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Multiple-Household Fuel Use –

a balanced choice between firewood, charcoal and LPG

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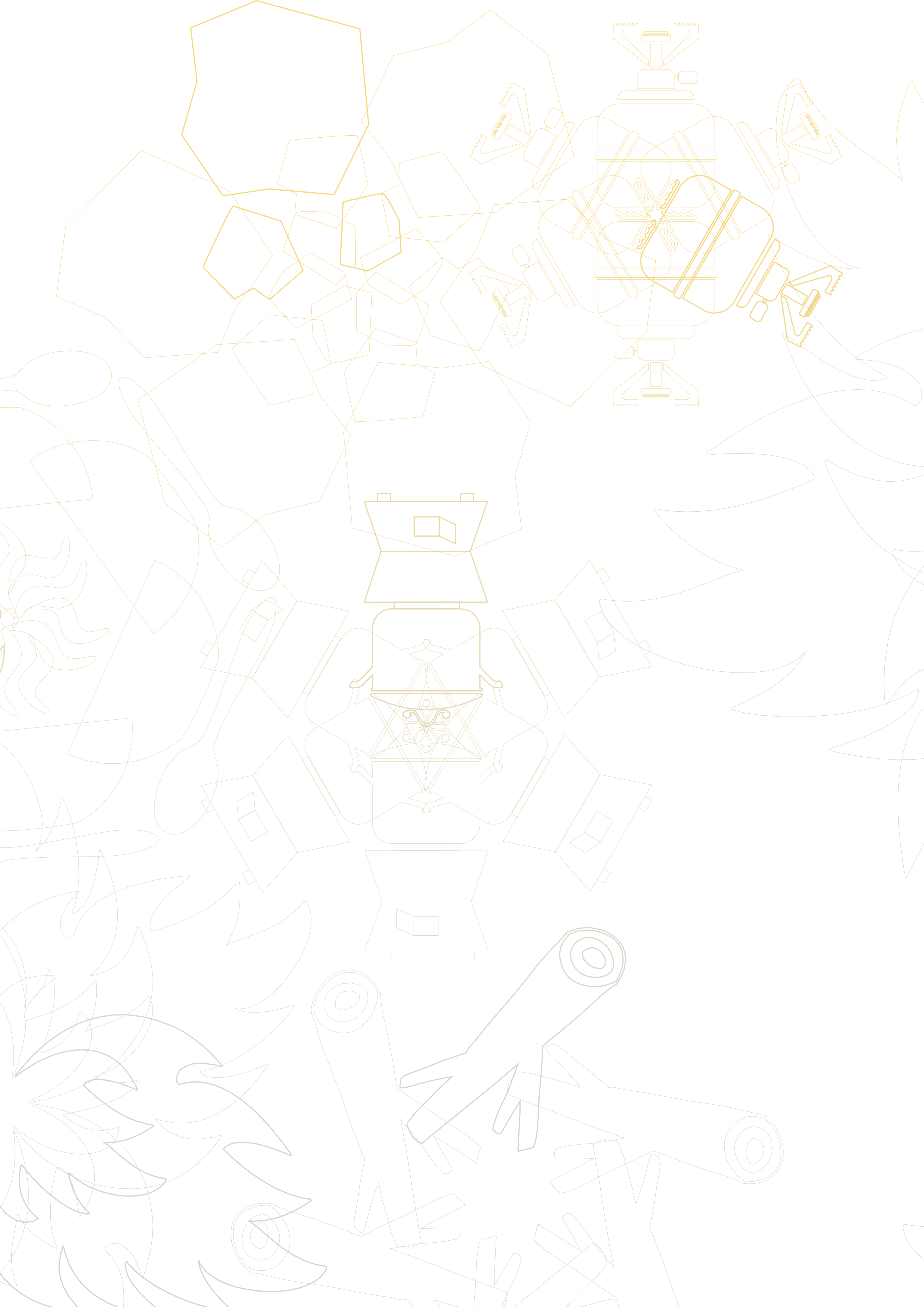

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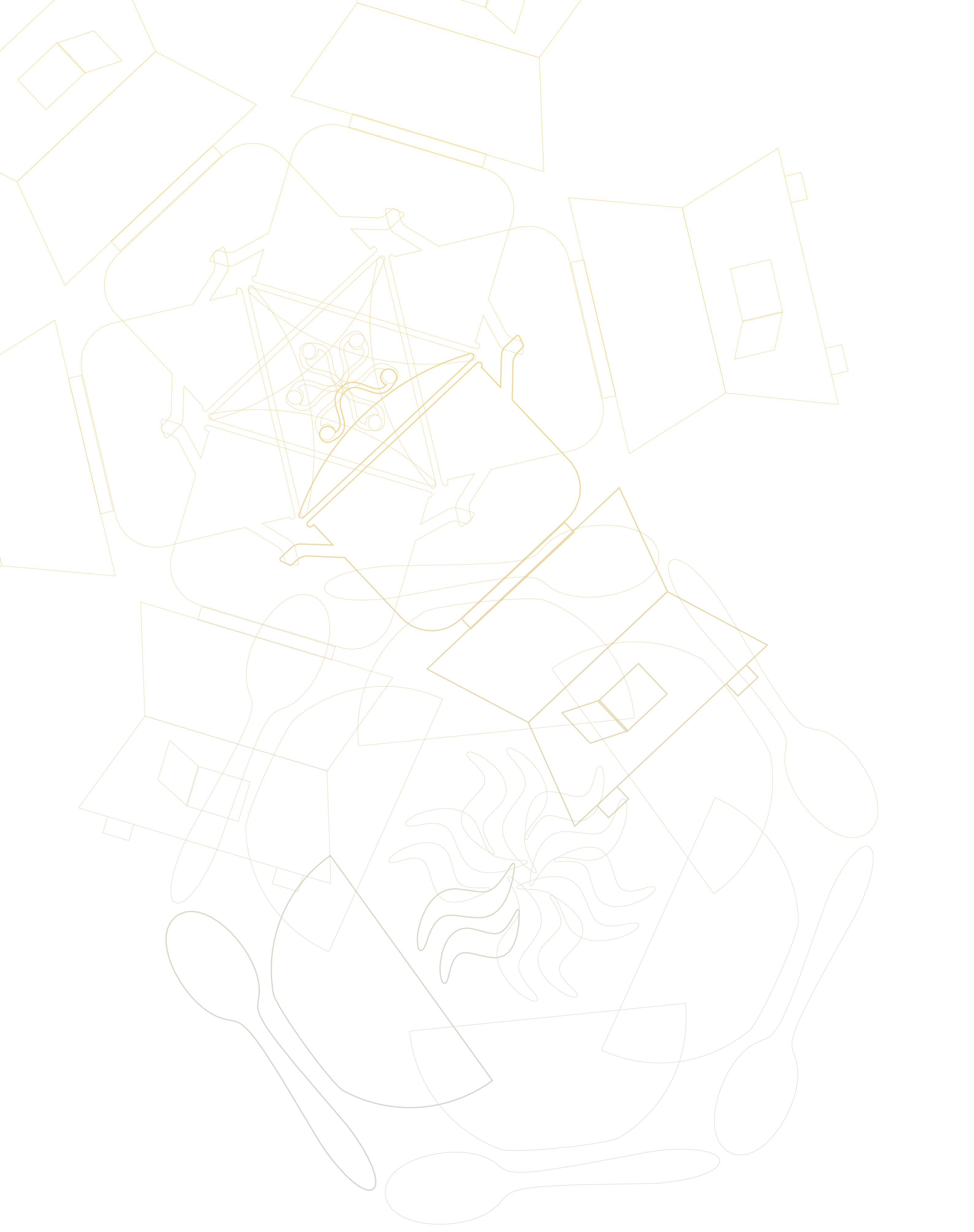
Content



1.0 Multiple-Household Fuel Use –

a balanced choice between firewood, charcoal and LPG

1.1 Fuel theory

The current energy discourse frequently differentiates among "*modern*" and "*traditional*" fuels, assuming that there is a linkage between the income level of households and their fuel choice; this is generally referred to as the "*energy ladder hypothesis*". Petroleum products such as kerosene and LPG as well as electricity are considered to be *modern* fuels at the top of the energy ladder whereas *traditional fuels* such as woodfuels and agricultural waste end up at the bottom. Charcoal is often considered as a transition fuel, being that it is a marketable commodity with a higher level of convenience than *traditional fuels*.

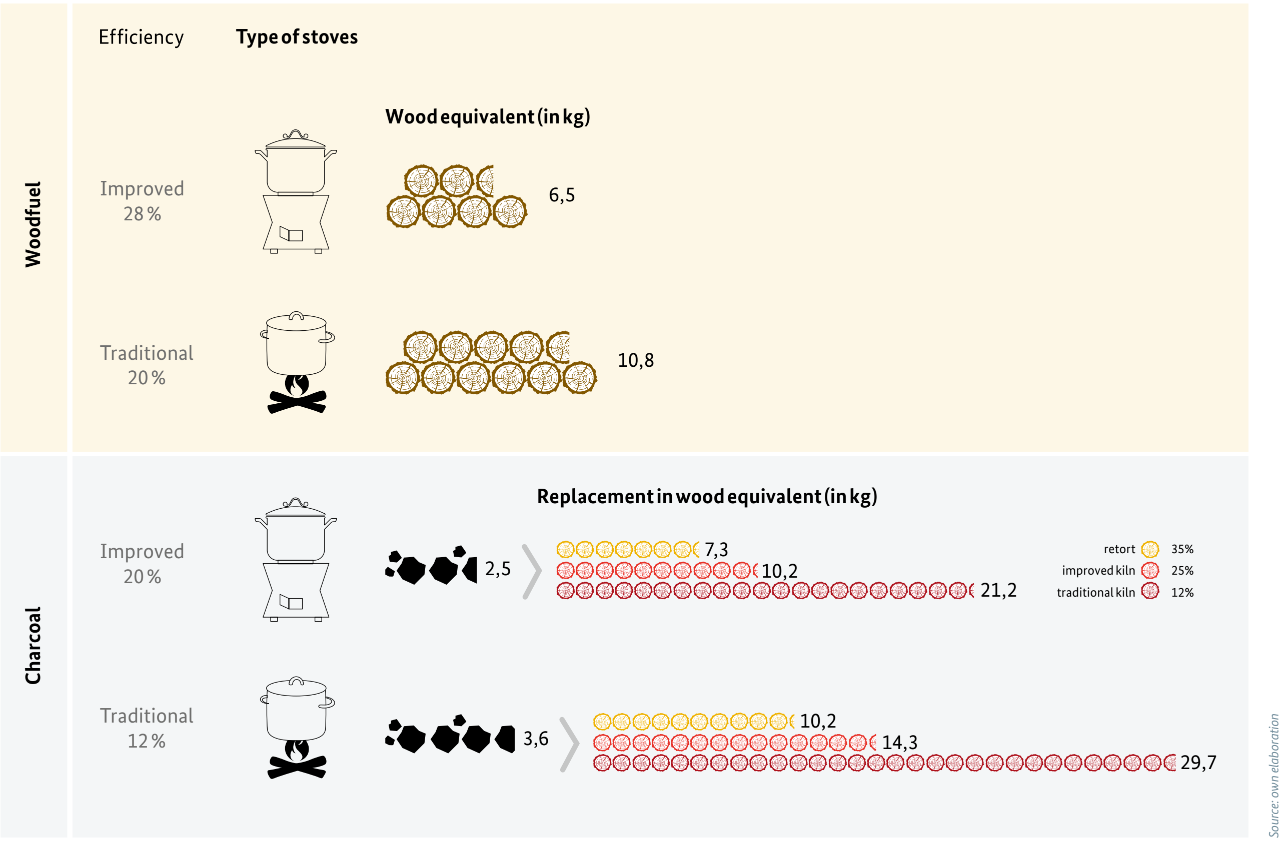
However, upon closer inspection of the energy carriers firewood, charcoal and LPG (see *chapters 2-4*), it becomes apparent that it is not the fuel itself but rather the processing procedure and related technology that make a fuel *modern* from the perspective of energy efficiency, convenience, health benefits and environmental impacts. Additionally, various fuels are often used for certain cooking purposes within a household. Therefore, we must rethink the oversimplified differentiation between *modern* and *traditional* fuels as stipulated by the *energy ladder hypothesis*. New developments in the processing and usage of firewood prove that it can be a highly efficient, renewable and clean energy source.

1.2 Fuel-specific efficiency aspects

In respect to energy density, combustion efficiency, heat-transfer efficiency and heat control characteristics, LPG assumes the leading position among the energy carriers. Despite the fact that it is a fossil fuel, LPG can be burnt very efficiently and emits few pollutants. 1 kg of LPG has an useful energy value of 20.7 MJ [2]; *Figure 1.1* depicts how much firewood would be needed to produce the equivalent amount of useful energy from 1 kg of LGP used in a LPG cooker with 45 % efficiency. As an example: 1 kg of LPG replaces 2.5 kg of charcoal when used with an improved cookstove, equivalent to 21.2 kg of raw wood carbonised with a traditional kiln.

