon | 0.00% | South_Africa | 0.00% | Cameroon | -0.09% | Cameroon | 0.00% |
| Lesotho | -0.02% | Gabon | -0.01% | Lesotho | -0.17% | Gabon | -0.01% |
| Gabon | -0.34% | Lesotho | -0.02% | Gabon | -1.95% | Lesotho | -0.02% |

**Annex 3: Assumptions on cooking fuels prices**

The prices considered in this study are a cruel simplification of reality. Prices of cooking fuels vary considerably from one place to the other due to a number of factors. First, there is an important variation on cooking fuel prices across countries depending on the subsidies or taxes policy in place. Second, the urban versus rural can be considerable. For example, in rural areas wood-fuel may be considered to be free since families gather it directly. Generally speaking one should expect to find cheaper prices of LPG and kerosene in urban areas since the supply chain is more developed than in rural areas. A third factor affecting the high variance of cooking fuels price is the endowment of the area as well as its geography.

The prices considered in this study exclude the capital costs of each technology. A rule of thumb is to think that the capital cost is higher as we move up in the energy ladder. A kitchen using LPG will be much more expensive than a three-stone oven which uses wood-fuel. Thus including discounted capital costs of the respective technologies in the price of each cooking fuel would change some of our results, in some cases even reversing trends.

The prices used for LPG and kerosene in this study are taken from a study of urban areas of 13 developing countries - 6 of them from SSA (Barnes et al 2005). Indeed this assumption has its limitations, but it seems to be the best that can be done with the current data constraints. On top of that, we take the prices of kerosene as being representative of the whole kerosene category, once again because of data constraints. The prices used in US$, expressed in per energy unit (both kgoe and MJ) and in per weight unit (kg or liters), are the following:

| **LPG** | **Kerosene** |
|---|---|
| **0.61 $/kgoe** | **1.11 $/kgoe** |
| 0.61 $/kgoe * 1.059 kgoe/ kg = **0.65 $/kg** | 1.11 $/kgoe * 0.824 kgoe/liter = **0.91 $/liter** |
| 0.65 $/kg * 1 kg/45 MJ = **1.4 $ cents / MJ** | 0.91 $/kg * 1 liter/35 MJ = **2.6 $ cents / MJ** |

For the price of wood-fuel, we use data from the AICD Household Surveys Database in the following manner. We have around 10 country observations divided in wood and charcoal, and urban and rural within each category. We obtain an average wood price of $0.12 and of charcoal of $0.17. We take the average of these two values and obtain a price for the wood-fuel category of **$0.14 per kg**.