Republic of Kenya
Ministry of Environment, Natural Resources and Regional Development Authorities

KENYA Forest Service

IMPROVING EFFICIENCY IN FORESTRY OPERATIONS AND FOREST PRODUCT PROCESSING IN KENYA:

A VIABLE REDD+ POLICY AND MEASURE?

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP
Empowered lives. Resilient nations.

UNEP

Disclaimer

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

This publication has been made possible with funding from the UN-REDD Programme and with support from UNDP and FAO. The report should be referenced as follows:

UNEP (2016) Improving efficiency in forestry operations and forest product processing in Kenya: A viable REDD+ policy and measure? Summary for policy makers. United Nations Environment Programme

Acknowledgements

Jackson Bambo, Hugo Douglas Dufresne, Miharu Furukawa, Gideon Gathaara, Bernard Gitau, Dr. Githiomi, Noor Hassan, John Kapolon, Karega, Elsen Karstad, John Kihara, Philip Kisoyan, Obed Koringo, John Koskei, Joshua Laichena, George Makatelo, Joseph Mbagara, Francis Ngigi Mbogo, Jonathan Mitei, Edward Mungai, Julius Muchemi, Emilio Mugo, Friday Mugo, Grace Mukasa, Samuel Mureithi, George Muthike, Charles Peter Mwangi, Dr. Mary Nganga, John Njuguna, Nelly Oduor, Walter Ogada, George Oselu, Surest Patel, Kamau Waithaka, Phyliss Wakiaga, Wamae, Kishiki Diana Wavua, Simiyu Wekesa, Elizabeth Eggerts.

Authors:

Jérôme Maurice (SalvaTerra), Maden Le Crom (SalvaTerra), Olivier Bouyer (SalvaTerra), Fabio Pesce (ForTeA), Paolo Cielo (ForTeA), Michael Gachanja (Consultant), Lyndall Bull (Lynea Advisory).

Edited by:

Ivo Mulder (UNEP) and Jaime Webbe (UNEP)

Project coordination:

Alfred Gichu (Kenya Forest Service), Rose Akombo (Kenya Forest Service), Thais Narciso (UNEP) and Ivo Mulder (UNEP)

Summary

Tables

Figures

Glossary

BAU	Business-as-usual
BEF	Biomass expansion factor
Bsavings	Biomass savings
CDM	Clean development mechanism
Cf	Carbon fraction
CPA	Charcoal Producers Associations
EMCA	Environmental Management and Coordination Act
ER	Emission reductions
EU	European Union
FAO	Food and Agriculture Organization
fNRB	Non-renewable biomass fraction
FOSA	Forest and Outlook Study in Africa
FRA	Forest Resources Assessment
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ha	hectares
ICS	Improved cook stoves
IPCC	Inter-Governmental Panel on Climate Change
KAFU	Kenyan association of forest users
KCJ	Kenya Ceramic Jiko
KEFRI	Kenya Forestry Research Institute
KES	Kenyan Shilling
KFMP	Kenya Forest Master Plan
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
KTDA	Kenya Tea Development Agency
LPG	Liquid petroleum gas
m^3	cubic meters
MEWNR	Ministry of environment, water and natural resources
MRV	Measuring, Reporting and Verification
NWFP	Non-wood forest products
OWL	Other wooded lands
REDD+	Reducing Emissions from Deforestation and forest Degradation, and the role of conservation, management of forests and enhancement of carbon stocks
REL	Reference emission level
RSR	Root-shoot ratio
RWE	Round wood equivalent
SME	Small and medium enterprises
tC	tons of carbon
tCO_2e	tons of carbon dioxide equivalent
TEV	Total economic value
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar

Summary for policymakers

KEY MESSAGES

- **Kenya's new Constitution establishes a 10% forest cover target. Additionally, the country has demonstrated sustained commitment to anchoring REDD+[1] in its national policy framework and development strategy.** In this context, Kenya is in the process of identifying the best ways to address the direct and indirect drivers of deforestation and forest degradation. According to the Kenyan Readiness Preparation Proposal (R-PP), the lack of security of timber supply to the sawmilling industry (i.e.: low investment in timber processing technology, poor timber conversion ratios) is a key indirect driver of deforestation and forest degradation. As such, REDD+ in Kenya must ensure sustainable utilization of wood resources (KFS, 2010).
- **This analysis assesses whether increased efficiency in forestry operations and forest product processing and utilization constitute viable REDD+ policies and measures (PAMs) for the Government of Kenya, with the potential to attract public and/ or private investments to enable REDD+ implementation.** In particular, the report focuses on the extent to which efficiency improvements could address supply deficiency in the forest sector, reduce pressures on forests, and ultimately reduce or eliminate net forest carbon emissions. To this end, cost-benefit analyses inclusive of emissions reduction potential proxies were undertaken in the five following sectors:
  1. Forestry operations (commercial logging)
  2. Timber conversion (sawmills)
  3. Charcoal production
  4. Use of charcoal and firewood in cooking stove technology
  5. Wood usage in industrial processes
- The concept of **'non-renewable biomass'** was a key-parameter to estimate the potential emission reductions from deforestation and forest degradation of each sector. The United Nations Framework Convention on Climate Change (UNFCCC) defines this as the **proportion of total annual (woody) biomass removals that is demonstrably not renewable.** Although wood is a renewable material, it becomes non-renewable when the harvesting rates exceed the ecosystems production capacity. Thus, for each sector, the fraction of non-renewable biomass (fNRB), which indicates the proportion of biomass used that is not renewable and from which are calculated the potential emission reductions, is discussed.
- **With regards to *forestry operations* and *timber processing from forest plantations*, while strong socio-economic benefits may be derived from efficiency improvements, there is no evidence that increasing efficiency will help alleviate illegal harvesting pressure on natural forests.** According to Kenya Forest Service (KFS), nationally, most of the timber produced comes from forest plantations and most of the timber used in Kenya is sourced from across the border. Small, illegal saw millers rely mostly on timber from private farms and illegally accessed timber from forest reserves, especially through indiscriminate and uncontrolled selective cutting in forests. Forest products such as pine, cypress and eucalyptus plantations are hardly substitutable with the precious woods illegally harvested in natural forests. Moreover, rare commercial species such as Camphor and Sandalwood are not only exploited for their precious wood but also for other products (bark used in perfume industry, medicinal use) and therefore not affected by increasing the efficiency of forestry operations in pine, cypress and eucalyptus plantations.
- Although the proposed policies and measures for each of the five sub-sectors have a positive cost-benefit balance (assuming a hypothetical carbon price of US$5.6/t$CO_2$-e), **REDD+ results are only expected when investing in enhancing efficiency in charcoal production and fuelwood consumption at household and industrial levels.** Investments to improve efficiency in charcoal production (increased supply) and fuelwood consumption (reduced demand) at household and industrial levels are both economically-attractive and have the highest potential to generate REDD+ results, with an

estimated emission reduction potential of more than 20 million tCO_2-e per year.

- **The assessment results underwrite the mitigation activities proposed by the Government of Kenya in its *Intended Nationally Determined Contribution* (INDC) submitted to the UNFCCC (July 2015)**, including: "*Enhancement of Energy and resource efficiency across the different sectors" and "Making progress towards achieving a tree cover of at least 10% of the land area of Kenya*". The INDC states that Kenya's total greenhouse gas (GHG) emissions were around 73 million tCO_2-e in 2010, out of which 75% were from the land use, land-use change and forestry (LULUCF) and agriculture sectors. **If Kenya were to implement the measures proposed in this report, the potential reduction of 20 million tCO_2-e identified in this study could lead to a total greenhouse gas reduction of around 27%** against 2010 numbers.
- The assessment, therefore, supports the Government of Kenya by shedding light on how stimulating investments in the forest sector can derive economic benefits while also reducing pressures on remaining forests. This is particularly the case for dry forests, where 75% of the charcoal is sourced and the risk of over-harvesting of non-renewable biomass is higher.

FORESTS, MORE THAN TIMBER

Forests are an important feature of Kenya's landscape, ranging from montane forests (also called 'water towers') in the mountainous areas, to western rainforests, dry forests, coastal and riverine forests. But forests also have an understated importance to Kenya's economy. While the system of national accounts (SNA), a set of rules that determine a country's Gross Domestic Product (GDP), puts the total annual contribution of forests at 1.1% of GDP in 2010, this is a gross underestimation (UNEP, 2012).

Aside from timber and other wood products, forests also provide a range of services that directly or indirectly support other key productive sectors such as energy (water regulation and soil retention for hydroelectric power generation), agriculture (enhancing soil quality, reducing soil erosion) and tourism. A report by the KFS, the Kenya Bureau of Statistics and international partners (UNEP, 2012) revealed that the contribution of forests to GDP is undervalued by at least 2.5% if a broader range of ecosystem services is accounted for, which would raise the estimate of its annual contribution to GDP to at least around 3.6%. However, even this is an underestimate, because this work only looked at Kenya's montane forests and did not include other types of forest areas in the analysis (such as dry forests, western rainforests, coastal and riverine forests).

There is, therefore, a clear domestic economic rationale to reduce deforestation rates and increase efforts to rehabilitate degraded forest areas. The underlying idea behind this study is to assess if efficiency improvements can address the supply deficiency, reduce subsequent pressure on forests and therefore be a potentially interesting REDD+ policy or measure (PAM) by reducing or eliminating net forest carbon emissions.

OPPORTUNITIES FOR EFFICIENCY IMPROVEMENTS

1. **Forestry operations (commercial logging).** There is a great potential to improve the quality and quantity of plantation resources in Kenya, both in the public and private realms. In order to ensure adequate wood supply, improved management practices are needed to address the current poor performances of public plantations while increased investments will be necessary to increase the stocked plantation areas. Improved sawn log quality from appropriately managed plantations is a precondition to investments in more efficient equipment in the timber processing sector to increase the timber processing average recovery rate. Afforestation and reforestation as well as improving plantation management by appropriate silvicultural practices such as thinning, pruning and extension of rotation age, can reduce forest carbon emissions in both public and private plantations. Improving harvesting techniques, which is the only field of improvement taken into account in the cost and benefits analysis, has the potential to cut down logging waste from harvesting volumes by 5%. Given that there is no evidence that increased rate of recovery from harvesting in forest plantations will decrease the pressure on natural forests for timber production, and given that the fraction of non-renewable biomass in public and private plantations is close to zero, these measures are unlikely to generate emission reductions from deforestation and forest degradation. However, these measures might have socio-economic positive impacts, such as increasing the safety of harvesting operations and harvested timber quality.
2. **Timber conversion (sawmills).** Increasing efficiency in timber processing might help to increase the national

timber production by about 210,000 m^3 round wood equivalent (RWE) per year. To reach this goal, investments in sawing and drying wood technologies as well as on vocational training are required. The timber and wood industry is closely linked to the building sector and the 2030 Vision places sawmills, as small and medium enterprises (SMEs), at the heart of Kenya's development plan. The sector, despite being latent for several years as a consequence of the logging ban in 1999, developed steadily over the last years and abundantly exceedes the previous production levels with almost three times volume of sawn wood produced compared to the level of 1999. However, for the same reasons described above, most of these measures are unlikely to generate emission reductions or removals from deforestation and forest degradation. Promoting the substitution of fuelwood from non-renewable forest sources with briquettes made of recycled sawn wood can lead to a small amount of biomass savings per year (25,000 m^3 RWE), generating around 46,000 tCO_2e per year of emission reductions from deforestation and degradation. It is reasonable to assume that increasing wood production will increase safety and healthcare on working sites, create more value added and jobs in the wood supply chain and contribute to sustainable development of the country.