Depending on the type of woodfuel, charcoal production, and cookstove, between 7.3 and 29.7 kg of wood would be required to provide the same amount of useful cooking energy found in 1 kg of LPG.

Figure 1.1: Amount of woodfuel (in kg) replaced by 1 kg of LPG
(depending on the conversion and combustion technology used)



1.3 Household fuel choice

Evidence that has been gathered in many countries does not support the notion that a transition from wood-based energy to fuels such as LPG follows any regularised pattern. Decisions related to energy consumption and fuel type are strongly influenced by accessibility, affordability and the convenience of the fuel. These criteria are closely related to one other and also depend on household income. The decision-making process is complex with economic and technical aspects interlinked with social and cultural issues (see *Table 1.1*). Cooking with woodfuels, for instance, is so deeply ingrained in many local cultures that other fuels have little appeal, even when the potential health and environmental benefits are recognised by users. Furthermore, the prevalence of woodfuel in many developing countries can be explained by the fact that it is still the most readily available, affordable or even cost-free cooking and heating fuel.

The prospects for switching fuels within households as well as for effective government interventions are markedly different for urban and rural areas. Given the fact that

Table 1.1: Determinants of fuel-stove choice

Social/cultural	Economic	Technical
- Family size	- Household income	- Efficiency
- Sex of household head	- Stove affordability	- Emissions
- Age of household head	- Usage costs	- Safety
- Education level	- Fuel availability	- Stove quality/durability
- Taste of food	- Fuel affordability	- Functionality/Speed of cooking
- Cooking habits/customs		- Convenience/portability
- Convenience of fuel		- Aesthetic features
- Food preferences		

Source: own elaboration

woodfuel will continue to remain the primary practical option for rural households, the promotion of improved stoves should be given greater attention.

In urban settings, the availability of LPG, higher education levels and correspondingly higher levels of household income provide the momentum for switching to LPG. However, several household surveys have shown that households do not simply substitute one fuel for another all at once but first begin by using multiple fuels, also known as fuel stacking [3]. Some of the reasons may include:

- LPG is used for quick cooking purposes such as heating water and/or frying,
- meals cooked on traditional stoves are often perceived to taste better [4],
- households with irregular incomes cannot afford refilling their LPG supply once their cylinder is empty,
- unreliable LPG deliveries and the volatile nature of LPG prices necessitate the use of woodfuel stoves as *back-up* stoves.

Thus, fuel stacking also provides a sense of energy security, since complete dependence on a single fuel or technology would leave households vulnerable to price variations and unreliable services, especially in the case of LPG. Conclusive evidence has been provided by the following country cases in which the price of LPG reached a certain threshold, causing users to return to using woodfuels. In Senegal, large numbers of consumers reverted to wood-based biomass for cooking after subsidies for LPG were removed [5]. In Madagascar, the upper-middle class has become increasingly unable to afford LPG due to a price increase of more than 55 % between 2009 and 2013, therefore being forced to revert to charcoal [6]. The case of Dar es Salaam is also noteworthy as the number of households using charcoal for cooking increased from 47 % – 71 %, while the use of LPG declined from 43 % – 12 % [7].

Another barrier is that LPG is seldom sold in small cylinders. As a result, households earning money on a daily or weekly basis are not able to afford the LPG offered in cylinders of 12 kg or more. However, there are developments underway to create distribution channels for smaller cylinders. As incomes increase, households are more likely to make the switch over to charcoal and LPG. Without the introduction of subsidies, LPG use is often limited to the income groups which are able to afford the start-up costs for LPG and are able to withstand volatile LPG price fluctuations.

1.4 Impacts

Health
Exposure to indoor air pollution from the burning of solid fuels for cooking and heating accounts for a significant portion of the global burden of death and illness, disproportionately affecting women and children in developing regions. According to the WHO (2010), indoor air pollution was responsible for 2 million deaths, including over 1 million deaths from chronic obstructive pulmonary disease, and another million deaths from pneumonia in children under the age of 5 [8].

Health impacts depend on a range of parameters related to fuel properties, the type of stoves used, the kitchen environment and cooking behaviour. Generally, emissions from burning firewood have a greater negative impact on health than charcoal or LPG, which are considered relatively clean-burning fuels.

Modern processing and usage technology such as micro-gasifier stoves allow for cleaner firewood combustion. Furthermore, research over the last few years has clearly shown that improved cookstoves can reduce particulate matter (PM) and carbon monoxide (CO) from burning firewood by 24 % – 70 %. As a result, firewood can nowadays be considered a relatively clean-burning fuel given the appropriate equipment. Charcoal emits fewer pollutants, has a higher energy content and is easier to transport than firewood. A complete transition to charcoal would reduce the incidence of acute respiratory infections by 65 % [7]. LPG stoves emit 50 times less pollutants than biomass burning stoves [9].

Environment and Climate
In many developing countries, the demand for woodfuel destroys forests around urban and semi-urban agglomerations, resulting from unsustainable management practices and inefficient conversion and combustion technologies. This leads to a loss in biodiversity, soil erosion and a decline in water and air quality.

As a response strategy, community-based forest management that aims at promoting stewardship and responsibility among local communities and user groups can create incentives for resource-savings and sustainable approaches to forestry.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Furthermore, reforestation of degraded sites not only alleviates existing pressures on forest resources but likewise counters erosion and similarly adverse environmental impacts that arise from overexploitation. Several GIZ-supported projects bear witness to this, such as those in Madagascar and Senegal [10]. Coupled with the introduction of innovative technical developments, woodfuel can become a renewable and climate friendly energy source for populations in rural and urban settings.

When considering charcoal processing, firewood production generally has less negative environmental impact than charcoal, primarily for two reasons. Firstly, the direct use of firewood requires smaller quantities of wood to satisfy the same energy needs as there are no conversion losses such as those related to the carbonisation process for charcoal. Secondly, firewood is less commercialised and a great portion of the rural energy supply comes from the collection of dead branches and trees outside of forests or from fallow land. The introduction of improved kilns can easily double or even triple output (*see Figure 1.1*), therefore deserving particular consideration by decision makers.

Though woodfuel can sustainably be produced in principle, woodfuel production is limited by natural growth conditions and cannot always satisfy the rising demand of a gradually increasing population. Especially in countries with relatively little forest cover or those facing serious deforestation problems, the dissemination of alternative fuels or LPG is of utmost importance as it can considerably reduce woodfuel consumption (*see Figure 1.1*).

Employment and Income

The World Bank/ESMAP estimate that charcoal creates between 200 to 350 jobs per TJ of consumed energy whereas electricity only creates between 80 and 100 jobs, LPG 10 to 20 jobs and kerosene 10 jobs for the same amount of consumed energy [1], suggesting

Figure 1.2: Estimated employment per 1 Tera-Joule consumed energy *= 2 Tera-Joule*

Source: Adapted from RWEDP-FAO, Regional Study on Wood Energy Today and Tomorrow in Asia that the promotion of charcoal can create more jobs than any other fuel. In Sub-Saharan Africa, it is estimated that 13 million people are employed in the biomass energy sector [11]; if the substitution of biomass through LPG is encouraged, people will have to find alternative employment. This likewise brings the risk of increased deforestation and greenhouse gases as people would be forced to clear more forests and woodlands for agriculture and pastoralism.

1.5 Regulatory aspects

Governments still exhibit a serious lack of political will to become involved in the wood energy sector. They often deliberately leave it in the hands of the informal sector and abstain from measures for fighting corruption and the abuse of power by forest officials. Sudden interventions such as banning charcoal (e.g., in Chad, Kenya and Tanzania) proved to be counter-productive and did not end up stopping charcoal production but drove the industry further into informality in escaping public regulation and revenue collection [12]. Areas of open access still prevail as forest administrations are unable to enforce sustainability criteria or exercise effective control of forest dues. Consequently, woodfuel remains underpriced with producer costs not reflecting actual production costs.

Governments must strengthen the institutional frameworks that oversee household energy services and provide also an adequate policy framework for the promotion of sustainable woodfuel production and plantations. To this end, supervision and law enforcement have to be expanded since they play a key role in influencing and interacting with all other components of sustainable woodfuel supply strategies.

Being that consumers are sensitive to relative energy prices, government policies could play an important role in household fuel choices. Incentive-based policies such as taxes and subsidies can particularly help alter fuel choices for households. Market-based schemes that assist households in paying for the start-up costs of LPG or those that subsidise fuel prices have proven to be effective in countries such as Senegal and Brazil [8,9]. However, for low-income countries in particular, it is costly for governments to bear the cost of subsidies, which are also difficult to phase out without the risk of losing consumers.

1.6 Conclusions

A comparison among firewood, charcoal and LPG shows that each energy source has its own specific advantages, inconveniences and limitations. They should be considered jointly within a comprehensive, inter-sectoral energy strategy that provides an effective framework for governments. Fossil fuels are required in areas where the ecological limits of woodfuel production have been reached or even exceeded. Particularly in areas with low forest cover and an exponentially rising population, efforts must be made to decrease the per-capita consumption of woodfuels.

However, the aim of supplying all households with LPG, for example, is impossible from a practical point of view owing to the fact that LPG will remain a fuel for high-income households, leaving many people dependent on woodfuel.

Several new technologies exist that can make woodfuel a competitive renewable energy. Particularly in places where biomass is already a widely used resource, strong arguments in favor of building on the potential of modern usage and processing technologies and improving governance in the forest sector exist. Modernising the woodfuel value chain can help safeguard employment levels, especially in structurally disadvantaged areas, as a greater amount of manpower is needed to sustainably produce wood energy than to supply the same amount of energy through fossil fuels (see *1.4 Impacts*).

This suggests a two-fold policy approach in which woodfuel and fossil fuels are both promoted depending on the circumstances for each region. This recommendation is in line with the World Energy Outlook 2006 which states [13]: *"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"*.

As woodfuel is not placed high on energy policy agendas, formulating and implementing effective policies and strategies through the integration of modernising aspects are crucial factors for ensuring an appropriate energy mix. In view of these circumstances and the importance of wood energy as energy source, the main challenges are:

- including biomass in national energy strategies and performing informed planning (to maximise the effect of development initiatives such as access to energy),
- planning and implementing sustainable and efficient ways to exploit natural resources linked to energy uses; and at the same time taking into account the entire chain, from biomass production to its final use, in order to attain maximum efficiency in production, transport, supply, transformation, technology and use,
- identifying further market opportunities which derive from and encourage development for the poor.

Technological research and innovation as well as experimental testing and assessment in practice remain a focal concern for closing the gap between traditional and highly efficient but costly technologies used in developed countries. New intermediate technologies must systematically be evaluated for their replicability as well as ecological and socio-economic (including health) implications. Proven innovations can create the basis for modern energy value chains and therewith provide a future for countless people engaged in the areas of production and marketing.

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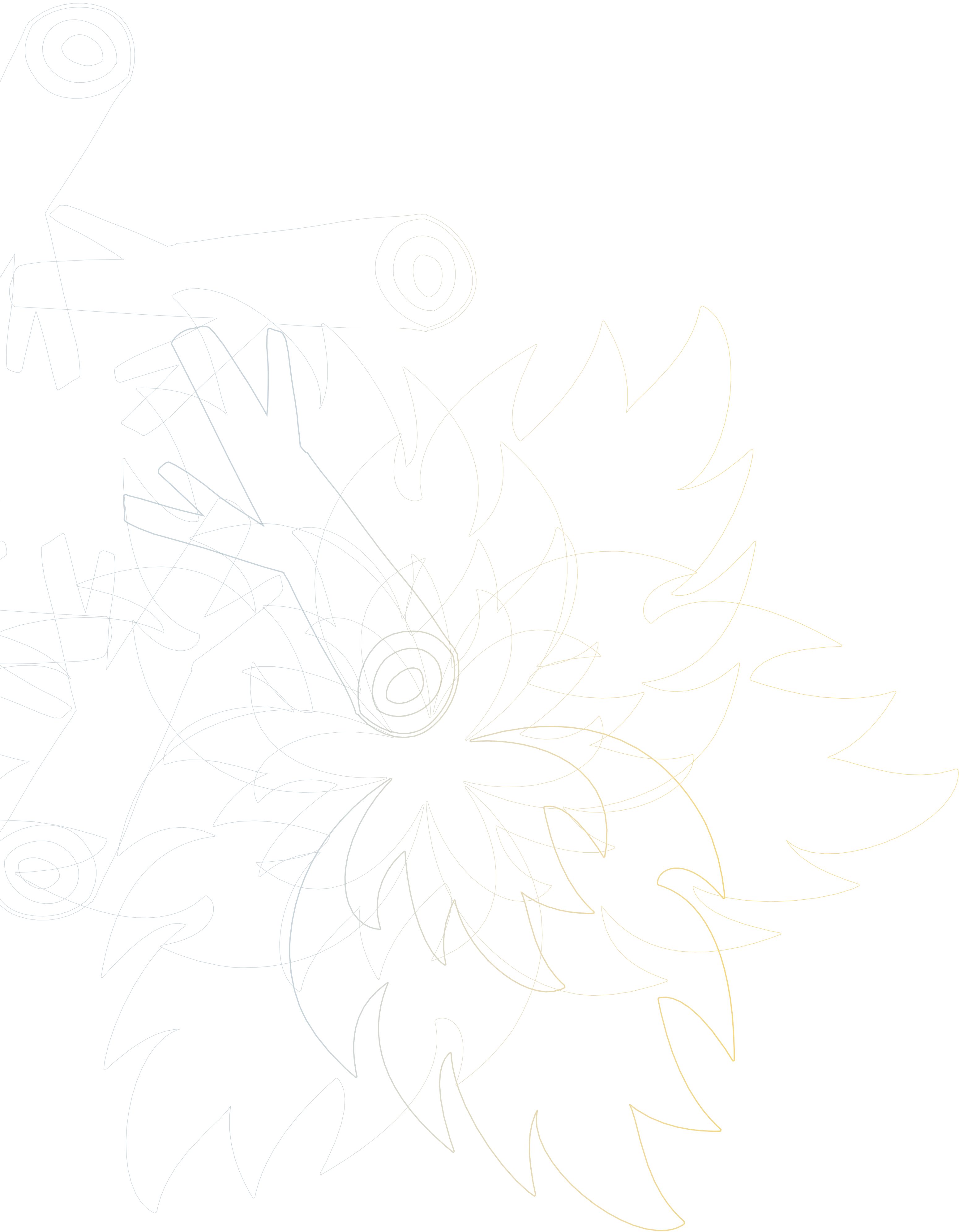


2.0 Firewood –

the cheapest and most widespread fuel

2.1 What is firewood?

Firewood (synonym: fuelwood) is defined by the Food and Agriculture Organization of the United Nations (FAO) as *"wood in the rough (from trunks and branches of trees) to be used as fuel for purposes such as cooking, heating or power production."* In this chapter, the definition of firewood comprises all wood products where the original composition of the wood is preserved, including chips and pellets.

Firewood can be categorised into hardwood and softwood: in comparison to hardwoods, softwoods burn more quickly and generate less heat owing to a lower energy content per volume [1]. However, energy content per weight is similar for all hard- and softwoods; the moisture content of a firewood primarily determines its energy content. The drier the biomass, the less energy required to evaporate the water inside the wood, and, thus, the more energy available for heating or cooking purposes:

Table 2.1: Typical properties of firewood

Volume of a stere/stacked volume:	0.65 solid cubic metre (cum)	
Density:	0.725 tons/cum	
Average moisture content:	Air-dried wood: 15 %	Freshly harvested wood: >50 %
Energy content:	Air-dried wood: 16.0 MJ/kg	Freshly harvested wood: 8 MJ/kg

2.2 How much firewood is produced world-wide?

The available statistics on firewood are generally poor. This is due to the fact that the definitions and conversion rates for firewood vary and since it is primarily produced and traded in the informal sector. Statistics are often only available on *wood fuel*, which is firewood and wood transformed into charcoal. *Figure 2.1* also only depicts global production of wood fuel by region; world-wide wood fuel totals amounted to around 1.86 million m^3 in 2010.

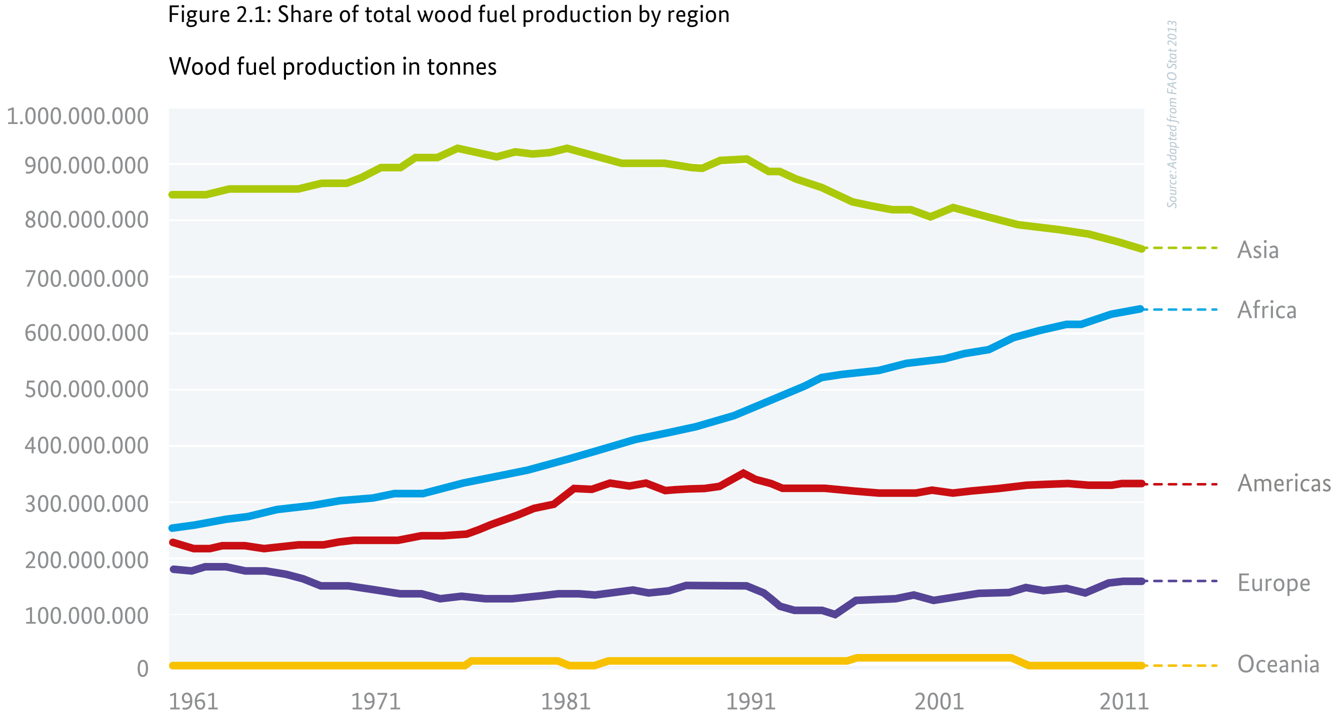
Firewood is produced from tree fallow, shrub fallow, woodlots, tree plantation sites, reforestation sites, agroforestry systems (fruit trees or scattered trees) and shrubland areas [2]. The majority of firewood is not actively *produced* (in the sense of management inputs) in developing countries; rather, households collect it directly as a *common property resource*.

Asia is the region with the highest production of wood fuels, accounting for 771 million m^3 or nearly 45 % of global production. This role is strongly driven by China and India: these two countries account for more than one quarter of global wood fuel consumption. However, Asian consumption of wood fuel has decreased by 3.2 % in the past five years on account of substitution for other fuels; wood fuel consumption in Africa and Latin America have continued to grow [FAO Stat 2013]. *Figure 2.1* makes clear that the production of wood fuel in Africa has constantly been increasing since the 1960s whereas consumption in the Americas has stagnated since the 1990s.

Presently, climate policies in Europe and North America are contributing to growing demand for wood fuel. Densified wood fuel (wood pellets, briquettes) and chips in particular are gaining in importance due to the increasing share of heating and electricity generation applications that utilise wood fuel. Consequently, Europe's wood production increased from 125 million m^3 in 2001 to nearly 160 million m^3 in 2011 (FAO Stat 2012).

Figure 2.1: Share of total wood fuel production by region

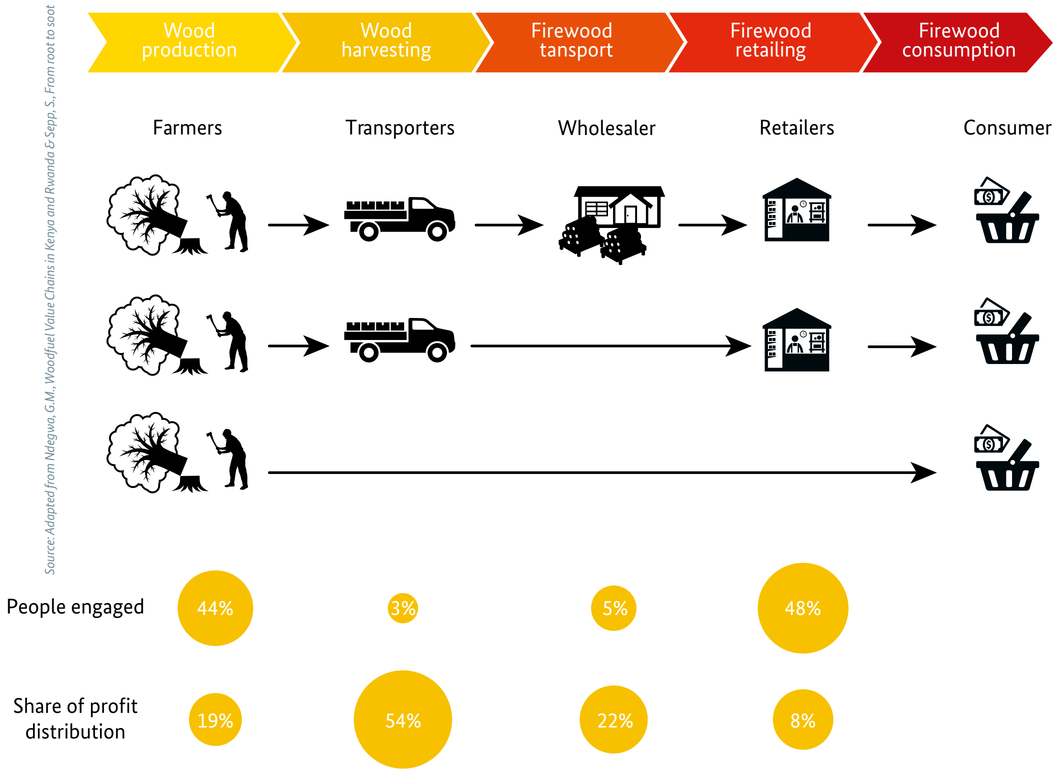
Wood fuel production in tonnes



2.3 How is the firewood market organized?

In developing countries, firewood is either privately collected by households or is acquired at a firewood market. The firewood value chain does, however, have a relatively high degree of informality and poor development; wood production often does not receive proper management inputs since it is generally collected for free in rural areas.

Figure 2.2: Common structure of a firewood supply chain



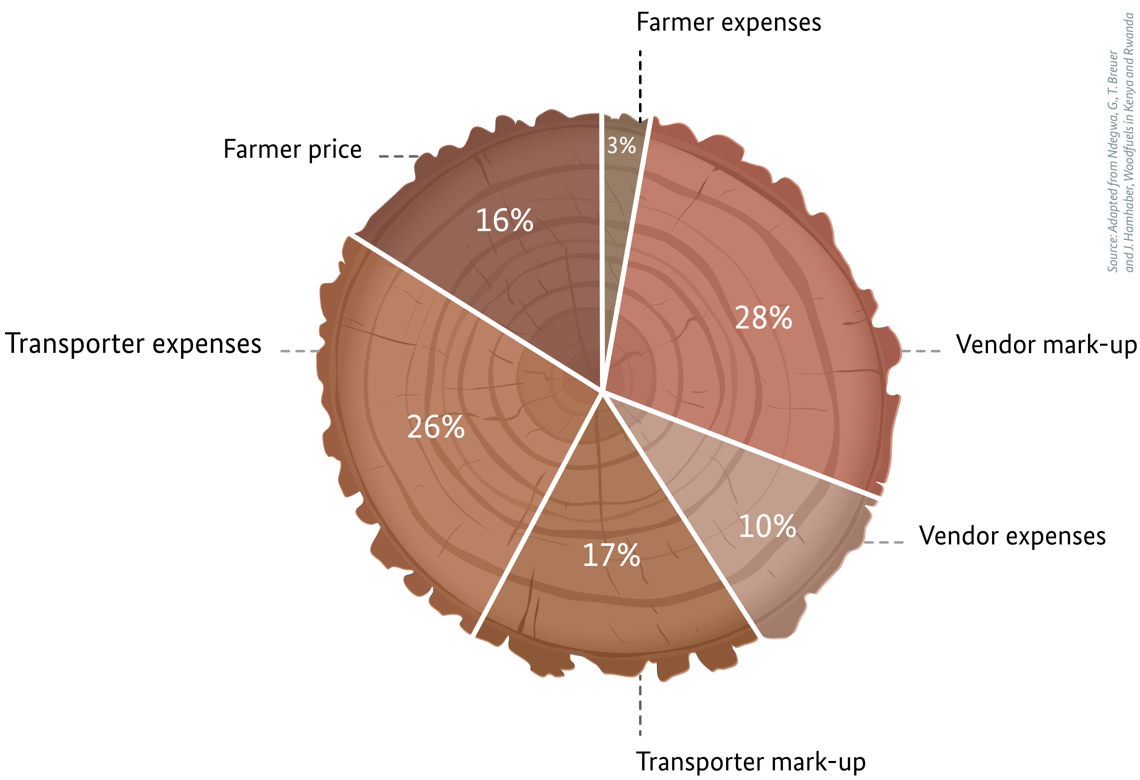
During wood harvesting, local farmers gather firewood and bring it to the nearest road side by head-loads, bicycle-loads or donkey carts. They can sell the firewood to local traders or to transporters, the latter who serve as the principal carriers of firewood to urban areas (see *Figure 2.2*). Commercial firewood traders hire teams of woodcutters for dispatch into forested areas. According to the legal provisions in most countries, a cutting permit is required in order to harvest a prescribed amount of wood from a designated area. In reality, however, wood harvesting, transport and trade are often unregulated. In places where legal restrictions actually do apply, they are frequently ignored due to a lack of legal-regulatory coherence and enforcement capacities in those countries.