3. **Charcoal production.** The proposed measures range from basic improvements, training of 100,000 charcoal producers to "improved earth kilns" best practices, and the construction of 50,000 Casamance kilns (with metallic chimneys, promoted by KEFRI for several years), to technological substitution such as the use of retort kilns instead of traditional direct-combustion earth kilns. Increasing efficiency in charcoal production can reduce the pressure on forests: instead of using 10 kg of wood to produce 1 kg of charcoal, improved technologies can cut the use of wood down to 3 to 6 kg according to the technology used and best practices applied. Considering the high proportion of non-renewable biomass used to produce charcoal (between 90% and 95%), these measures can lead to 5.7 million m^3 RWE of non-renewable biomass savings per year from dry forests, generating more than 16.5 million tCO_2e per year of emission reductions from deforestation and forest degradation. The resulting forests total economic value that is preserved by reducing drivers of loss is estimated at around US$ 30million per year. The overall balance of costs and benefits is positive, and the profitability of the sector is likely to increase through such measures. Moreover, charcoal production efficiency measures can generate positive impacts such as the reduction of accidental burning and respiratory problems amongst charcoal producers. These measures can also generate more qualified jobs in the sector. Therefore, improving charcoal production could be an attractive measure for the Kenyan government as part of its National REDD+ Strategy and implementation plan.
4. **Use of charcoal and firewood in cooking stove technology.** The proposed measures target the large-scale adoption of 5 million improved cook stoves in urban and rural areas to replace the present inefficient cooking devices and reduce the demand of fuelwood (firewood and charcoal). Increasing efficiency in the consumption of fuelwood, mainly sourced from natural forests where high levels of non-renewable biomass are estimated, can lead to 960,000 m^3 RWE of non-renewable biomass savings per year from natural forests, generating more than 2.4 million tCO_2e per year in terms of emission reductions from deforestation and forest degradation. The resulting forests total economic value that is preserved by reducing drivers of loss is estimated at around US$ 3.5 million per year. The overall balance of costs and benefits is positive, and the profitability of the sector is likely to increase. Moreover, these measures will generate positive impacts such as the reduction of respiratory problems amongst the fuelwood consumers, especially women and children and can create additional jobs in the cook stoves manufacturing sector. These measures are therefore potentially attractive for the Kenyan government as part of its National REDD+ Strategy, generating both emission reductions from deforestation and degradation and positive co-benefits.
5. **Increasing efficiency in wood usage in industrial processes** may represent up to 1.1 million m^3 RWE of non-renewable biomass savings per year, generating more than 2.0 million tCO_2e per year in terms of emission reductions from deforestation and forest degradation. The forests total economic value that may be preserved by reducing drivers of loss is estimated at around US$ 1.9 million per year. The overall balance of costs and benefits is also likely to be positive. However, more data on fuelwood origin by sector (tea, tobacco, restaurants and kiosks, etc.) is necessary to refine this conclusion. It is yet not clear whether a significant amount of non-renewable biomass from natural forests is used in these industrial processes, or if they rely only on renewable biomass harvested in forest plantations. If that would be the case, the potential emission reductions from deforestation and degradation would be drastically diminished.

An overview of investment opportunities in the forest product and processing sector is shown in Figure 1.

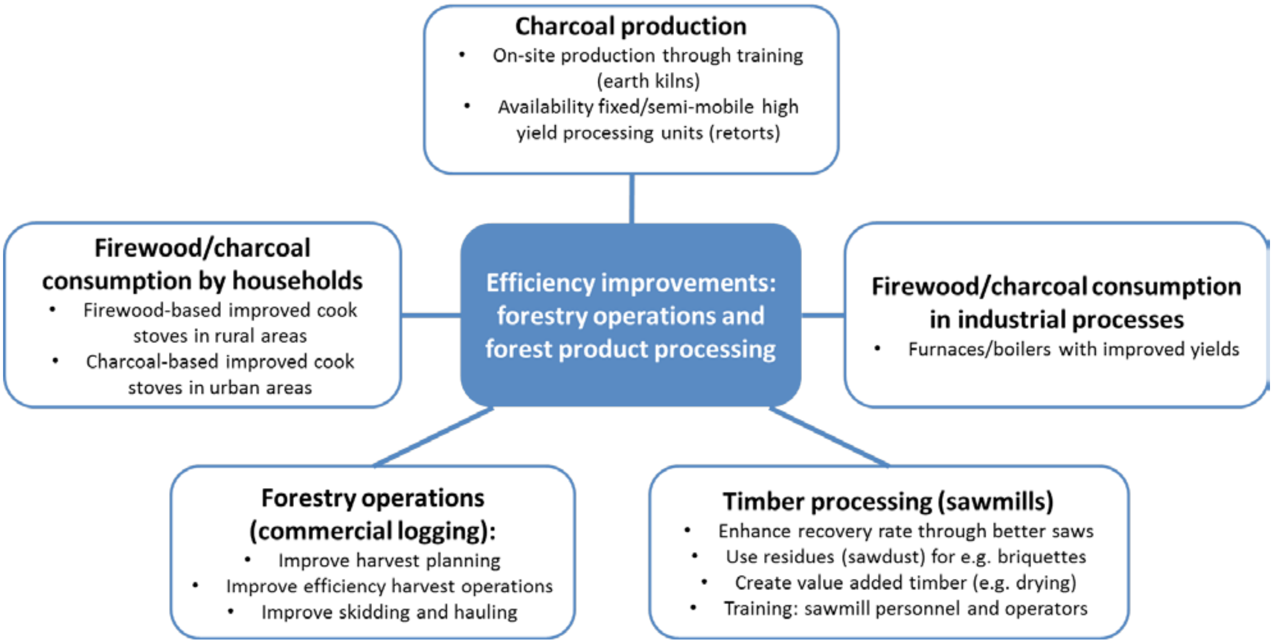

Figure 1: Investment opportunities to enhance efficiency in the forest sector

CONCLUSION

In July 2015 Kenya submitted its Intended Nationally Determined Contribution (INDC) to the UN Framework Convention on Climate Change (UNFCCC). In the INDC, Kenya pledges to cut its carbon emissions to 30% below business-as-usual levels by 2030. The Kenyan government has indicated that, to meet this ambitious target, a number of measures will be required including expanding solar, wind and geothermal power, and bringing forest cover up to 10% of the country while reducing reliance on wood fuel. The analysis carried out in this project is therefore very relevant in the context of Kenya's INDC, but also its National Climate Change Response Strategy (NCCRS 2010) and National Climate Change Action Plan (NCCAP 2013).

Table 1, below, provides an overview of the costs and benefits of efficiency improvements in the five forestry sub-sectors that were analysed given a certain amount of upfront investment. For each sub-sector the proposed measures have a positive cost-benefit balance (assuming a hypothetical carbon price of US$ 5.6/tCO_2-e). However, only efficiency improvements in charcoal production and fuelwood consumption at household and industrial levels are expected to generate REDD+ results.

	Estimated Investment (US$ per year)	Potential biomass savings (m^3 RWE per year)	Estimated emission reductions from deforestation and degradation (tCO2e per year)	Benefits* (US$ per year)
Forestry operations (harvesting)	375,000	86,000	n/a	1,166,000
Timber processing (briquettes production)	1,415,000	237,000	46,000	3,249,000
Charcoal production	15,642,000	5,974,000	16,476,000	144,892,000
Fuelwood consumption at household level	10,000,000	1,026,000	2,386,000	20,734,000
Fuelwood consumption at industrial level	11,430,000	1,191,000	2,040,000	17,854,000
Total	38,862,000	8,514,000	20,948,000	187,896,000

Table 1: Summary cost-benefit analysis

**Using a hypothetical carbon price of US$ 5.6/tCO_2e*

These results are relevant as they show that investments in efficiency measures in charcoal production as well as fuelwood consumption at household and industrial levels are: i) viable REDD+ policies to reduce or eliminate net carbon emissions; ii) economically attractive for Kenya; and iii) could significantly contribute to Kenya's GHG emission reduction targets.

Based on Kenya's 2010 GHG emission level of 73 million tCO_2-e per year as stated in the INDC reducing emissions by 20 million tCO_2-e per year, as identified in this report, would go a long way in Kenya's efforts. Given that the policy options identified in this study are economically-attractive, they offer preliminary reflections that may be strategically relevant to the design of Kenya's National REDD+ Strategy and future REDD+ investment plan.

Special consideration needs to be given to the role of the private sector both in relation to capital expenditures to finance efficiency improvements, and the potential need for additional regulation to prevent possible adverse effects from these investments. For the efficiency improvements that can generate emissions reductions it is important to assess if and what financial (and other) incentives need to be provided in order to stimulate private actors to finance such improvements. From a regulatory perspective, it is important to understand that productivity improvements could have the unintended consequence of actually enhancing pressures on forests as efficiency improvements can lead to higher incomes, which can perversely incentivize additional encroachment on forests. It is therefore important to identify how any financial incentives to stimulate efficiency improvements can be made conditional on private users adhering to social and environmental criteria

ASSUMPTIONS

The following underlying assumptions and targets for the proposed improvement measures have to be carefully considered to analyse the overall findings.