Limiting factors to trading firewood include its bulky shape and expensive transportation costs. As a result, production is concentrated to areas around consumption centres which often leads to an overuse of surrounding forest resources and ultimately to the degradation of forests.

Firewood is usually sold in bundles varying from 2 to 40 kg. When traded, firewood prices exhibit high fluctuation as they are influenced by accessibility, transportation costs and availability. Consequently, the market price is not a reliable measure of its scarcity. As an example, the price for a tonne of firewood in rural areas in Malawi amounts to 46 USD whereas the price in urban areas is 57 USD. In the Democratic Republic of Congo, citizens in Kinshasa pay 134 USD per tonne of firewood while they would only pay 20.5 USD for the same amount of firewood in Kinsangani.

Figure 2.3 depicts the share that each actor in the firewood value chain receives from selling one stere of firewood. The price mark-up serves as either the farmers' income or as labor wages of residents. The sale of firewood oftentimes provides much-needed, and often the one and only, possibility for income generation [5]. *Figures 2.2* and *2.3* make apparent that most of the profit in the firewood market is retained by transporters despite their small share of engagement in the overall value chain. Farmers and wood harvesters, who comprise the largest group in the value chain, receive a very small share of the overall profits.

Figure 2.3: Price share for actors in one stere of firewood in Rwanda



Source: Adapted from Ndegwa, G., T. Breuer and J. Hamhaber, Woodfuels in Kenya and Rwanda

2.4 How is firewood used for cooking?

It is very common for rural households to use firewood as their main cooking energy in many developing countries all over the world, especially Sub-Saharan Africa. The use of firewood in rural areas is still predominant since it is often the only available, accessible and affordable fuel in the region. The collection of firewood is typically the responsibility of women and minors and can take up to several hours per day in less forested countries such as Niger and Ethiopia. Countries in which urban households also predominantly rely on firewood are all located in Africa (except for the case of Bangladesh) – *see Table 2.2*. Firewood also plays a role for productive uses, for instance agricultural processing or brick and tile manufacturing.

Table 2.2: Firewood consumed in selected countries by urban and rural areas (in % of population)

Country	Urban / Wood	Rural / Wood
Bangladesh	58	89,6
Burkina Faso	59,6	96,4
Burundi	65,4	97,5
Malawi	51,2	98,3
Mali	59,9	92,5
Niger	94,9	96,1
Rwanda	58,2	98
Sierra Leone	61	99

Source: Adapted from UNDP and WHO (2009)

Accessibility of firewood is a crucial factor for households using firewood for cooking purpose, especially in rural areas where alternative fuels such as LPG are scarce. Households can collect firewood close to their homesteads at all times due to the fact that it is available year-round and not susceptible to heavy seasonal fluctuations. Nonetheless, due to steadily decreasing availability, people are faced with ever-increasing distances and must therefore expend more labour and time to collect firewood, particularly in arid and semi-arid areas.

Affordability plays a decisive role in the use of firewood for cooking. Considering that many households can collect firewood for free, it will remain the cheapest energy source for cooking and heating. If it is purchased at the firewood market, households can chose to only acquire small amounts of wood, allowing for a degree of financial flexibility. The relative price for cooking with firewood remains substantially below that of potential substitute fuels (e.g., Mozambique: firewood 100 %, charcoal 176 %, LPG 282 %). However, one must point out that firewood would be extremely expensive if the additional cost of labor done by women and children collecting firewood were considered as well as the negative impacts on health and the environment were internalised.

Acceptability of firewood is very high as it has been used since ancient times and has shaped cooking habits accordingly. For developing countries in which firewood is used as a main cooking fuel, annual consumption amounts to an average of 680 kg per capita.

2.5 What are the impacts on health and the environment?

Nowadays, wood energy consumption is no longer the primary cause of global deforestation but rather the clearing of land for farming. Around 95 % of cleared forest areas in Sub-Saharan Africa, for example, are attributed to new land requirements for crops [7]. However, concentrated industrial and urban demand for firewood combined with weak regulation and control can still contribute to forest degradation and deforestation around major centres of consumption.

Compared to charcoal, the production of firewood contributes less to deforestation and degradation for two reasons. Firstly, the direct use of firewood requires smaller quantities of wood to satisfy the same energy needs as there are no conversion losses. Secondly, firewood is less commercialised and a great portion of consumed firewood is covered by the collection of dead branches, trees outside of forests or fallow land. However, in many areas (especially around larger villages and cities), the amount of harvested firewood exceeds the annual growth rate of forest resources while inefficient harvesting and utilisation practices are prominent. This counteracts the potential for firewood to be a renewable resource and calls for the establishment of a conducive policy framework that fosters (i) sustainability in forest production and management and (ii) the promotion of efficient conversion and consumption technologies.

Despite popular belief, all fuels can achieve relatively clean combustion granted that proper technologies and techniques are used. The environmental and health benefits of a fuel are primarily dependent on its processing and usage techniques. However, since many people still use traditional stoves, burning firewood continues to have a highly negative impact on health due to high emissions. Households using wood in an open fire experience particulate matter (PM) concentrations of over 3000μg/m^3 in the air compared to households using charcoal stoves, which are only exposed to PM concentrations of around 500μg/m^3 [8].

Health impacts depend on a range of parameters such as human exposure, fuel moisture, burning rate, ventilation and cooking behaviour. According to a Global Burden of Diseases study, 3.5 million premature deaths per year are directly attributable to household air pollution from the use of solid fuels [9]. Research over the last few years has clearly proven that improved cookstoves can reduce both PM and carbon monoxide by 24 % – 70 % [10-12].

2.6 What are challenges and opportunities for modernisation of the firewood value chain?

Firewood is accessible, affordable and highly accepted even among the poorest in societies and is a primary source for national energy supplies in many countries. Though often considered to be a dirty and out-dated fuel, firewood can actually turn into a renewable, climate friendly energy source in the long-term if the resource is properly managed and used [13]. Wood energy is set to receive increased attention as the international, commercial market will likely expand on account of the renewable energy directive issued by the European Union. A significant biomass supply gap of 55 to 85 million tonnes of wood pellets is expected to exist in Europe by 2020; this will require significant imports from Russia, the southern United States, South America and Africa [14].

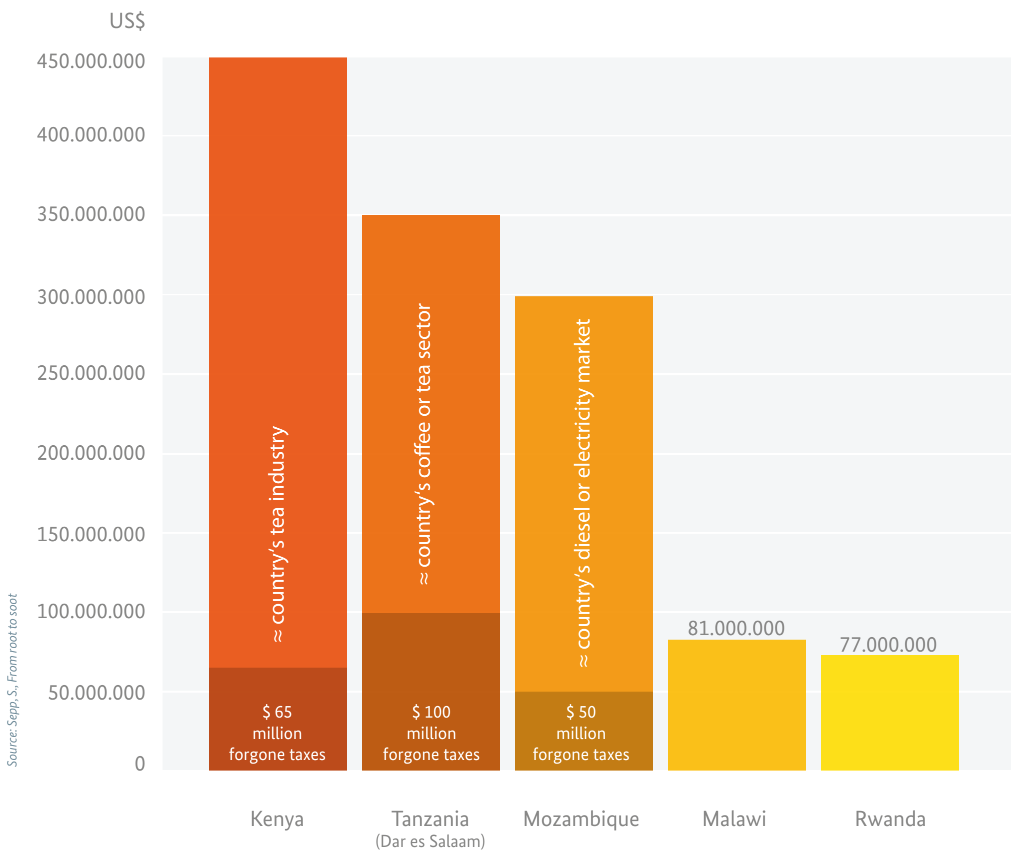
European companies are currently investing in large-scale plantations to meet the impending gap. On the one hand, this raises concerns for sustainable forest biomass supplies while, on the other hand, also presents an opportunity for countries to scale-up their firewood markets and exports. Sustainable markets need regulation and the development of respective pre-conditions in order to avoid problems such as the biofuel-boom several years ago, in which countries were unprepared to establish the framework conditions for sustainable market development.

One of the main problems is that local firewood and exports are still underpriced. Prices do not reflect sustainable production costs and, at the same time, sustainable production is in competition with illegal wood harvesting in open-access areas. *Fig. 2.4* displays annual generated revenues by the wood energy sector (mainly charcoal) in selected African countries and highlights the opportunity for collecting taxes by the government, should the wood market become formalised. The principal challenge is setting basic conditions and policies that control firewood utilisation and aim at bringing wood production into the formal sector. Consequently, this would likely lead to price increases that would curb local overutilisation. The Biomass Energy Stategies (BEST) set out possible approaches for setting basic conditions that promote the sustainable use of solid biomass.

A successful approach is embodied by the current policy shift in the forest sector: communities and/or local user groups in many countries are becoming more and more empowered to manage trees and generate income. Furthermore, international support is being offered through programmes such as Global Environment Facility (GEF), Clean Development Mechanism (CDM), Reducing Emissions from Deforestation and Degradation (REDD+) that promote sustainable forest management.

An opportunity for the technical development and modernisation of firewood use lies in the dissemination of improved cookstoves. The fuel-saving potential of improved cookstoves allows households to save between 22 % and 46 % of firewood compared to a three-stone fire (depending on the technical properties of the cookstove

Figure 2.4: Annual turnover generated by the wood energy sector



and individual cooking habits). There are also other emerging technologies such as micro-gasifiers – stoves which operate on volatile gases, leaving charcoal instead of ash – which provide the cleanest burning option available. The use of micro-gasifiers would lead to increased demand for wood-based fuels such as pellets and wood chips. While firewood can only be transported locally, global trade in wood pellets, briquettes and chips will offer new opportunities in the future as it can economically be transported across long distances.

Another potential lies in an immense amount of industrial timber residue which is often simply disposed of during wood production. In Cameroon, industrial timber residue amount to 2 million m^3 annually. Considering the immense wastage in the timber industry, great potential exists in recycling timber residue into forms such as pellets for energy generation.

Further Reading

The FAO Wood Energy Website
http://www.fao.org/forestry/energy/en

The Global Alliance for Clean Cookstoves
http://www.cleancookstoves.org

The BIOS BIOENERGIESYSTEME Website
http://www.bios-bioenergy.at

Biomass Energy Strategies (BEST)
http://www.euei-pdf.org/publications/flagship-publications

Cooking Energy Compendium - Cooking with Woodfuels
https://energypedia.info/wiki/Cooking_with_Woodfuels_(Firewood_and_Charcoal)

Wood Energy - Renewable, profitable and modern (GIZ 2014)
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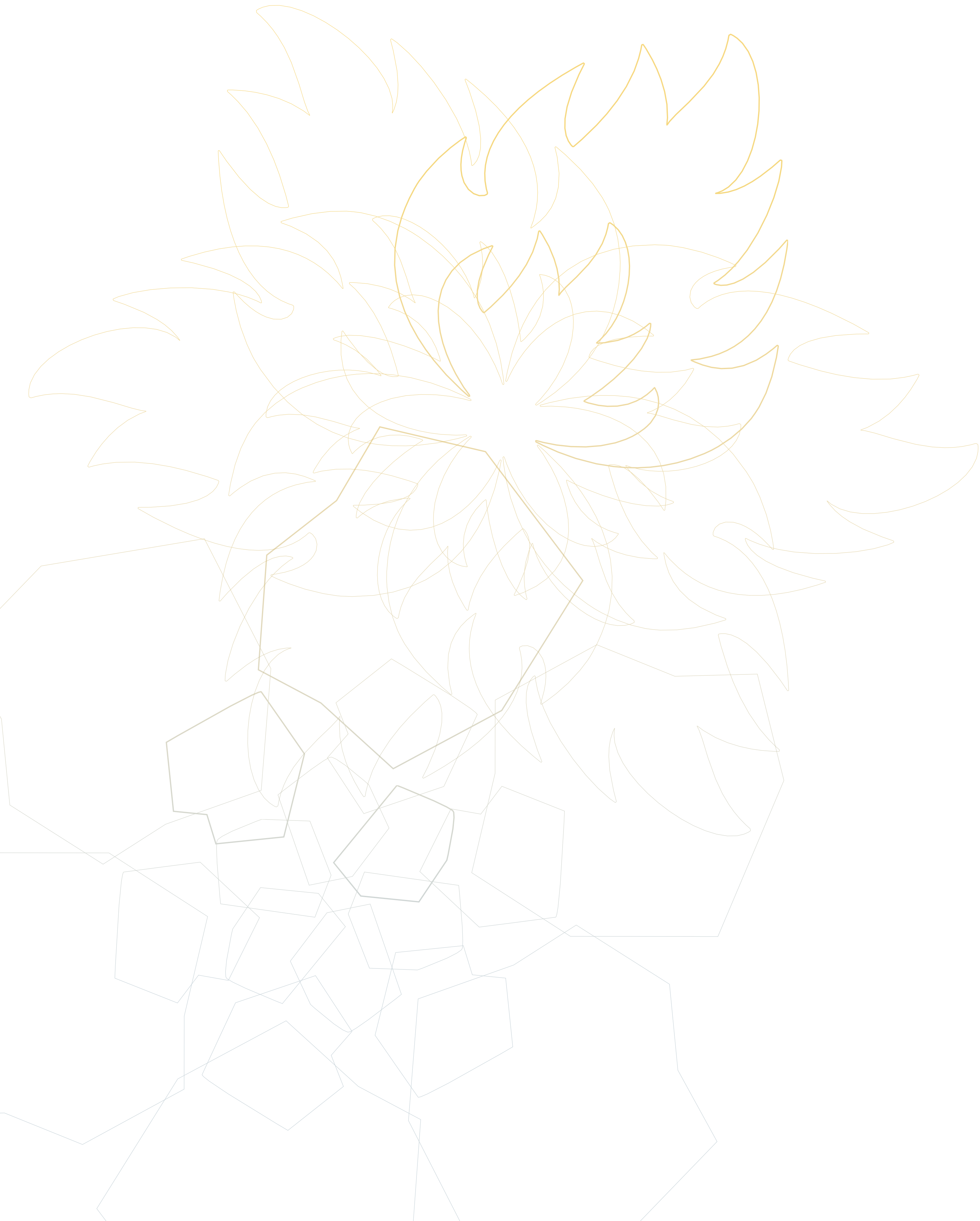


3.0 Charcoal –

the preferred household fuel in urban and peri-urban areas

3.1 What is charcoal?

Charcoal is a solid biofuel obtained through the carbonisation of wood. During the carbonisation process – also called pyrolysis – high temperatures induce the absorption of heat which leads to the complete decomposition of the biomass, separating it into volatile gases, vapors and solid char. At 400°C, the transformation of the wood into charcoal is complete. At this stage, however, the charcoal still contains a considerable amount of tar which must be reduced through additional heating in order to achieve a final carbon content of around 80 % [19].

Charcoal is predominantly produced by using various sorts of wood; however, it can also be formed from a wide range of alternative feedstocks, such as bamboo, cotton stalks.

The energy efficiency of the carbonisation process as well as the quality of the charcoal are dependent on many factors, such as:

- the type of kiln (open pits, earthen kilns or steel cylinders – also called retorts),
- moisture content,
- wood species and wood stacking,
- production skills of the producer.

Table 3.1: Typical properties of charcoal

Density	200 kg/ m^3 - 600 kg/m^3 (depending on the parent wood density)	
Bulk density: :	200 kg/ m^3 - 300 kg/ m^3	
Average moisture content:	5 %	
Energy content:	27 – 33 MJ/kg (depending on the fixed carbon and the carbonisation temperature)	
Fixed carbon content:	80 % - 90 %	
Conversion:	a) 1 kg firewood = 0,1 kg – 0,3 kg charcoal	b) 1m³ firewood (weighing 750 kg – 859 kg) = 165 kg charcoal

Source: FAO, Conversion and Emission Factors

Charcoal has an average energy content of 30 MJ/kg, which is higher than the 16 MJ/kg average for firewood. However, the carbonisation of firewood into charcoal requires the consumption of energy: the conversion of 1 kg of wood yields only 0.1 – 0.3 kg of charcoal (at 10 %-30 % kiln efficiency). In other words, in order to produce 1 kg of charcoal with a specific energy content of 30 MJ/kg, 3.3 to 10 kg of firewood are required, which would otherwise have a total energy content of 53 to 160 MJ. Therefore, by using charcoal instead of firewood, one loses up to six times the total amount of energy contained in the original firewood.

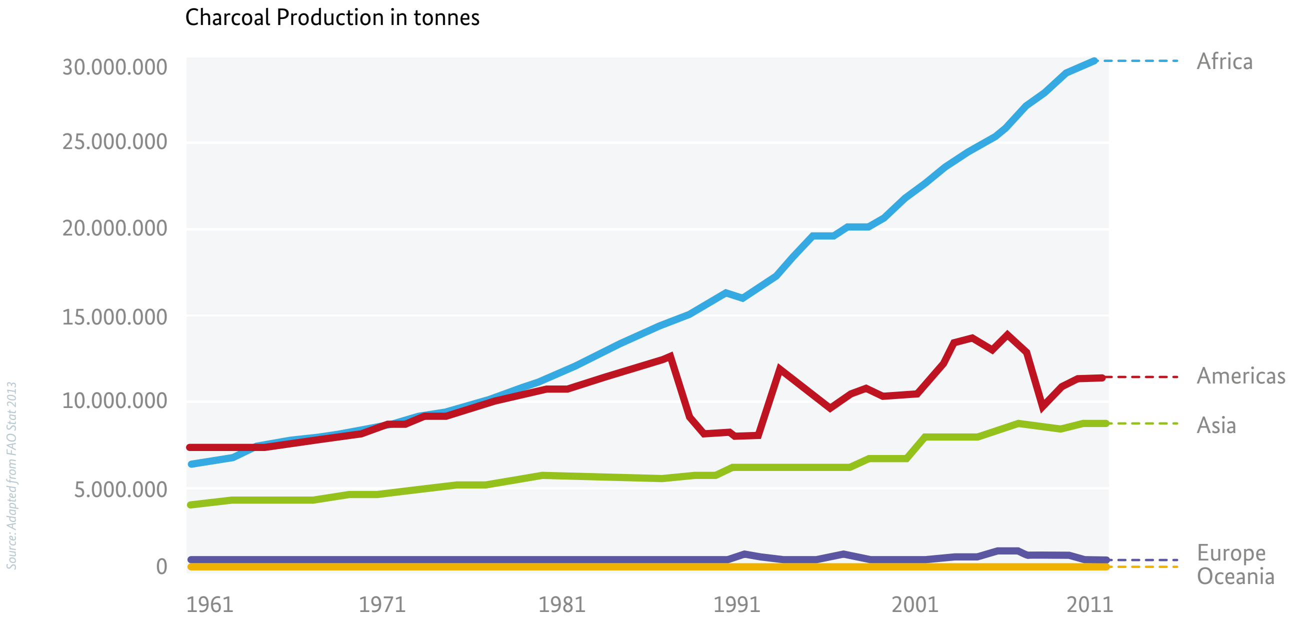
3.2 How much charcoal is produced world-wide?

Global production of wood charcoal was estimated to be 47 million metric tonnes in 2011. Since 2003, global production of charcoal has increased by 11 % [FAO Stat 2013]. More than 80 % of this wood-based energy is used for domestic purposes; due to population growth coupled with increasing urbanisation, charcoal demand is expected to continue to grow, especially in low-income countries. The fact that alternative fuels such as LPG, natural gas or electricity are often neither available, accessible nor affordable contributes to a dependence on charcoal. Furthermore, the charcoal business in developing countries is often deliberately left to the informal sector; this results insufficient monitoring of production and consumption data and an ensuing lack of necessary baseline information for shaping charcoal policies.

As *Figure 3.1* illustrates, the increases in charcoal production are strongly influenced by growing demand in African countries. Charcoal production in Sub-Saharan Africa alone had an estimated value of roughly 8 billion USD in 2007 and is likely to grow to 12 billion USD by 2030 according to the International Energy Agency consumption predictions [3]. Increased urbanisation also contributes to accelerated demand for charcoal as it is the fuel of choice for most urban residents in Sub-Saharan Africa [3]. In this region, the switch from firewood to charcoal is estimated to lie between 4 % and 10 % per year.

In Latin America and the Caribbean, the demand for charcoal dropped by almost 30 % between 2004 and 2009, which was strongly influenced by Brazil. The latter accounts for nearly half of charcoal production in the region, charcoal mainly being used in the steel and iron industries. Production marked a decrease in the wake of the economic downturn, but the latest national data indicate that it has almost entirely recovered. Brazil remains the largest charcoal producing country in the world with 6.9 million tonnes produced in 2011. India and China are the two most important charcoal producers in Asia and have experienced stable charcoal production over the past 10 years [FAO Stat 2013].