1. Timing in scenario analysis: A 10-year period was used to compare efficiency improvements across these five sub-sectors to allow for comparison. This can be an appropriate timeframe for the firewood and charcoal consumption at household level where cooking devices have to be replaced regularly in order to sustain the efficiency improvement outcomes. However, this is not applicable for timber processing and firewood consumption at industrial level where the equipment has a write-off or amortisation period is substantially longer.
2. Number of stakeholders: There are large differences in the five sub-sectors in terms of number of operators targeted by the proposed efficiency improvement measures. The 10-year timeframe of vocational training to bring about more efficiency in harvesting operations could target almost 100% of forest workers in the country. Investments in new sawing equipment and training in the timber-processing sector was based on reaching 20% of the total number of saw millers. Similarly, the number of producers taken into account to set up the estimation of improved charcoal production scenario was not more than 20%. The population targeted by the action aimed at improving the cooking devices was between 80 and 100% depending on the type of device and location (rural vs. urban areas, wood vs. charcoal cook stoves). Moreover, the improvement of energy conversion in the agricultural and cottage industries targeted 30% of the total number of businesses. It is straightforward that if the number of people or businesses targeted by the improvement measures increases, the prospective biomass savings will increase accordingly. Indeed, proper goals have to be set according to political willingness and available resources.
3. Abatement costs: These have been estimated in terms of US$ per ton of CO_2 equivalent or tCO_2e in order to allow meaningful comparisons between the results of each sector. The lowest abatement cost was found in the charcoal production sector (US$ 0.9 /tCO_2e) and the highest in the sector of firewood and charcoal consumption at industrial level (US$ 5.6/tCO_2e). The estimated abatement cost from the production of briquettes made of recycled saw-dust is US$ 4.9 /tCO_2e and US$ 4.2 /tCO_2e for the use of improved cook stoves at household level. In the charcoal production sector, efficiency can be strongly improved at a relatively low cost, as compared to the other sectors.
4. Biomass saving: The maximum potential biomass savings from the alternative scenarios is more than 85 million m^3 RWE over 10 years. This outcome is almost six times higher than the potential biomass production from increasing the growing stock of public plantations from afforestation-reforestation and improving management techniques, which was estimated in this report at 15 million m^3 RWE. Moreover, it has to be noted that the potential outcome from growing stock increase in public plantations can be achieved over a much longer timeframe because the expected effect of improved management techniques take place during the whole rotation period, which for pine and cypress species is around 30 years. Afforestation and reforestation have to be progressive in order to properly integrate new establishments with the ages of previous plantation stands. On the contrary, the options discussed in this report may potentially lead to immediate, short-term results.
5. Biomass savings can be more easily achieved in agriculture, charcoal production and firewood/charcoal consumption sectors. These activities involve both large wood supply volumes as well as great efficiency improvement potential from technological innovation ranging from 10% to 50%. In the field of harvesting and timber processing efficiency improvement, no more than 5% to 20% increase can be expected from the current recovery rates levels, which is limiting the potential of total biomass savings.

1. Introduction

There is a considerable potential to improve efficiency in wood and biomass utilization which may lead to improved profitability of the industry, reduced demand for wood raw materials for household energy needs, and increased contribution of the forest sector to climate change mitigation.

However, at present wood conversion efficiency in Kenya is poor and the quality of the final product has declined. Due to obsolete machinery, the timber industry suffers from low recovery rates and high levels of residues both in harvesting and processing operations. Rural and urban households are highly dependent on fuelwood (firewood and charcoal), especially for cooking. Inefficiencies in the charcoal production sector raise important concerns in Kenya, where arid and semi-arid lands are subject to forest degradation.

The Kenyan REDD+ Preparation Proposal (KFS, 2010) assumes that wider-use of already existing best practices and technologies may significantly help the forest sector reduce emissions from deforestation and forest degradation. In this context, the present report presents the feasibility and cost-benefit analysis of five areas within the broader forest sector where an improvement in efficiency might provide a viable option for decreasing deforestation and forest degradation rates in the country, while increasing the forest sector's value added. The five areas are: i) forestry operations (commercial logging); ii) timber processing (saw mills); iii) charcoal production; iv) consumption of fuelwood at household level; and v) usage of fuelwood in agricultural and cottage industries (tea, tobacco, etc.).

The objective of this study is to assess the feasibility and socio-economic and environmental implications of increased efficiency in forestry operations and forest product processing and utilization as potential options for REDD+ implementation in Kenya. For each of the above mentioned sectors, research on current efficiency rates and recovery rates and on globally available, tested and readily available efficient technologies has been carried out. Moreover, the potential environmental – including carbon and socioeconomic costs and benefits have been estimated. Final results indicate the of policies and measures that may be suitable for REDD+ in the country.

This report focuses on harvesting operations and subsequent processing and consumption of timber and fuelwood (e.g. firewood and charcoal) in Kenya. It must be noted that not all aspects of timber production have been captured, with increasing carbon stocks through improved forest management of natural and plantation forests not in the scope of this study, neither is the enhancement of carbon stocks through afforestation and reforestation.

The objective of this study is to assess whether increased efficiency in forestry operations and forest product processing and utilization can be a viable policy or measure (PAM) by the Kenyan Government as it moves towards REDD+ implementation.

The underlying ideas behind this study is to assess if increased efficiency in forestry operations and forest product processing can address the supply deficiency, reduce subsequent pressure on forests and therefore be a potentially interesting REDD+ policy or measure (PAM).

2. Methodology

2.1 SCOPE

In 2013, the Ministry of Environment, Water and Natural Resources (MEWRN) reported a wood supply deficit of 10.3 million m^3 per year in Kenya (MEWNR, 2013). Low levels of supply are explained by inefficiencies in forestry operations and wood processing and utilization, among others.

Forests in Kenya covered 4,138,000 ha in 2010 according to KFS (2013), divided into natural forests (93%), plantations (4,6%), bamboo forests (2,1%) and mangrove forests (0,2%). Ownership is divided between public, community and private forests. The Governmental target is to increase the forest cover up to 10% by the year 2030 (Kenyan R-PP, 2010) against 7.0% in 2010 according to KFS (2013) (see Table 2 below).

Area (ha)	Public (gazetted)	Private incl. Communities	Total
Natural forests	905,000	2,945,000	3,850,000
Plantations	120,000	72,000	192,000
Bamboo forests	71,000	15,000	86,000
Mangrove forests	1,000	9,000	10,000
Total	1,097,000	3,041,000	4,138,000

Table 2: Forest ownership by broad category – according to KFS (2013)
Source: GIS analysis carried out on KFS forest cover dataset (KFS, 2013).

Public forests: natural public forests are managed for the provision of environmental services and firewood production, whereas public plantation forests are used for timber products, poles, and wood energy production. These forests are also used for grazing and providing non-wood forest products.

Community forests: community forests operations are regulated by county Governments. They provide both goods and services, especially building poles and fuelwood (MEWRN, 2013). Management of these forests is not always effective, and many harvests occur without consideration of sustainable management.

Private plantations: forest plantations that are privately owned and managed account for an important part of the total wood supply in Kenya. In most cases, the genus chosen is Eucalyptus, and the targeted products are electricity poles, fuelwood[2] and sometimes sawn wood. Some tea and tobacco companies have established such plantations to secure part of their supply in fuelwood (they also sell the surplus as poles).

Farms and agroforestry systems: farmlands – often scattered trees – also account for a significant amount of raw material. Nevertheless, log quality is less suitable for sawn wood and most of it is transformed into charcoal.

Kenya's national wood potential supply has been recently estimated at 31.4 million m^3 (of which 67% is represented by fuelwood, 23% by timber and 10% by poles). However, only 9% of the potential wood supply comes from natural forests. According to MEWNR (2013), farmlands represent 70% of potential wood supply and plantations 21%. Since 1990, a boom in the planting of private forest area has been observed in Kenya (+3,000 ha per year on average) whereas public plantations area have decreased (-1,750 ha per year on average). However, according to FAO (2015), plantations in public forests increased between 2005 and 2010 (+2,400 ha per year on average). Wood waste (sawdust, timber rejects, off-cuts) represent additional potential sources of available wood biomass (MEWNR, 2013).

National wood demand has been estimated at 41.7 million m^3 in 2013, showing a national deficit of more than 10.3 million m^3. According to MEWNR, the main factors explaining this deficit include relatively small forest areas, low average yields, and poor processing methods resulting from inefficient approaches and technologies. This deficit is expected to increase by almost 26.5% by 2032 (MEWNR, 2013). Total wood supply in Kenya is highly limited by particularly low recovery rates. This inefficiency is partly attributed to the use of old, inappropriate and inefficient machinery for sawmilling. Best management practices and more efficient technologies in the forest and wood products sector are thus expected to influence both the supply and demand for wood products (KFS, 2010).

According to the Kenyan R-PP, unsustainable practices such as slash and burn agriculture, overexploitation of timber and charcoal are direct drivers of deforestation and forest degradation (KFS, 2010).

According to the Kenyan Readiness Preparation Proposal (R-PP), the lack of security for timber supply to the sawmilling industry (low investment in timber processing technology, poor timber conversion ratios) is a key indirect factor of deforestation and forest degradation. REDD+ in Kenya must ensure sustainable utilization of wood resources (KFS, 2010)

Both public and private forestry have potential for improvement. Actions needed to improve public and private forestry have been established by KFS in its Strategic plan (KFS, 2011) and further recommendations to foster commercial sustainable forestry were put forward by several authors (ILEG, 2011 and PWC, 2014).

Both timber and fuelwood demand are increasing and the challenge ahead is to allow public and private plantations to meet their future demand in a sustainable way, by reducing the quantity of non-renewable biomass used to bridge the demand shortfall.

2.1.1 The definition of forests: a reference for REDD+ cost-benefits analysis

Deforestation is defined in IPCC's guidelines on national GHG inventories as the "long term or permanent conversion of land from forest use to non-forest use". The UNFCCC has defined deforestation as "the indirect, human-induced conversion of forested land to non-forest land" (UNFCCC, 2005 – Decision 16/CMP.1).

Deforestation induces a change in land-use, and usually also in land cover towards agriculture (cropland, pastures, perennial plants, etc.) or other forms of land use. According to the Global Observation for Forest Cover and Land Dynamics (GOFC-GOLD) (2013), although there is no official, clear definition, forest degradation can be defined as a decrease in carbon stocks that does not qualify as deforestation (e.g. no conversion from forest use to another land use), resulting in anthropogenic GHG emissions. The link between degradation and deforestation is highly dependent on the context and the combination of various drivers. Therefore, **from a REDD+ perspective, the national definition of forest is a key parameter to calculate the cost and benefits of particular measures.** Indeed, Measurement, Reporting and Verification systems (MRV) are built on a forest benchmark, on which the estimations of GHG absorptions and emissions in the forestry sector over time are based. They are compared to the Forest Reference emission levels (FRELs) or Forest Reference Level (FRL).

The forest area in Kenya varies widely according to sources. According to KFS data (2013), Kenyan forests covered 4,138,000 ha in 2010, whereas the Global Forest Resources Assessments (FRA) 2015 country report indicates an area of 4,413,000 ha (FRA 2015). The forest cover threshold used to define the Kenyan forests by both institutions is different,[3] which induces a strong discrepancy between both estimations. In the context of this study, the KFS forest definition has been used.

NB: Given the previous definitions, farmlands with trees may not necessarily be considered as forests from a strictly REDD+ perspective. According to MEWNR (2013), they are qualified as "agroforests". The analysis made in this report show the impacts of the proposed measures at national level distinguishing – when possible - the forest types on which they occur. The results are expressed in terms of the potential to generate REDD+ results in terms of a reduction a forest carbon emissions stricto sensu, according to the forest cover area reported by KFS in 2013 for year 2010 (KFS, 2013).

2.1.2 Diversity of wood products produced in Kenya:

Timber: Timber is produced from public plantations (mainly for urban markets, especially the construction sector), community/private forests and farms (mainly for local use). In 1999, Kenya had 450 sawmills with transformation capacities ranging from less than 500 m^3 per year to more than 30,000 m^3 per year, employing around 20,000 people in total. As of today, registered sawmill companies number about 700 (dated on August 2015, according to KFS Registry) and there are 32 producers of treated transmission poles, in addition to about 400 producers of firewood. Another 300 small unregistered businesses are estimated (KTMA, informal report), together with around 3,000 individual operators working with chainsaws (Muthike 2015, informal report). Sawn wood production from these mills targets almost exclusively the domestic market.

There are 3 different types of operators: (i) large industrial wood processors operate in public plantations under license, (ii) poorly equipped small and medium scale processors operate in public plantations and in community/private forests and (iii) individuals using bench-saw or mobile saws operating mainly in farmlands. Efficiency in timber processing decreases from the industrial operators to the individuals. By-products are usually used for energy production.

Given poor harvesting conditions which could not ensure a sustainable management of public forests (both natural and planted), the Government of Kenya imposed a ban on timber harvesting in public forests in 1999 (GoK, 1999). Some large companies with relatively high processing capacities were exempted from the ban and have since then accounted for almost all Kenyan sawn wood production from public forests (Robinson, 2010). Furthermore, the ban gave rise to a well-developed black timber market (often consisting of low quality wood given poor harvesting practices and processing techniques). The ban was lifted in November 2011.

People dependent on timber harvesting and processing from public forests and processing for their livelihoods, meant that domestic demand remained high (MEWNR, 2013). Despite the black market the total volume of harvested logs from public forests significantly decreased because of the ban, while logs prices increased, at the expense of the sawmilling industries and downstream manufacturers (furniture, electric poles, etc.). In 2008/2009, four companies (Pan Paper mills,[4] RAI Ply Ltd, Tim Sales Ltd, and Comply) accounted for 350,000 m^3 of sawn wood (only 5% of the total sawn wood production potential), based on logs extracted from public planted forests (KFS, 2009).

Poles: poles are harvested from any forest type. They are used for construction, transmission and local farming use (as fences). Many Eucalyptuses have been planted, especially on private lands, to meet the growing domestic demand in poles. By-products are usually used for energy production.

Firewood: firewood from public forests is extracted by licensed operators. In community/private forests and farmlands, firewood is extracted by the owners, who consume a certain quantity and sell the surplus. Firewood is mainly used in rural areas for domestic and agro-industrial use (tea, tobacco), because of prohibitive transportation costs preventing large distance transport.

Charcoal: charcoal is mainly produced in rural areas to generate incomes and is consumed in urban areas. Most of the charcoal is produced in community/private forests and farmlands, especially from natural (dry) forests and savannahs. Charcoal production is a strong driver of degradation and deforestation. Artisanal processing of wood to produce charcoal (carbonization) employs earth kilns to prevent oxygen from burning the wood. Those kilns have a very low recovery rate estimated at 16% according to MEWNR, (2013) but it can be as low as 10% (SalvaTerra, 2014). Local producers often lack the skills, raw material and investment capacities to switch towards more efficient technologies. Few producers invest in sustainable plantations for charcoal production, but the quantity of charcoal produced from sustainable sources is not yet significant. Use of charcoal in urban areas at household level is highly inefficient, despite important efforts to disseminate charcoal efficient stoves since the 1980s'.

2.2 COSTS AND BENEFITS ANALYSIS

The balance between costs and benefits of the adoption of more efficient technologies takes into account both socio-economic and environmental aspects.

2.2.1 Socio-economic aspects:

Socio-economic aspects may be treated under three categories:

- **Substitution costs**, e.g. the difference of costs between a business-as-usual process and an alternative process. For example, the cost of acquiring an improved cook stove (ICS) compared to the cost of a traditional stove (sometimes equal to zero).
- **Beneficiary margin**, e.g. the surplus of added-value or surplus of revenue made available through the use of an alternative process as compared to a business-as-usual process. For example, in theory, households spend less income to buy charcoal when using an ICS. Producers generate more charcoal and thus achieve more added-value when controlling oxygen during the carbonization.
- **Jobs creation, health and safety**. These aspects can only be treated on a qualitative basis, rather than quantitative. Measures might have adverse impacts on "poor jobs" such as traditional charcoal making, but have positive impacts on health and safety – especially in the fuelwood production and consumption sector. Gender aspects are discussed as well.

2.2.2 Environmental aspects:

WHAT IS THE TOTAL ECONOMIC VALUE (TEV) OF FOREST ECOSYSTEMS?

Forests produce multiple goods and services beyond carbon sequestration. Economic analysis needs a coherent analytical structure to systemically take into account all potential benefits and avoid double-counting. The total economic value (TEV) concept has been developed in order to identify – and quantify when possible – the different components (benefits) of the forests total value. The TEV evaluation protocol relies on the capacity of the economist to quantify in physical terms, and then monetary terms, a set of market and non-market goods and services. The economic valuation of Kenya's montane forests is an example of this (KFS and UNEP, 2012).

The TEV concept is used in this study to realize a monetary estimate of the potential benefits of preserving forests. Carbon sequestration is one such benefit, but Kenya's forests generate many additional benefits in terms of watershed protection, biodiversity conservation, production of non-wood forest products, and of course, production of fuelwood and timber. The monetary estimation is used to assess the overall cost-benefits of a given policy or measure.

GAIN OR LOSS OF TOTAL ECONOMIC VALUE (TEV)

In this report, the link between TEV preservation and increasing efficiency in forestry operations and timber processing is explored. The underlying hypothesis is that more efficient processes have less impact in terms of deforestation and forest degradation, and thus help to maintain more ecosystem services than business-as-usual processes. These values can be converted into benefits because, although forests provide environmental services that can be described qualitatively (protection of soil, water, biodiversity, production of ligneous and non-ligneous forest product, etc.), it is possible to quantify their value on one hectare of forest as outlined in figure 2 below using:

- **direct use values**, resulting from the immediate use of forest resources such as timber, non-wood forest products, recreational aspects, etc.;
- **indirect use values**, as the benefits resulting from services provided by forest ecosystems (watershed protection, water purification, etc.);
- **option values** (the values placed in future use);
- **non-use values (including philanthropic and altruism)** resulting from the desire of individuals to transmit a heritage linked to the forest (also known as "bequest value") or intrinsic value related to the mere fact that a property exists ("existence value").

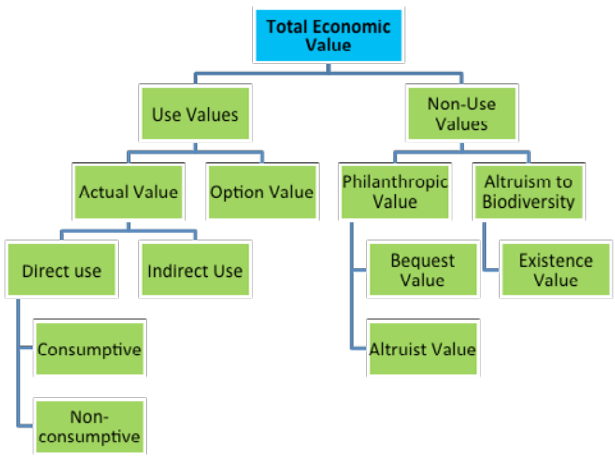

Figure 2: Overview of forest ecosystem services based on the 'Total Economic Value' concept

All of the above value components may be estimated using national data, regional data or even default values in absence of the previous.

The direct use values are estimated through the commercial value of annual harvested log volumes including fuelwood under sustainable practices (harvest equal to mean annual increment). The assessment takes into account the commercial value of other forest-based activities, such as recreational activities (including tourism), non-wood forest products harvesting, etc. It is illegal in Kenya to undertake any form of hunting in the forest, therefore this component of the total economic value is not considered in this report.

The indirect use values of forests refer to environmental services such as landscapes and soil protection against fires, landslides and erosion, water catchment protection, biodiversity, etc. In this study, we focused on water-related environmental services including water regulation, hydropower generation, water quality and inland fisheries – the other services being not well documented. Carbon sequestration is also an indirect-use value, but in this study it is isolated from other environmental services and subject to specific analysis (see Chapter 2.3.3).

The option value represents the value placed in a future use of the forest – for example, wood harvesting under sustainable forest management plans. However, due to lack of specific data on the matter for Kenya, this value is not taken into account in the study.

The non-use values (such as inheritance or existence values) are the values attributed to forests as patrimony – including for biodiversity. Usually, these values are estimated through national (or regional) surveys using contingent methods. Willingness to pay to protect forest areas is a common way to assess non-use values. In the absence of a proper assessment, the hypothesis used for Kenya is that these values are negligible as compared to direct and indirect use values.

BALANCE OF GHG ABSORPTIONS AND EMISSIONS:

The GHG absorptions/emissions balance represents the difference of emissions and absorptions between business-as-usual and an alternative process, estimated with the support of specific methodologies (CDM, Gold Standard, etc.) and IPCC guidelines. By giving a value to carbon, it is therefore possible to monetize the potential direct benefits of adopting alternative processes. The hypotheses on carbon prices are presented in Chapter 2.3.3 below.

2.3 HYPOTHESES ON TEV AND CARBON PRICES

2.3.1 Forest area

Estimations from KFS data (2013) shows a total area of 4,138,000 ha of forests, divided into 5 main types for the purpose of this study (Table below, adapted from Table 3):

Forest types	Area (ha)
Natural forests	3,850,000
Public plantation forests	120,000
Private plantation forests (including community)	72,000
Bamboo forests	86,000
Mangrove forests	10,000
Total	**4,138,000**

Table 3: Extent of forests in Kenya in 2010 (KFS, 2013)