Figure 3.1: Share of global charcoal production by region in 2012

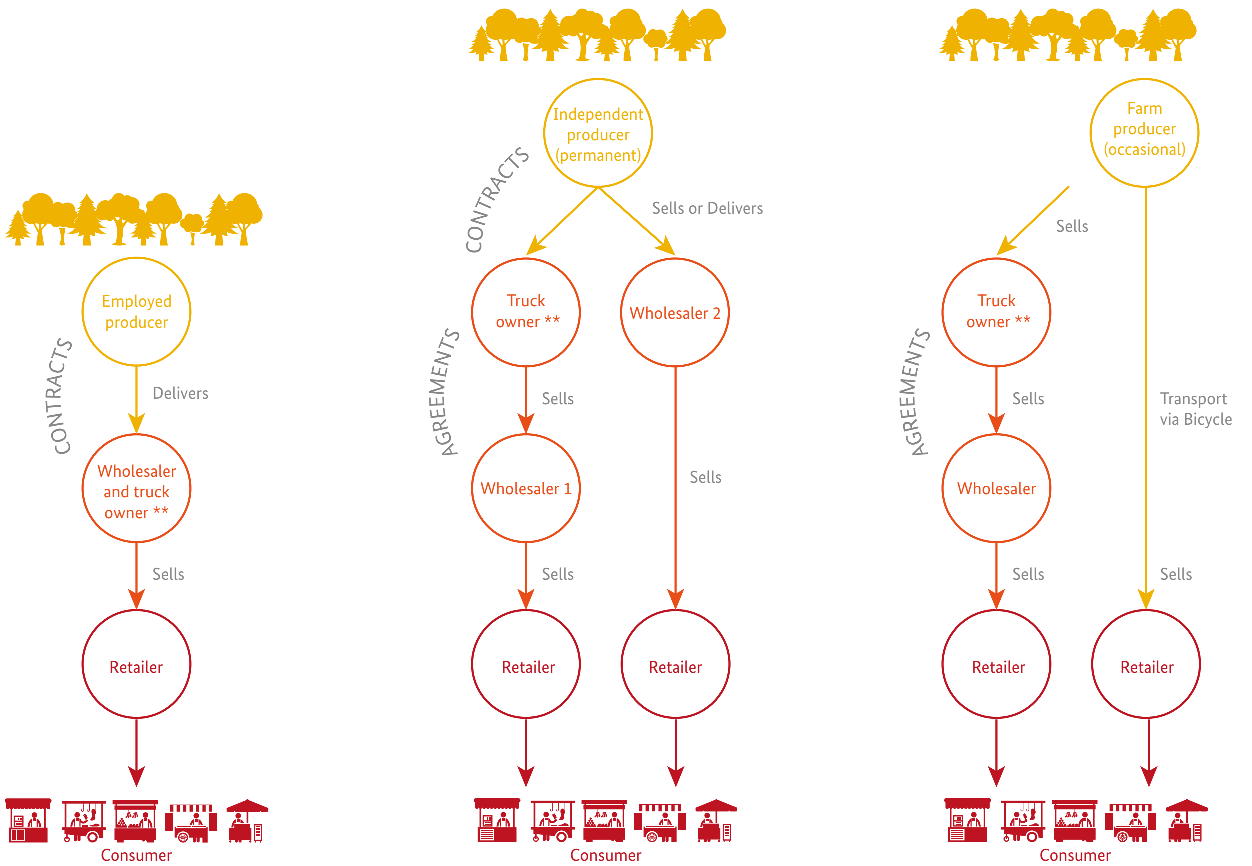


3.3 How is the charcoal market organised?

The structures of the charcoal supply chain are typically complex and interlinked, involving a number of various actors (see *Figure 3.2*). There are generally two types of charcoal producers: the independent / occasional farm producers who are members of a community in which charcoal production takes place, on the one hand, and the employed producers who are outsiders of this community, on the other. There is a distinction to be made between permanent producers and farmers who only occasionally produce charcoal among community-based producers. Community-based producers sell their goods to wholesalers, transporters on the roadside or directly to retailers. Employed producers outside of a community are contracted by wholesalers in exchange for monthly payments or for produced charcoal.

It should be noted that also in the case of charcoal (similar to firewood see *chapter 2*), it is often a small group of transporters and wholesalers who earn the highest profits, whereas producers and retailers receive the smallest income share on the market. However, almost 50 % of the final price for a sack of charcoal on the charcoal market is retained by the rural areas; this provides substantial income for farmers, charcoal producers and labourers (*see Figure 3.3*) [7]. The World Bank/ESMAP estimate that charcoal creates between 200 and 350 jobs for each TJ of consumed energy, whereas electricity creates 80-110 jobs, LPG 10-20 jobs and kerosene only 10 jobs [9].

Figure 3.2: Structures of the charcoal supply chain

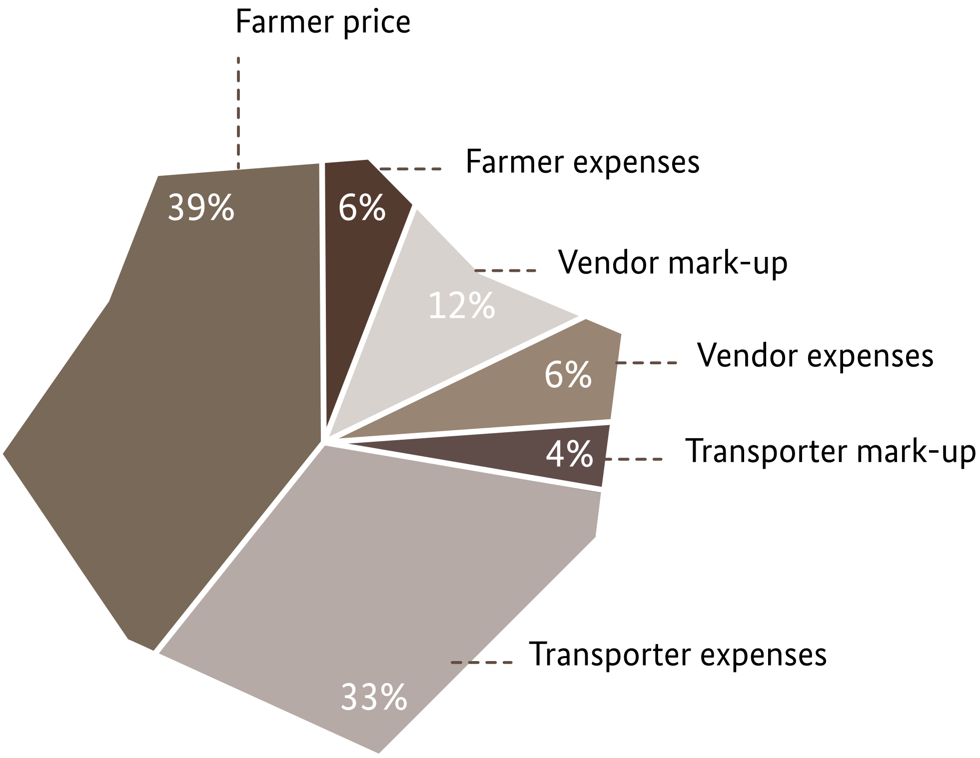


Source: Adapted from EUEI/GIZ, Biomass Energy Strategy (BEST)-Mozambique

Charcoal is usually sold by the bag, tin or pile. The price of charcoal varies according to state or region; the charcoal price in Mozambique (Maputo), for instance, is around 400 USD per tonne, whereas people pay 732 USD per tonne in South Africa (KwaZulu-Natal). Furthermore, price fluctuations occur when charcoal production is hampered during the rainy season. Transport costs comprise a significant portion of total costs for charcoal. In the past 10 years, the prices for charcoal in real terms have seen less of an increase compared to petroleum-based energy carriers. This fact has failed to make governments aware of the situation that the resource base is in decline, also failing to create incentives for users or producers to consume and produce charcoal more efficiently.

The informal market is relatively large in areas where charcoal is produced, transported and traded clandestinely in an attempt to avoid authorities, taxation and penalties, especially in African countries [5]. Due to a lack of capacity in controlling forest exploitation on the side of forest administrations, clandestine charcoal production and trade have led to substantial losses in potential tax revenues at the national level. The Mozambican government, as an example, has lost around 55 million USD in potential tax revenue [2], the Kenyan government 72.9 million USD [6] and the Tanzanian government 100 million USD (see *Figure 2.4*) [3].

Figure 3.3: Price share for actors per sack of charcoal in Kenya



Source: Adapted from Ndegwa, G., T. Breuer, and J. Hamhaber, Woodfuels in Kenya and Rwanda

3.4 How is charcoal utilised for cooking purposes?

In most developing countries, charcoal is the primary cooking fuel for urban households, whereas in industrialised countries, charcoal is mainly used in the metallurgical industries and for barbecues. In places where charcoal is used as a primary cooking fuel, the annual consumption per capita is around 150 kg. Charcoal users often demand certain quality requirements of the charcoal: solid consistency, pleasant smell and certain burning characteristics, such as an absence of sparks. Switching from firewood to charcoal in urban areas can have the following advantages for end-users:

Accessibility of charcoal can be improved as it is produced locally and is made available in most places throughout the country. It is easy to transport and store due to its lightweight physical property. It can even be stored for a long period of time without the risk of insect or fungal intrusions.

Affordability is still a decisive factor in fuel decisions made by households. Considering that charcoal is cheaper than kerosene, Liquid Petroleum Gas (LPG) or electricity in most cities, it is preferred by many households. Furthermore, as in the case of firewood, charcoal can also be purchased in small quantities for very little money on a daily basis. Although the purchase price per kg of charcoal is often many times higher than that of fire wood, this is not necessarily the case for the price per unit of useful energy. This owes to the higher energy content of charcoal and the higher efficiency of charcoal-burning stoves. The data in *Table 3.2* shows that households which utilise firewood sometimes even spend more per unit of useful energy than those that use charcoal.

Convenience is another advantage of using charcoal compared to cooking with firewood. Users do not need to as attentive with the fire when using charcoal and it also produces less noxious fumes when burnt. Consequently, cooking pots stay cleaner for a longer time.

Table 3.2: Urban consumer prices in Diego-Madagascar: 2013 (in Malagasy currency)

Energy type	Energy content (MJ/kg)	Price per kg (Ariary)	Price per MJ (Ariary)	Cooking efficiency	Price per useful energy (ariary/MJ)
Firewood	16	236	14,8	0,12	123
Charcoal	29	409	14,1	0,2	71
LPG	46	6,930	150,7	0,45	335

Source: ECO/GIZ 2013

3.5 What are the impacts on health and the environment?

Charcoal production has been singled out as a major cause of forest degradation and deforestation in many African countries, particularly in peri-urban areas. This is due to the fact that more wood and consequently more forest area are needed for producing charcoal in order to meet the same energy needs compared to fire wood. Furthermore, uncontrolled commercial charcoal production predominantly takes place in the vicinity of a market so that transport costs are kept down. Nonetheless, due to the sustainable production capacity of forests, charcoal production can actually contribute to preserving forests when it is well regulated and provides clear economic benefits to the local populace.

In addition to the issue of deforestation, substantial greenhouse gas emissions are also released, ranging between 7.2 and 9.0 kg CO_2 equivalent per kilogram of produced charcoal [14-15]. Improved kiln technologies can increase carbonisation efficiency while additionally reducing greenhouse gas emissions. As an example, current semi-industrial-type kilns have 10 % less methane emissions compared to traditional kilns. Furthermore, the carbon sink potential of forests is preserved as less wood is required for an equivalent charcoal yield. However, the adoption rate of more efficient kilns for charcoal production is still very low, mostly due to the informal – and often illegal – nature of charcoal production [2].

In areas where wood is a freely accessible good, traditional charcoal makers have no incentive for improving production. Increasing the efficiency of charcoal production requires regulatory measures, systematic training and demonstration programs.

Inefficient practices, conversion and end-use technologies for charcoal can also have serious implications for local and regional air quality. During charcoal production, the unloading of kilns, the collection of charcoal ashes for briquettes, and the burning of charcoal in households, gases and particulate matter (PM) are emitted into working and living environments. PM, carbon monoxide, nitrogen oxides, sulphate oxides and other volatile compounds emitted during charcoal processing and burning may lead to respiratory problems and ultimately illnesses such as acute respiratory infection (ARI), chronic obstructive pulmonary disease (COPD), asthma, lung cancer or low birth weight [13]. Indoor air emissions from charcoal stoves are lower than those from the combustion of fire wood in traditional and improved stoves.

3.6 What are opportunities and the challenges for the modernisation of charcoal production and usage?

Charcoal is a marketable, highly commercialised commodity and valued among households, especially in urban settings. Its production and marketing benefit local employment and the local economy. The higher economic value of charcoal compared to fire wood provides stronger incentives to participate in the charcoal business, leading to investments. Charcoal can be transported farther than firewood due to lighter weight and also produced in areas beyond the direct vicinity of consumption centres.

However, the charcoal value chain faces the same problems in sustainable production as the market for firewood: low producer benefits jeopardise sustainable forest management due to market distortions, corruption and oligopolistic marketing structures. Current market prices for charcoal are rarely sufficient for covering investments in sustainable forest management. Vested interests impair the modernisation and formalisation of the charcoal value chain, while the supervision of forest services and law enforcement remain ineffective and arbitrary. The Biomass Energy Strategies (BEST) created by EUEI PDF and GIZ HERA provide possible approaches for establishing policy and enforcement frameworks that can promote the sustainable use of solid biomass.

From both the energy perspective and the economic perspective, improvement in kiln technologies produces one of the best leverage effects for increasing the efficiency of the charcoal value chain. The traditional production process in open pits or earthen kilns, as carried out in most rural areas, is often highly inefficient with an efficiency rate of just 8 % - 15 % or even less. Due to the low wood conversion rates of traditional kilns, many projects are aimed at introducing more efficient carbonisation technologies. Improved technologies can improve the efficiency by 25 % – 30 % and can reduce batch times, reduce emissions and create purer charcoal products.

Improved technologies can be broadly classified into five categories, namely (i) earthen kilns, (ii) metal kilns, (iii) brick kilns, (iv) cement or masonry kilns and (v) retort kilns. Earthen and metal kilns are moveable while the other kiln types are stationary. There has been relatively little progress in disseminating advanced kiln technologies due to the fact that they entail higher initial construction costs.