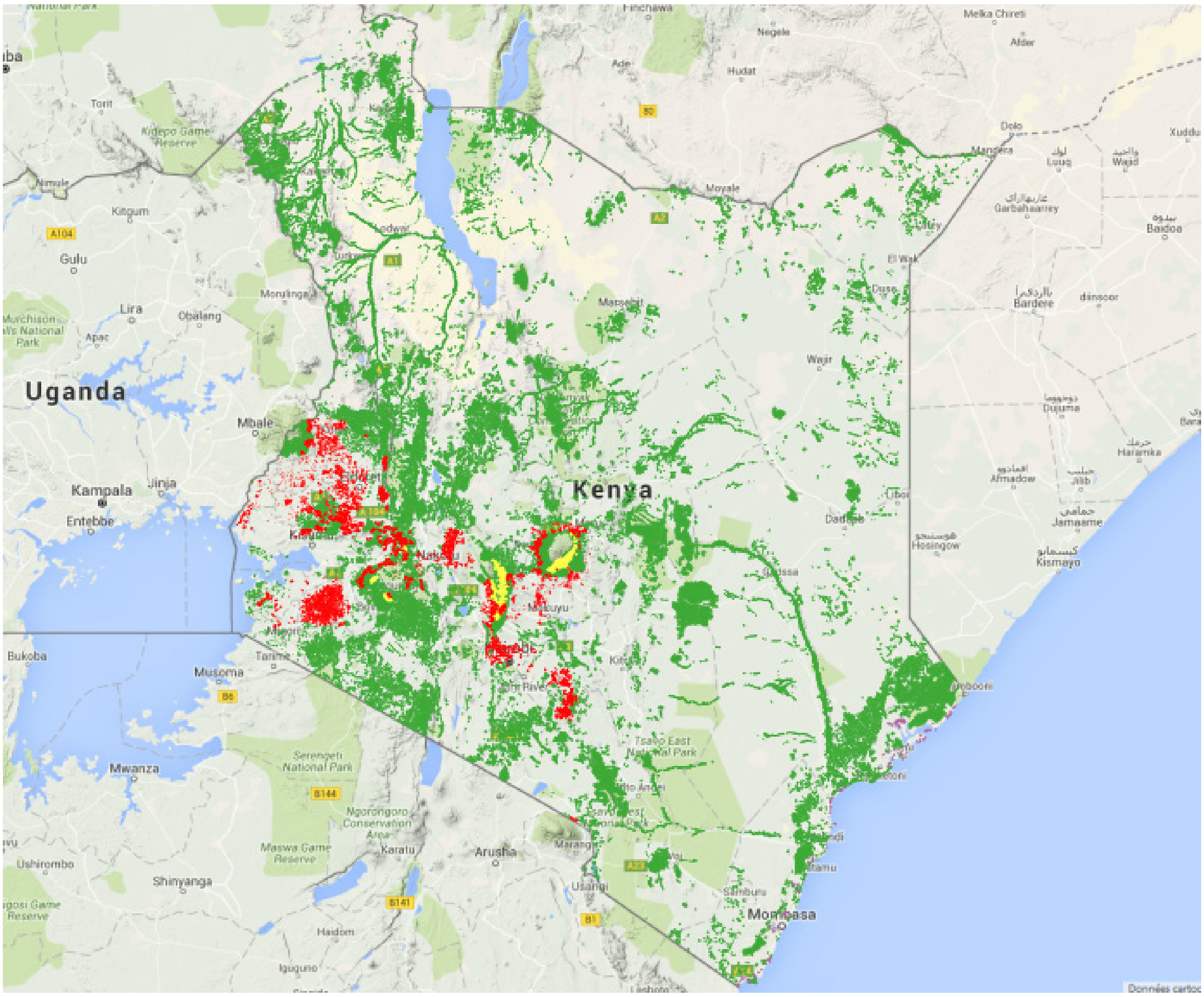

Figure 3: Forest cover map, Kenya 2010 (KFS data, 2013). In green: natural forests, in red: plantations, in yellow: bamboo forests, in purple: mangrove forests (see coastal range).

Total economic value of the Kenyan forests

As explained in section 2.2, improving efficiency in forestry operations and forest product processing may be converted into environmental benefits by "putting a value on forest environmental services". According to the methodology described above, the Total economic value (TEV) of Kenyan forests may be calculated as the sum of its direct use values, indirect use values, option values and non-use values (Montagne, 2010).

$$\text{Forests TEV (USD)} = \text{Direct use values} + \text{Indirect use values} + \text{Option values} + \text{Non use values}$$

Equation 1: Simplified expression of total economic value (in USD)

HOW IS THE TEV ESTIMATION ADAPTED TO THE KENYAN CONTEXT?

Private plantations and public natural forests do not play the same role in the Kenyan society. Given the diversity of forest ecosystems and ownership modalities, the TEV has to be calculated separately for each main type of forests. The production of goods and services should also be based on national statistics when available. In the following, a full description is provided on how the TEV has been calculated for the purpose of this study. If necessary, further work might be undertaken at the national level to update these results with statistics that were not available at the time of this assessment.

The distinction between indigenous forests and plantations for the assessment of their economic values is relevant as they produce different goods and services. Statistically, plantations produce more wood annually – up to 20 m^3/ha/year for Eucalyptus plantations in comparison with 1.5 m^3/ha/year for natural forests (MEWNR, 2013), but their biodiversity value is lower. Indeed, only 3 genuses – Cupressus (cypress), Pinus and Eucalyptus – account for more than 91% of the planted species (Mbuga, 2000; MEWNR, 2013). Different management practices applied to public and private/community forests also influence the economic value produced by forests, however publications on forest environmental services generally do not take into account this parameter.

FORESTS CLASSIFICATION BY ECOLOGICAL TYPE IN KENYA

According to Peltorinne (2004), Kenyan forests diversity can be summarized in six main ecotypes:

- The high volcanic mountains and high ranges forests (commonly referred to as **montane forests or Kenya's Water Towers**): Elgon, Mt. Kenya, Aberdares, Cherangani and Mau, which are evergreen seasonal forests and evergreen forests. A recent publication on forest-produced economic values focuses on these forests (UNEP, 2012). According to this publication, montane forests covered 1,240,000 ha in 2000 and 1,140,000 ha in 2010. The Kenya Water Towers Agency estimates the current area of the five main water towers at 1,083,493 ha.
- Western plateau forests (also called **western rainforests**): Kabarnet, Kakamega, Nandi, Trans-Mara. Kakamega are the only tropical forest remnants in Kenya. KFS estimates these forests contain the richest biodiversity in Kenya (Ireri, 2012).
- Northern mountains forests (also called **dry forests**): Ndotos, Mathews, Leroghi, Kulal, Marsabit. According to Prime Africa and LTS International (2009), more than 20% of dryland forests are woodlands and over 73% are shrublands.
- **Coastal forests**, coral rag and **mangrove areas**: Arabuko-Sokoke, Tana, Kayas. These forests shelter rare and endangered animal species. Kaya forests were sacred sites during the 19th century but the breakdown in traditional beliefs and demand for forests products now undermines their traditional protection.
- **Southern hills** (including the Eastern arc mountain forests): Taita Hills, Kasigau, Shimba Hills, Chyulu Hills, Nguruman. The Taita Hills forests, part of the Eastern arc mountains, has high rates of endemism and is one of the 25 world's biodiversity hot-spots. They also serve as catchment areas supplying fresh water to over 200,000 people.
- **Riverine forests**: Tana and tributaries, Ewaso-Ngiro, Kerio, Turkwell, Galana. The width of these forests extends 1-3km on either side of the rivers.

KFS also distinguishes urban forests (Karura, Ngong road, Dagoretti, Olula, Kabiruini, Menengai, etc.).

SPECIFIC FORESTS CLASSIFICATION FOR ESTIMATING THE TEV

The calculation of the total economic value of forests used in this study is based on the following forest classification:

- Natural forests: (i) "indigenous" montane forests, (ii) dry forests and (iii) other natural forests excluding bamboo forests and mangrove forests (hence western rainforests, southern hills forests, riverine forests and coastal forests excluding mangrove areas),
- Plantations forests: (iv) public forests and (v) private forests, including community forests.

For the purpose of this study, natural dry forests are defined as natural forests present in arid, semi-arid and very arid areas (moisture content zone V to VII, see Figure 3 below). A GIS analysis has been carried out on KFS's forest cover dataset (2013) to determine the natural dry forests cover area, estimated at 2,268,000 ha in 2010.

The KFS dataset from 2013 does not distinguish indigenous montane forests from other types of natural forests but UNEP (2012) provides an estimation for 2010 (1,140,000 ha in 2010). As a consequence, the area covered by "other natural forests" is estimated at 442,000 ha in 2010.

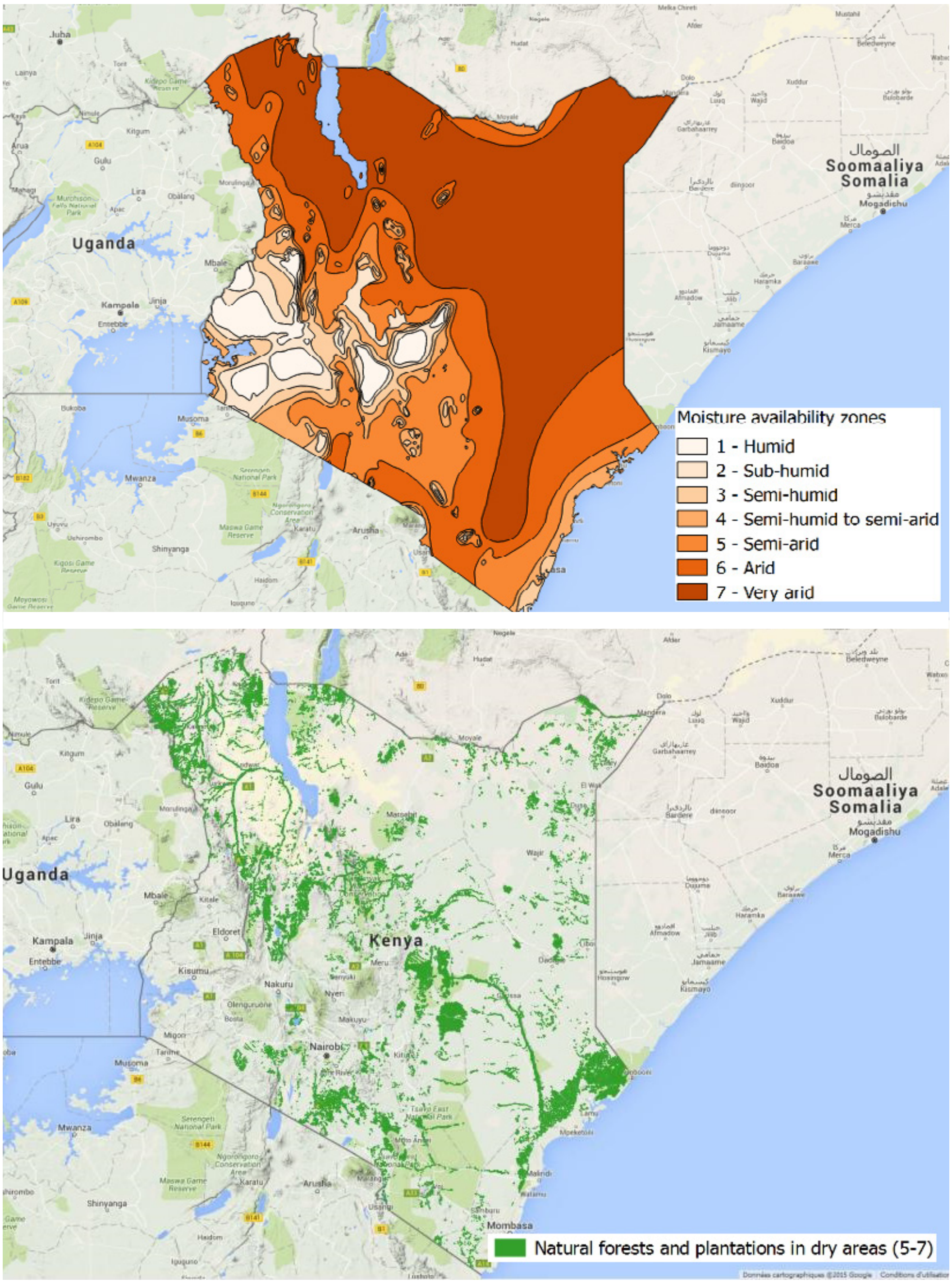

Figure 4: Dry forests in Kenya, 2010 (KFS data, 2013). Moisture availability zone in Kenya (data from ILRI GIS portal), (b) Natural forests and plantations in dry areas (moisture availability zones 5, 6 and 7).

DIRECT-USE VALUE – ROUND WOOD AND POLES

According to the Kenyan report for FRA 2015, planted forests are designated for production and natural forests for production of environmental services, mainly biodiversity and water catchment protection.

Based on 1994 data, MEWNR (2013) estimated the yield of community natural forests at 0.2 m^3/ha/year for poles and at 0.9 m^3/ha/year for round wood. For plantations, round wood and poles yields vary according to species (MEWNR, 2013). See Table 4.

Species		Round wood yield (m^3/ha/year)	Poles yield (m^3/ha/year)
Cypress		10.9	1
Pine		11.0	1.1
Eucalyptus	In public plantations	1.1	4.7
	In private plantations		8.5

Table 4: Round wood and poles yields in public and private plantations, by species (MEWNR, 2013)

According to the distribution in species given by MEWNR (2013), the mean yields may be calculated as shown in Figure 5.

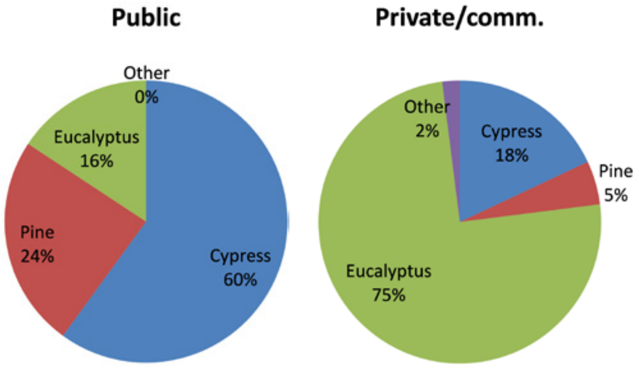

Figure 5: Distribution of species in public and private plantations (MEWNR, 2013)

Forest types	Round wood yield (m^3/ha/year)	Poles yield (m^3/ha/year)
Public plantations	9.4	1.6
Private plantations	3.4	6.8

Table 5: Round wood and pole yields in public and private plantations

Mean value for round wood (growing stock price) is estimated at 1,400 KES/m^3 (based on the price paid by a company for harvesting in plantation forests - Vermeulen and Walubengo, 2006) and mean value for poles at 15 KES/m^3 (Mbugua, 2000). Finally, the round wood and poles component of the direct use value of Kenyan forests may be estimated according to Table 6.

Forest types	Value produced (KES/ha/year)
Indigenous montane forests	
Natural dry forests	1,263
Other natural forests	
Public plantations	13,184
Private plantations	4,862

Table 6: Value of the sustainable production of round wood and poles by forests

DIRECT-USE VALUE – FUELWOOD COMPONENT

According to Kenya's report for the Forest Outlook Study in Africa (FOSA) (Mbugua, 2000), the main sources of fuelwood are woodlands and shrublands (some of them included in dry forests). Fuelwood production from woodlands and shrublands (or "bushlands") accounts for 14.24 m^3/ha and the sustainable annual fuelwood production is estimated at 2% of the growing stock (Mbugua, 2000). The sustainable production is therefore estimated at 0.28 m^3/ha/year.

Fuelwood is also sourced from gazetted closed canopy forest. These forests can be public or private/community forests. Public natural forests are managed for provision of environmental services with no commercial extraction of wood products. However, forest neighbouring communities collect fuelwood from dead trees for household-level use (MEWNR, 2013).

Community and public closed canopy forests yield for fuelwood is estimated at 0.9 m^3/ha/year (MEWNR, 2013; Mbugua, 2000). The data do not distinguish between types of closed indigenous forests. For plantations with multiple production objectives, fuelwood yield depends on species (MEWNR, 2013) as shown in Table 7.

Species		Fuelwood yield (m^3/ha/year)
Cypress		1.9
Pine		2.2
Eucalyptus	In public plantations	12.2
	In private plantations	10.5

Table 7: Fuelwood yields in public and private plantations (MEWNR, 2013)

Based on the species distribution already presented above, the mean yield for fuelwood is estimated at 8.5 m^3/ha/year in private plantations and 3.6 m^3/ha/year in public plantations. The price of fuelwood is estimated at 800 KES/stere (Ndegwa, 2010) (farm gate price), without distinction between species. For Ndegwa (2010), a stere in Kenya represents between 0.33 and 0.65 m^3, depending on the stacking. For the purpose of this study, we use the mean value of 0.49 m^3/stere. The price of fuelwood may therefore be estimated at 392 KES/m^3. Finally, the fuelwood component of the direct use value of Kenyan forests may be estimated as shown in Table 8.

Forest types	Yield (m^3/ha/year)	Unit value (KES/m^3)	Value produced (KES/ha/year)
Indigenous montane forests	0.9	392	353
Other natural forests (excluding dry forests)			
Natural dry forests	0.28		110
Public plantations	3.6		1,411
Private plantations	8.5		3,332

Table 8: Sustainable production of fuelwood by forests – Volume and value

DIRECT-USE VALUE – NON WOOD FOREST PRODUCTS (NWFP) COMPONENT

Natural forests provide medicinal herbs, resins, gums, aloe vera, honey, fish (trout), fruits, vegetables, fibres, nuts and tubers (important sources of food for forest-adjacent households especially during periods of drought and famine).

In 2000, NWFP on the market in Kenya were herbal medicines, plant resins, plant gums, oleoresins, aloe vera gel and tannins (Mbugua, 2000). Wild fruits, edible mushrooms, indigenous vegetables, nuts, arabic gum, silk, aloe vera, traditional oils, resins and medicines have a real market potential. In 2000, the Kenyan association of forest users (KAFU, 2000) estimated that NWFP generated about 2.8 billion KES/year countrywide. According to KFS (2013), the forest area in 2000 was 3,492,116 ha. The value generated by NWFP was therefore 802 KES/ha.

Emerton (1997) calculated that the Mount Kenya forest provided 300 US$/year/household to 40,000 households, with the following distribution among sources (see Figure 5):

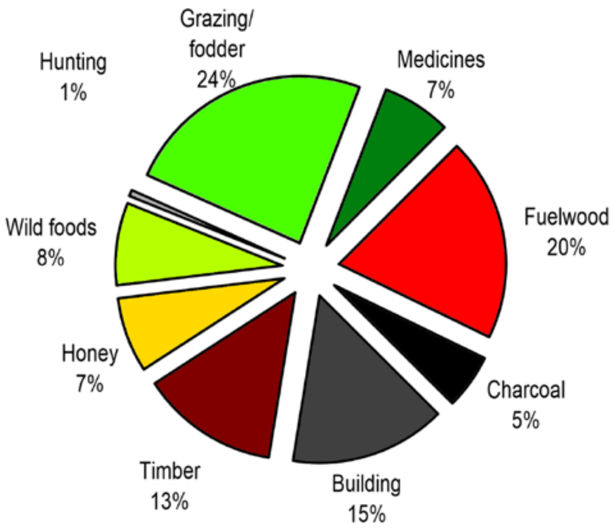

Figure 6: Economic value produced by the Mount Kenya forest (Emerton, 1997)

Considering wild edible foods, grazing/fodder, medicines and honey, NWFP represent 138 USD/year/household or 5.52 million USD/year (557 million KES/year), for a forest area of 200,891 ha in Mount Kenya. The annual production of value per ha is therefore 2,772 KES/ha/year.

For the purpose of this study, the estimate from Emerton will be used for indigenous montane forests, while the value estimated by KAFU will be used for natural dry forests and other natural forests (Table 9). In the absence of value for plantations, a conservative value of 0 KES/ha is used.

Forest types	Value produced (KES/ha/year)
Indigenous montane forests	2,772
Natural dry forests	802
Other natural forests	
Public plantations	0
Private plantations	

Table 9: Value of the production of NWFP by forests

INDIRECT-USE VALUE – WATER

According to UNEP (2012), Kenya's montane forests or 'water towers' ensure the provisioning of around 15,800 million m^3 of water each year, which represent more than 75% of the renewable surface water resources in Kenya. Hence, in the following analysis, an assumption is made that other types of forests as described above allow the availability of 25% of the renewable surface water resources (5,667 million m^3 of water/year), including plantation forests.

NB: It is generally admitted that forest cover – be in natural forests or well managed plantations - has a positive role on surface water quality and runoff reduction.[5] Mismanaged plantation forests may, however, have adverse effects on water resources - according to species, site conditions and management techniques (Calder et al., 2007). Unfortunately, the information on the area of mismanaged plantation in Kenya was not available at the time of this publication, thus we do not consider these potential negative externalities in this report.

The effects of forests on water (yield regulation, hydropower generation, inland fisheries, water quality) are calculated based on the ratio: 75% by montane forests (1,140,000 ha, to remain consistent with the data used by UNEP in 2012), 25% by other forests (2,710,000 ha).

UNEP (2012) estimated that annual deforestation of 5,000 ha of montane forests between 2000 and 2010 reduced the available water by 62 million m^3/year by 2010, causing a loss of 2,626 million KES (for 2010) due to the inability to irrigate and cultivate some lands. Based on this assumption, one can put a price on water of 42.355 KES/m^3. From a water yield prospective, the cost of deforestation of montane forests is therefore estimated at 52,520 KES/ha/year (see Table 10).

Forest types	Yield (m^3 of water/ha/year)	Unit value (KES/m^3 of water)	Value produced (KES/ha/year)
Indigenous montane forests	1,240	42.355	52,520
All other forest types	162[6]		6,861

Table 10: Value of the water regulation by forests

The publication on the role and contribution of montane forests and related services to the Kenyan economy (UNEP, 2012) attributes the loss of 690 tons of fish catchment to the deforestation of 50,000 ha of montane forests. The loss is explained by the elevated phosphate loads in catchment area, caused by deforestation.

Considering a linear effect,[7] deforestation of one ha of montane forests would therefore result in a reduction of 0,0138 ton of fish catchment, with a value of 124,638 KES/ton (calculation based on data from UNEP, 2012) as shown in Table 11.

Forest types	Yield (ton of fish available/ha/year)	Unit value (KES/ton of fish)	Value produced (KES/ha/year)
Indigenous montane forests	0.0138	124,638	1,720
All other forest types	0.0018		225

Table 11: Value of the effect of forests on inland fisheries

Most of Kenya's hydropower capacity (70%) is situated in 10 hydropower stations on the Tana River (UNEP, 2012). Hydropower in Kenya is derived indirectly from the forested catchments of Kenya's Water Towers, and principally the Aberdares and Mount Kenya. Deforestation (50,000 ha between 2000 and 2010) induced a loss of 600,000 KWh in 2010 (12KWh/ha/year), at an average price of 20 KES/KWh, see Table 12.