Great potential also exists for promoting improved charcoal stoves that can help reduce average charcoal consumption per meal. One of the most striking success stories is the dissemination of the Kenyan Ceramic Jiko charcoal stove which reduces charcoal consumption by 30 %. This improved charcoal stove costs around 7 USD, reduces fuel costs for households by 30 % – 40 % [12] and has a pay-back period of 2 to 3 months. Several recommendations to promote improved charcoal stoves include active marketing of its efficiency advantages, the creation of an enabling business environment for stove producers including possible financing models, and awareness raising of the health and cost benefits [9].

Though alternative fossil fuels are becoming increasingly accessible, charcoal will remain an essential fuel for cooking purposes for the next two to three decades. On the one hand, this raises concerns for the current woodfuel stock in countries where deforestation and degradation is a current problem. On the other hand, new opportunities for improved kiln and stove technologies will arise from the predominance of charcoal in the near future. New technological developments coupled with sustainable forest management can help charcoal become a renewable and climate friendly energy source.

Further Reading

The Charcoal Project Website
http://www.charcoalproject.org/

The ODOE: Bioenergy in Oregon Website
http://www.oregon.gov/energy/RENEW/Biomass/Pages/index.aspx

The Household Energy Development Organizations' Network Website
http://www.hedon.info/

The ClimateTechWiki Website
http://climatetechwiki.org/technology/charcoal-heating-and-cooking

Cooking Energy Compendium - Charcoal Production and Cooking with Charcoal
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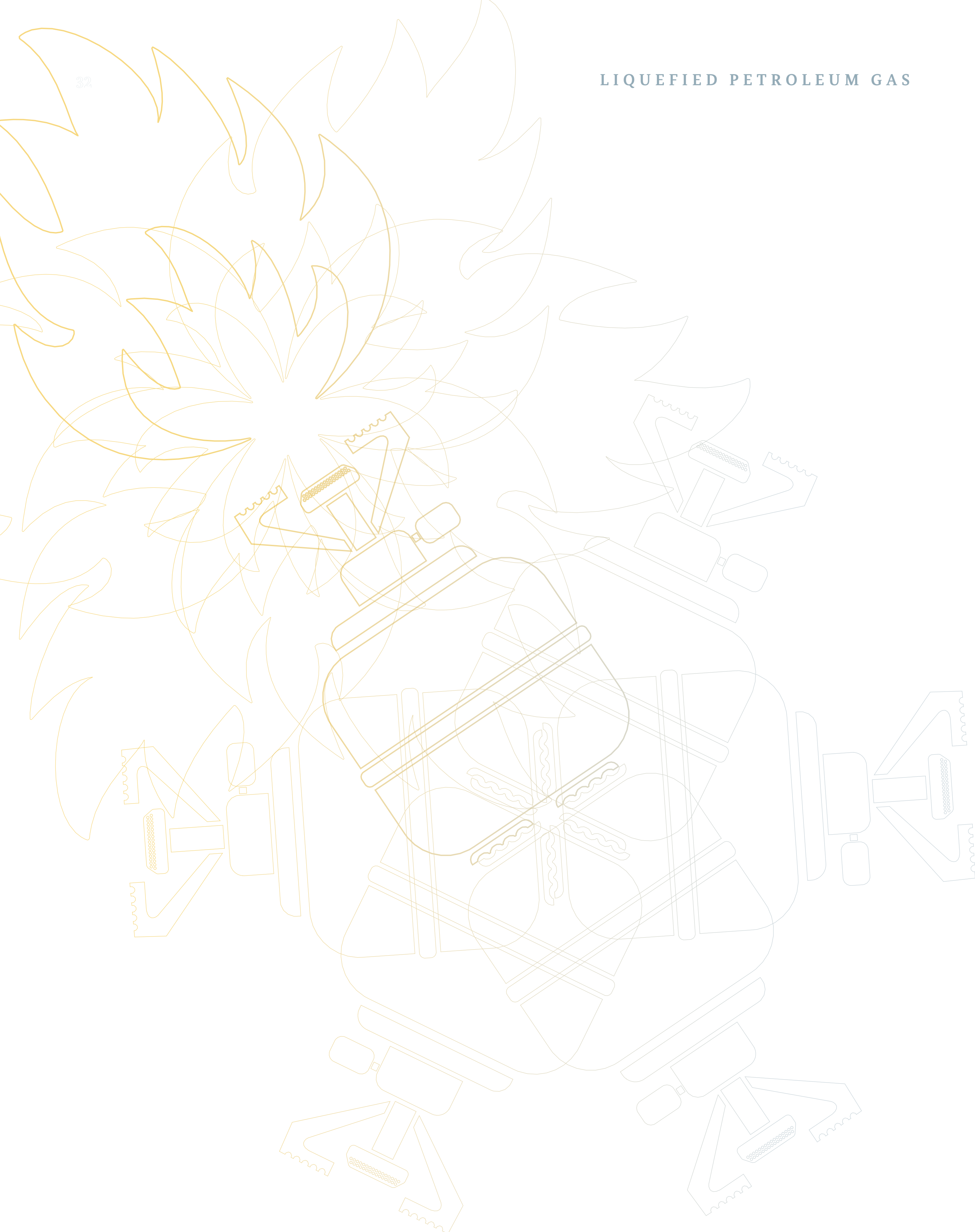


4.0 Liquefied Petroleum Gas

4.1 What is LPG?

LPG stands for Liquefied Petroleum Gas, of which 60% is a by-product of natural gas extraction and 40% comes from crude oil refining. LPG is a mixture of hydrocarbon gases, the two most common being butane and propane with traces of other compounds.

At room temperature, LPG is a colorless and odorless non-toxic gas. Under modest pressure or cooler conditions, it transforms into a liquid state and can thus be easily stored and transported in cylinders. For safety reasons, an LPG cylinder is only filled with 80% liquid while the remaining 20% contains gaseous LPG.

Table 4.1: Typical properties of LPG

Property (units in parentheses)	Propane	Butane
Chemical Formula	C_3H_8	C_4H_{10}
Boiling point at 101.3 kPa (°C)	-42.1	-0.5
Liquid density at 15 °C (kg/m^3)	506.0	583.0
Absolute vapor pressure at 40 °C (kPa)	1510	375
Upper flammable limit (% vol. in air)	9,5	8,5
Lower flammable limit (% vol. in air)	2,3	1,9
Vol. vapor per vol. liquid	269	235
Relative vapor density (air = 1)	1,55	2,07
Minimum ignition temperature (°C) in oxygen	470-575	380-550
Maximum flame temperature (°C)	1980	1990
Specific energy (gross) kJ/kg	49,83	49,40

Source: World LP Gas Association. LP Gas: The product. 2012

Propane vapor – one of LPG's gases – is more than one and a half times heavier than air and can accumulate above the ground. A foul smelling odorant (typically ethyl mercaptan) is added to help detect leaks and thus reduce the risk of explosion. When compressed, about 250 litres of gas turn into just 1 litre of liquid. A mixture of air and LPG can be ignited if the amount of LPG in the air is between 2% and 10% and the ignition temperature is above 380 °C. The maximum flame temperature for LPG is around 2,000 °C.

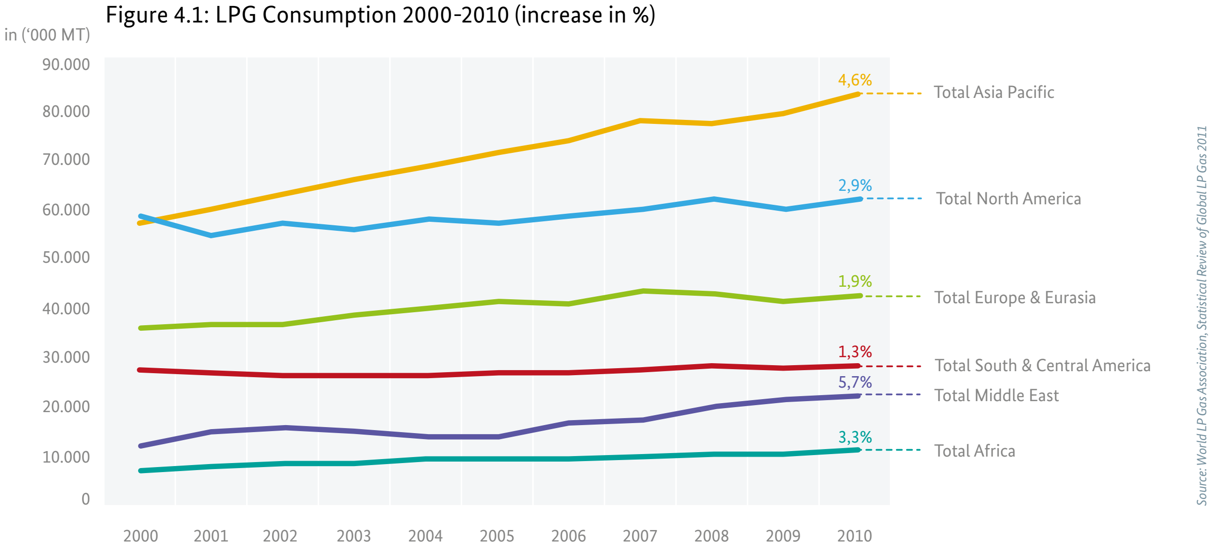
4.2 How much LPG is consumed and produced world-wide?

In 2010, LPG consumption amounted to around 249 million tonnes worldwide, of which Asia Pacific's share in global LPG consumption was the largest [2]. Asia Pacific has also experienced the highest growth rates, around 5 % since 2000.

The consumption of LPG in Africa is highly clustered in North African countries, comprising around 85 % of Africa's total consumption. Although Nigeria is the largest LPG producer in Sub-Saharan Africa, annual per capita consumption is less than 1 kg whereas in countries like Algeria, Egypt, Tunisia, Libya and Morocco, users consume 45 kg of LPG per year. Latin and Central America have only experienced a modest increase in consumption of 1.3 % since 2000 (*see Figure 4.1*).

A total of 47 % of global demand for LPG is covered by the domestic sector in which households use LPG for cooking, water and room heating; in Africa the domestic sector accounts for more than 88 % of demand [2]. The increasing rate of consumption throughout the world starting in 2000 can be traced back to population growth as well as a growing demand for autogas and LPG in the petrochemical industry. A supportive regulatory framework and adequate LPG infrastructure development can improve availability and are therefore crucial. In the short and medium term, the potential for domestic demand will be greatest in Asia as well as in urban and peri-urban areas of developing countries [3].

Figure 4.1: LPG Consumption 2000-2010 (increase in %)

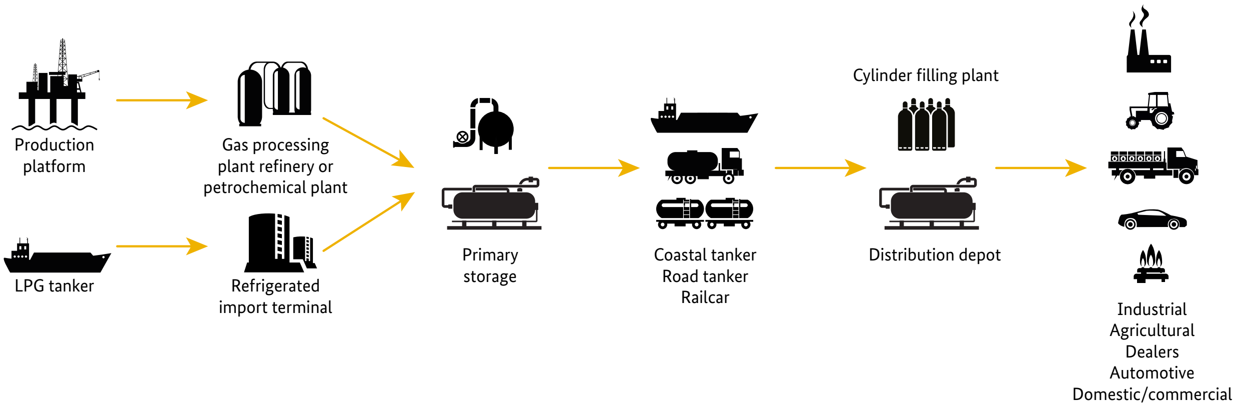


4.3 How is the LPG market organised?

LPG either comes directly from gas wells or is a by-product of crude oil refining. Subsequently, it is delivered from supply points in a *liquefied* form to primary storage facilities where it is stored under refrigeration or pressurisation. It can then be sold to distributors in its refrigerated or pressurized form.

Once purchased, the LPG is delivered to bulk distribution depots and cylinder-filling plants – some of which are combined at large sites – by means of wide-load road tankers, ships or railcars. From these distribution depots or sites, smaller delivery tankers bring deliveries to domestic customers. Supplies to the end user are organised through specialised shops, general dealers or filling stations.