Forest types	Yield (KWh/ha/year)	Unit value (KES/KWh)	Value produced (KES/ha/year)
Indigenous montane forests	12	20	240
All other forest types	1.57		31

Table 12: Value of the effect of forests hydropower generation

The increasing cost of water treatment (+192 million KES/year in 2010) is also attributed to the deforestation of montane forests (UNEP, 2012). Deforestation of one ha of montane forests would therefore translate to a loss of 3,840 KES due to water pollution (Table 13).

Forest types	Value produced (KES/ha/year)
Indigenous montane forests	3,840
All other forest types	503

Table 13: Value of the protection of water quality by forests

INDIRECT-USE VALUE – TOURISM

In 2012, KFS estimated that 18 accommodation facilities existed to host tourists in Kenyan forests. Tourists are comprised of domestic and international visitors, business travellers, specialists, etc. who visit Kenyan forests for walking, jogging, bird watching, fishing, cycling, cultural activities, adventure activities, etc.

Based on existing visitors' willingness to pay, Emerton (1997) calculated that Mount Kenya forests (200,891 ha) generated annually a recreational value of 770,000 KES/year or 3.8 KES/ha/year.

According to KFS (Ireri, 2012), all natural forests are attractive for tourists. A consideration is therefore made to use the same value for all natural forests. In the absence of value for forest plantations, a conservative value of 0 KES/ha is used (see Table 14).

Forest types	Value produced (KES/ha/year)
Indigenous montane forests	3.8
Natural dry forests	
Other types of natural forests	
Public plantations	0
Private plantations	

Table 14: Estimation of the touristic value of the Kenyan forests

For KFS and Mbugua (2000), eco-tourism in forests has important potential in generating foreign exchange at the same time providing employment opportunities. The value calculated by Emerton (1997) is most probably underestimating the current situation.

INDIRECT-USE VALUE – PROTECTION AGAINST MALARIA

UNEP (2012) estimated the health cost of malaria due to deforestation at 143 million KES in 2010, with an additional cost of 252 million KES due to productivity loss. As no value has been found for the other types of forests, we consider this value for all types of forests.

Forest types	Value produced (KES/ha/year)
All forest types	7,900

Table 15: Value of the protection against malaria by forests

CONCLUSION

Based on the previous estimates, the total value produced by forests is calculated hereafter as shown in Table 16. Please note that significant assumptions have been made as mentioned in this section.

Forest types	Round wood & poles	Fuelwood	Water	NWFP	Tourism	Malaria	Total (KES/year/ha)
Indigenous montane forests	1,263	353	58,320	2,772	3.8	7,900	70,612
Natural dry forests	1,263	110	7,580	802	3.8	7,900	17,659
Other natural forests	1,263	353	7,580	802	3.8	7,900	17,902
Public plantations	13,184	1,411	7,580	0	0	7,900	30,075
Private plantations	4,862	3,332	7,580	0	0	7,900	23,674

Table 16: Total economic value produced by the Kenyan forests per year and per ha

Unfortunately, data concerning the origin of wood products used in this study do not detail the type of forest but only distinguish natural forests (with a distinction made sometimes on dry forests) and planted forests. Mean values are therefore calculated for the value of these forests (see Table 17 below).

		Value produced (KES/ha/year)	Area in 2010 (ha)	Source for forest area estimate	Mean value produced (KES/ha/year)*
Natural forests	**Indigenous montane forests**	70,612	1,140,000	Calculated based on the data from UNEP (2012). Hypothesis: deforestation rate of the Water towers was the same between 2000-2010 and 2010-2015	33,366
	Natural dry forests	17,659	2,268,000	Calculated based on KFS data (2013) – GIS analysis (natural forests in Available moisture zone 5 to 7, e.g. arid to very arid).	
	Other natural forests	17,902	442,000	Based on assumptions made in section 2.3	
Planted forests	**Public plantations**	30,075	120,000	Calculated based on KFS data (2013) – GIS analysis.	27,675
	Private plantations	23,674	72,000	Calculated based on KFS data (2013) – GIS analysis	

Table 17: TEV and forest area by type used in this report

**weighted by forest types.*

Besides, it is important to note that the TEV is only a partial estimation of the environmental benefits generated by forests. Some ecosystem services are not documented in Kenya and many statistics are old and have not been updated for a long time.

Carbon prices

Assessing the economic value of carbon is inherently uncertain as there is no uniform market price. In addition, at the time of releasing this report the UNFCCC had not provided clear guidance on how funding for REDD+ results-based payments will be calculated, including whether a price per tCO_2-e will even be the main metric. Given this uncertainty, three hypotheses on carbon prices are used in this report to quantify the economic impacts of the proposed measures in terms of emission reductions:

- **US\$ 5.6/tCO_2-e**. A price of 5.6 USD/tCO_2e (577 KES/tCO_2e), corresponding to the lowest price observed on the European carbon market during the last years.
- **US\$ 8.4/tCO_2-e**. The average price observed globally on forest carbon markets: according to Ecosystem Marketplace (2013), both on compliance markets (linked to the Kyoto Protocol, therefore only from reforestation projects) and voluntary markets was 7.8 USD/tCO_2e (803 KES/tCO_2e). Global inflation rates are estimated at 3.9% in 2013 and 4% in 2014 (CIA, 2015). Based on these rates, a mean carbon price of 8.43 USD/tCO_2e (868 KES/tCO_2e) was used for 2015.
- **US\$ 111/tCO_2-e**. The “shadow price” in 2030: 100 €/tCO_2e (11,616 KES/tCO_2e or 111 USD/tCO_2e), representing the recommended carbon price to achieve the EU target of cutting GHG emissions by four by 2050 (Quinet, 2009).[8]

Sector issues

FORESTRY OPERATIONS

An overall picture of forests in Kenya including forest definition, forest cover and main types of forest categories was briefly presented in Chapter 2. The following analysis of forestry issues is focused on production forests. Opportunities for carbon sequestration from afforestation-reforestation and improved forest management of production forests will be discussed. However, according to the scope of this study, the alternative scenario taken into account for the costs and benefits analysis was informed only on emission reduction opportunities arising from improved harvesting practices.

Statistics, issues and prospects on forestry

In Kenya there are two types of production forests: open dry wood lands supplying fuelwood, and plantations supplying fuelwood, timber and industrial wood.

In 1999 the Kenyan Government suspended timber harvesting in all the government and indigenous forests. This logging ban was then lifted in 2011 but it was effective until 2012-2013. During this time timber supply from public plantations was heavily reduced. The impact on timber industry and on public and private plantations will be discussed in the following chapter along with related issues and prospects.

NATURAL FORESTS:

Indigenous closed canopy, mangrove and bamboo forests[9] are gazetted as forest reserves falling under the jurisdiction of the KFS, managed by national park bodies or Kenya Wildlife Service (KWS). A smaller proportion falls under the authority of local Governments (PWC, 2014). No commercial extraction of wood products is allowed except the collection of firewood from wind falls and other dead trees by forest adjacent communities. Some authors (ILEG, 2011) reported illegal harvesting practices on gazetted forests, particularly in densely populated areas.

Other authors highlight the potential of commercial forestry to address the current Kenya wood deficit supply and thus reduce forest loss and degradation. This assumption is made based on the fact that the regulatory framework and the Government ability to halt illegal logging practices in natural forest and dry woodlands (PwC, 2014) is limited. However, there are no data about the log volumes coming from illegal forest practices.

Woodlands[10] are predominantly found in arid and semi-arid lands. Along with various environmental services they account for a large proportion of its wildlife population which is essential for the country's eco-tourism interests (PWC, 2014). Woodlands are managed by a combination of KFS, KWS, County Governments, private land owners, and community-based associations with the ultimate goal to assure sustainable forest management and charcoal supply.

A detailed description of Government actions, management practices, and current and future charcoal production supply potential from woodland and other areas are presented in the Chapter 3.3. It was estimated that at least 75% of wood supplying the charcoal production come from woodlands areas (KFS, undated).

PLANTATIONS (PUBLIC AND PRIVATE):

For this assessment plantations were divided into three categories:

- **Public plantations**, which are managed by KFS to supply timber, industrial wood and fuelwood,
- **Private plantations:** Intensively managed private plantations, either owned by large companies or managed by small landowners, under various forms of partnerships and agreements with industrial companies to supply fuelwood for industrial processes,
- **Private agroforestry:** Planted trees on private agroforestry systems intercropped as small woodlots, trees on the boundary of agricultural plots, and windbreaks.

As shown in Figure 7, following the logging ban, both the area and size of private and public plantation increased. Within private plantations, this outcome is likely to be related to the diversion of timber supply from public to private plantations which in turn brought about incentives to landowners to invest in new plantations. Within public plantations, KFS increased planting during the logging ban, which remained above 4,000 hectares per year since 2000 (PwC, 2014).

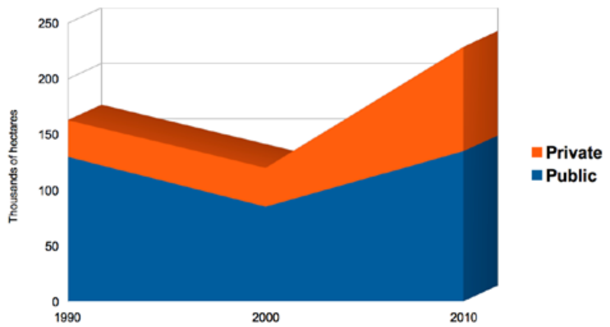

Figure 7: Plantation area by ownership from 1990 and 2010 (hectares)

Source: *1990 and 2000 data from FAO, 2010 data from KFS and PWC (2014)*

PUBLIC PLANTATIONS:

According to 2010 inventory data from KFS, there are 94,572 hectares of stocked plantations comprising mainly pine and cypress species and to a lesser extent Eucalyptus and other as shown in Figure 8.

KFS reported, in its Strategic Plan 2009/2010 to 2013/2014, an unstocked area of about 41,298 ha. This area is to be planted under the KFS national plantation development programme aiming at maintaining and enhancing productivity of industrial forest plantations and increase efficiency in wood utilization for wealth and employment creation. This should allow the extension of public plantation area up to 135,871 ha. By 2012 5,219 ha of industrial forest plantations were already established (KFS, 2012).

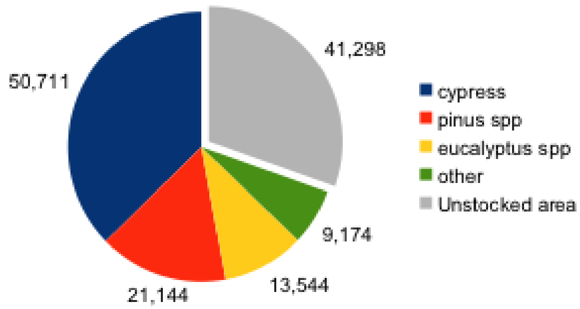

Figure 8: Plantation land cover by main species: stocked and unstocked area (hectares)

Source: *KFS 2010 data*

Log volumes harvested from public plantations from 2010 to 2014 are shown in Table 18 according to main species and wood categories: timber and fuelwood.