Figure 4.2: Typical LPG supply chain



Source: Adapted from World LP Gas Association's LPG Technical Fundamentals

4.4 How is LPG used for cooking purposes?

A typical LPG cooking system consists of a cylinder made of steel, a pressure regulator, a hose connecting the regulator to a burner and the burner itself. Potential safety problems can arise from leaking equipment or the improper storage and handling of LPG. LPG stoves have an efficiency rate of between 55 % and 60 %; they cost around 30 USD to 60 USD and have an expected lifetime of 5 to 8 years. LPG is typically supplied in cylinders of various sizes: either 2.7 kg, 6 kg, 12 kg, 16 kg or up to 47.2 kg. In a sample of 20 countries, the most commonly used cylinder sizes were 6 kg or smaller [9].

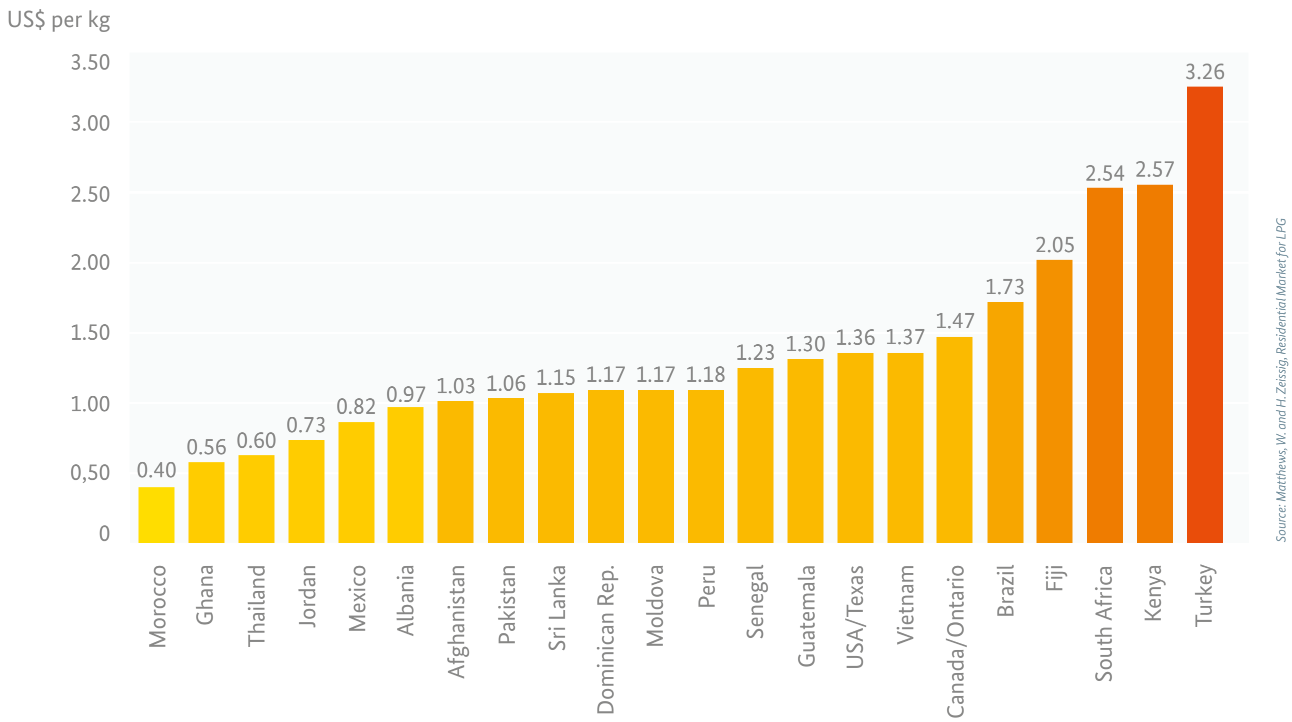
Accessibility is often not achieved in the case of LPG. In most countries, access to LPG is limited to urban areas and LPG supply shortages is a frequent occurrence in rural areas. Additionally, due to the low cost of woodfuel and lack of awareness, increased LPG use is currently not viable for most rural areas in developing countries.

Affordability is still a substantial barrier for many households who want to use LPG. Evidence shows that subsidies have benefitted wealthier urban users more than low-income users as the former are in a better position to afford the high initial costs associated with LPG. This is reportedly the case for most countries in which LPG is being subsidised [6, 9, 11, 12].

Depending on the amount of subsidies, the retail prices charged in December 2010 varied by a factor of eight (*see Figure 4.3*), ranging from 0.40 USD per kg in Morocco to 3.26 USD per kg in Turkey [6]. Research suggests a link between the level of education attained by members of a household and the likelihood of the household to select LPG as their main cooking fuel.

Convenience is one of the main reasons why the use of LPG has been growing world-wide. LPG heats quickly and provides much greater efficiency than even the most improved biomass stoves. LPG stoves can also be controlled more precisely to match the user's requirements and can save time for cooking and cleaning the kitchen. Additionally, LPG can be transported, stored and used virtually anywhere.

Figure 4.3: Retail prices of LPG in December 2010



4.5 What are the impacts on health and the environment?

A switch to LPG can bring about a significant reduction in indoor air pollution since it reduces health-adverse exposures by more than 90 % in comparison to open fires or traditional stoves [14 - 15]. LPG substantially reduces pollutants such as sulphur oxide (Sox), nitrous oxide (NOx) and particulate matter due to its more complete combustion compared to solid fuels.

From an environmental point of view, LPG usage has contributed to reductions of greenhouse gas emissions in many countries where most inhabitants still use wood or charcoal fuels that generally did not originate from sustainable forest operations and were burnt in traditional, inefficient cookstoves. For instance, households that cook with charcoal emit 5 to 16 times more greenhouse gases per meal than those using LPG [16].

Substitution through LPG can considerably reduce overall wooduel consumption in a country or region. Just 45kg of LPG are sufficient for replacing the thermal energy of 1 tonne of wood used to produce charcoal with traditional kiln and stove technologies. Moreover, an entire hectare of savannah forest is needed for the sustainable wood production of 1 tonne of firewood.

4.6 What are challenges and opportunities for further dissemination of LPG?

LPG is a fossil fuel and therefore not renewable. The quantity needed to satisfy this demand corresponds to about 120 million tonnes of oil equivalent LPG per year – this equates to 1 % of global commercial energy consumption or 3 % of global oil consumption [22]. Since LPG is a byproduct of oil and gas, the amount available is directly tied to the global amount of available oil and gas.

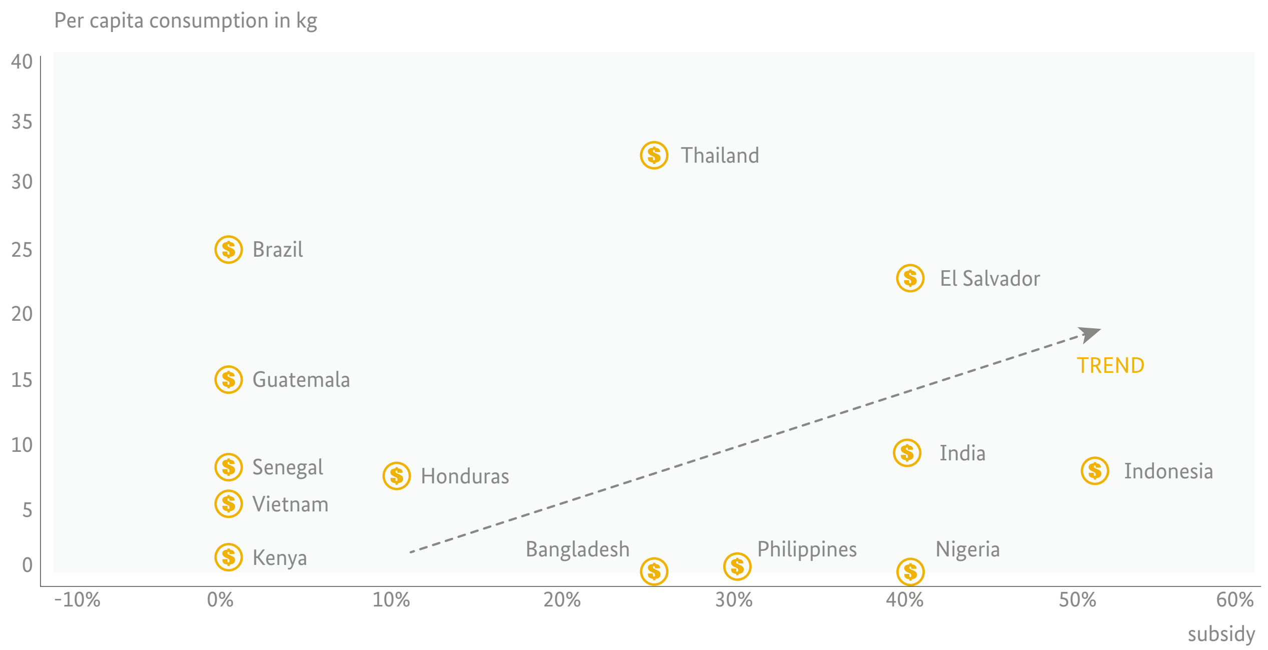
The main challenges for broader dissemination of LPG are its limited accessibility and affordability for its users. Furthermore, a lack of awareness of LPG as well as fear of accidents exist. The development of governmental policies and regulations to create incentives for increasing LPG use are therefore advisable to support LPG uptake. A review of experiences in 20 developing countries have revealed that, apart from a stable political and legal system, proper rules governing trade and investments such as the licensing of distribution, repatriation of profits and taxation of corporate profits are also essential for increasing LPG growth [6].

Further possible government interventions include designing favourable taxes/duties, industrial safety provisions and stronger enforcement procedures. This will also create incentives for distribution companies to develop commercial LPG infrastructure and ensure regular supply on a broad basis with close proximity to households. Affordability could be further improved by providing microcredit or loans for the sake of lowering upfront payments or by following Kenya’s example of installing structures that allow poorer households to purchase small amounts of LPG, much in the same way they purchase kerosene or charcoal.

Many governments concerned about the potential threat of high woodfuel use on forest resources have launched programmes with the aim of encouraging households to use LPG as a cooking fuel and gradually decrease the use of traditional biomass fuels. This often includes the provision of direct subsidies for LPG and/or for utilisation equipment. Consequently, the subsidised fuel has led to high dissemination rates in many countries (*see Figure 4.4*). Earlier subsidy programmes in Senegal and Brazil have also been successful: in Senegal, 85 % of the population in the capital have adopted LPG stoves [6] and in Brazil, 95 % of households use LPG due to a subsidy program that lasted from 1973 to 2001 [7].

However, with rising international prices of LPG having witnessed an average rate of 9 percent since 2001, subsidies have become increasingly unsustainable as governments are no longer able to shoulder the financial burdens [8 - 9]. The removal of subsidies as well as continuously increasing LPG prices bear the well-founded risk that many middle-income urban users might revert to the use of charcoal or fire wood as they are not able to pay for LPG (*see Figure 4.4*). Nonetheless, it has to be noted that the G20 nations called for a complete phase out of fossil fuels. An estimated 775 billion USD were spent globally on subsidies in 2012 [10]. A decisive factor for LPG growth is establishing an appropriate price level for LPG in relation to the prices of other fuels [6].

Figure 4.4: LPG Consumption versus subsidies



Source: Argus LPG World, Subsidy burden forces Indian initiative. Vol. Volume XVII, Issue 5, 2011

The development of LPG infrastructure (bottling plants and distribution chains) also remains an important challenge to enhancing LPG market penetration. For instance, Nigeria is theoretically self-sufficient in LPG but lacks necessary distribution systems and purchasing power. Regular supply shortages and difficulties in acquiring cylinders are often cited as additional deterrents.

On a technical level, new cylinders have been developed which have the benefit of being transparent. This allows end users to see how much liquid is left, especially when buying LPG and when using it. In addition, cylinders have been made light enough for women and children to carry and they have porous skins so that the LPG can escape out without exploding if subjected to a fire. However, the high price for these kinds of cylinders is still problematic, preventing large-scale market distribution, in particular on the rural household level.

It is likely that more people will gain access to LPG in the future as increasing urbanisation and corresponding increases in the share of households with higher incomes enables more urban households to afford the high initial costs. However, rising demand for LPG stemming from increasing use of autogas, the petrochemical industry and urban households are likely to result in LPG prices that cannot be met by rural households currently cooking with biomass. Although rural households would benefit most of the health and environmental potential of LPG, availability and affordability are and are likely to remain high barriers to LPG-access.

Further Reading

Website of the World LPG Association
http://www.worldlpgas.com/

Website of Propane Education & Research Council
http://www.propanecouncil.org/

Cooking Energy Compendium - Liquefied Petroleum Gas
https://energypedia.info/wiki/Liquefied_Petroleum_Gas_(LPG)

Cooking for Life
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Kenya
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