Species	Volume harvested in 5 years (m³)	Area harvested (ha)	Average stand volume at felling (m³)	Annual average harvested volume (m³)	Timber (*)	Fuelwood (*)
Cypress	2,268,001	14,367	158	453,600	426,384	27,216
Pinus spp	1,471,532	8,643	170	294,306	270,762	23,545
Eucalyptus spp	450,527	4,867	93	90,105	6,307	83,798
Other	483,661	881	549	96,732	87,059	9,673
Total	4,673,721	28,757		934,744	790,512	144,232

Table 18: Main wood harvesting parameters from public plantations (2010-2014)

Source: *KFS*

(*) breakdown into wood categories was done according to MEWNR (2013) average yield categorization for cypress, Pinus and Eucalyptus plantations. Wood categorization applied to 'other' log volumes were 90% of timber and 10% of fuelwood.

Given that, between 1999 to 2009, harvested volumes from public plantations ranged from 0.2 to 1.0 million m³ averaging at about 0,5 million m³ (ILEG 2011), following the lift of the logging ban public plantations experienced an increased rate of harvesting which, from 2010 to 2014, averaged 0.9 million m³.

Sustainable yield parameters are not available and, as such, it cannot be assessed whether or not this current rate of harvesting is sustainable. A proxy of annual sustainable yield was calculated per plantation species by dividing the growing stock volumes by the average rotation period, including the inter-rotation number of years. This parameter called 'presumed allowable cut volume' is compared in the following table with average harvested volumes from 2010 to 2014.

Species	Growing stock volume (m^3)	Annual average harvested volume from 2010 to 2014 (m^3)	Average rotation cycle	Annual allowable cut presumed from average rotation (m^3)	Volumes exceeding the presumed allowable cut (m^3)
Cypress	11,222,282	453,600	30	374,076	79,524
Pinus spp	5,532,889	294,306	30	184,430	109,877
Eucalyptus spp	1,699,179	90,105	10	169,918	-79,812
Other	1,231,108	96,732	40	30,778	65,954
Totals	19,685,458	934,744		759,201	175,543

Table 19: Growing stock and harvested volumes and related parameters (plantation inventory data 2010-2014)

Source: KFS

From 2010-2014, harvested volumes for cypress, pine and 'other' types of plantations exceeded the presumed allowable cut. However, this over harvesting cannot be considered unsustainable, at least in the short term. This is because, in the period following the logging ban, it is likely that there is a need to harvest over mature stands which can justify a rate of harvesting above the annual allowable cut. Nevertheless, this data shows that in the near future sustainable harvesting may not bring about higher timber volumes than those harvested over the period 2010-2014 as shown in the Table above.

As a consequence, the following costs and benefits analysis of opportunities arising from improved harvesting practices was based on the assumption that the whole current harvesting yield from public plantation is sustainable.

PRIVATE PLANTATIONS:

In 1990, the area planted in community and private forests was less than 20,000 ha and is now reaching more than 94,000 ha as a result of the country's policy favouring new plantations for the provision of wood. Private forest plantations account for an important part of the total wood supply in Kenya. In 2009 the total productivity of private plantations forests was estimated at 1 million m^3 RWE (PWC, 2014).

The following analysis divided private plantations into (i) plantations intensively managed and (ii) planted trees on agroforestry systems.

Intensively managed plantations

Privately owned plantations are usually aimed at supplying poles and fuelwood for agricultural and industrial uses. Eucalyptus is the main genus used with other exotic genuses, including Cupressus, Grevillea, Robusta and Pinus, typically grown for sawn wood production. Plantations largely supply building poles, sawn wood, fuelwood, and charcoal. The tea and tobacco industries have some fuelwood plantations to secure their own supply. Out growers plantation schemes exist as well.

There are no official statistics and little information was found on privately owned plantations, consequently this assessment was mainly informed by the following two case studies:

Finlays corporation, which manages 3,000 hectares of forest plantation to supply fuelwood for their five tea factories ;

Kenya Tea Development Agency (KTDA), which was set up to promote and foster the growing of tea on small farms relying on an out-growers plantation scheme and on their own plantations to supply fuelwood for their 65 tea factories.

FINLAYS CASE STUDY:

The Finlays Kericho tea estate produces more than 23,000 tons of tea every year with five tea factories supplied by a 6,000 ha tea estate. The estate is self-sufficient in terms of thermal energy, supplied by boilers fed with the firewood extracted from the 3,000 ha industrially managed Eucalyptus plantations.

Particularly favourable conditions in conjunction with intensive management practices results in Finlays Eucalyptus plantations reporting an average mean annual increment between 20 and 30 m^3 per ha per year. Tree planting is done by machine and stems, tree branches and stumps are all used for firewood (almost 95% recovery). Finlays has invested in green house sheds to dry the wood and heavy wood cutting machines (Personal interview).

Figure 9: Intensively managed Eucalyptus plantation stand and Eucalyptus logs at Finlays' estate (Kericho)

KTDA: KENYA TEA DEVELOPMENT AREA CASE STUDY:

KTDA supply is also supported by its out growers plantation scheme while small tea producers rely on firewood to meet energy requirements for tea processing. An out grower plantation scheme involves tree seedling production and release to local communities for future supply of firewood.

In pursuit of environmental sustainability, over the last five years, KTDA supported the expansion of their tea activity by increasing the release of seedlings (more than 20,4 million) to face an expected increased demand of firewood estimated at more than 4,5 million m^3. KTDA has set up a target to acquire more than 16,000 ha of land in the near future to increase their forest plantation area (KTDA, 2015).

PLANTED TREES ON AGROFORESTRY SYSTEMS

As it is the case for intensively managed plantations, official statistics on planted trees in agroforestry systems are not available. The assessment was carried out on the basis of information gathered from bibliography literature review.

Tree planting on farms for commercial purposes in Kenya dates back to the 1970s'. Late in the 1990s', following the enacting of the logging ban and timber shortage, farmers saw the potential for income from timber and investments in commercial tree planting on farms. However, at that time many trees harvested in agroforestry systems were not planted for timber. They were mostly intended to supplement farmers' incomes and provide animal fodder, firewood, or other wood requirements. Since they were not planted for timber, the silvicultural practices such a spacing, pruning and thinning were not carried out resulting in mature trees with poor quality stem form and knotty and reaction wood not suitable for saw logs. Furthermore, while day-to-day management of agroforestry systems is split relatively evenly along gender lines, women tend to have far less access to extension services and, as such, less knowledge of silvicultural best practices (ICRAF, 2011).

Nevertheless, the perceived declining ability of public forests and plantations to act as the major supplier of wood products has raised opportunities for agroforestry to fill the widening gap between demand and supply including for sawn logs and other timber. To promote tree planting on farms, the Government has drawn up favourable policies.

Carbon sequestration opportunities from forestry

There is scope for new public and private plantations to reduce the unbalance between wood demand and supply by increasing the wood supply. Furthermore, the investment in new plantations would also lead to enhanced carbon sequestration. This kind of investment, which is targeting the forest resources capital rather than the efficiency of operations, is out of the scope of this economic and social assessment. Nevertheless, estimations about the potential increase of plantation growing stock and related financial investments are provided hereafter. This information will allow meaningful comparisons with the actions taken into account in the costs and benefits analysis.

There are two main actions which can be undertaken in order to increase public plantations growing stock: planting unstocked areas and improving plantation management in order to maximize their yield potential.

The estimations provided in the following two sections for public and private plantations are based on the assumption that the goals of plantation management improvement and new plantation establishments can be achieved without any detrimental impact on the sustainability of plantations.

Indeed, increasing the growing stock has to be accompanied by the improvement of the quality of the timber supplied from plantation resources. As discussed on Chapter 3.2 (timber processing), one of the major factors impeding higher efficiency rate in timber processing is the poor quality of sawn logs supplied from private and public plantations (see Figure 9 as an illustration). Afforestation techniques and silvicultural operations such a pruning and thinning have to be appropriately and timely implemented to allow future plantation resources to supply quality sawn logs and thus enabling higher recovery rates in timber processing and maximising the return of investments made both in forestry and timber processing.

Figure 10: Poor quality sawn logs at a log yard in Nakuru

PUBLIC PLANTATIONS

Unstocked area in public plantations amounts to 41,298 hectares. Assuming that investments focus on cypress and pine plantations performing according to the potential yield reported by Wanleys (2013), this area could allow an increase of the current public plantations growing stock of more than 9 million m^3. KFS is incurring around 174 USD planting cost per hectare and consequently the investment needed to restock the 41,298 hectares is more than 7 million USD. Operating costs to be incurred during the rotation and related to pruning, thinning, respacing, coppice reduction, road maintenance, and fire management activities are not included.

The above result, however, might only be achieved in the long term by planting the whole area and only after the new establishments are fully integrated in the plantation estate rotation cycle. It is important to note that this afforestation investment will result in an increase wood harvesting potential of about 350,000 m^3 per year.

Data are not available to assess the appropriateness of public plantations management. However, among stakeholders there is widespread perception that public plantations management can be improved. The logging ban heavily disrupted the management carried out by KFS, mainly because of the lack of resources allocated for silvicultural operations such as pruning and thinning (ILEG, 2011). Backlogs, which are likely to disrupt the flow of future timber supply, are also well known and need to be carefully considered when planning harvesting as well as new establishments (Personal interview). Mean Annual Increment per plantation species is not known. However, the comparison of average volume at felling calculated from KFS inventory data from 2010 and 2014 with the potential volumes reported by Wanleys (2013) for cypress and pine plantations reported in Table 20 shows that the current yield potential of plantation is not fully exploited.

Species	Land cover (ha)	Current average stand volume at felling (m^3/ha)	Potential average stand volume at felling reported by Wanleys 2013 (m^3/ha)	Potential increase in growing stock from improved management of public plantations (m^3)
Cupressus spp.	50,711	157	250	4,672,455
Pinus spp.	21,144	170	250	1,685,951
Total	71,855			6,358,406

Table 20: Comparison of current and potential public plantation average volumes at felling and expected outcome from the improvement of public plantations management

Source: *KFS inventory data (2010-2014)*

Given that environmental conditions such as soil fertility and climate are reasonably favourable for cypress and pine species, it is likely that the problems disrupting the full potential come from inadequate management practices resulting in poor yields. Assuming that improved plantation management can increase the yield potential to their average level, the total increase of the public plantations growing stock would be more than 6 million m^3, which is an increase of 30% from the current level.

From the combined additional growing stock from afforestation-reforestation on unstocked public lands and improvement of public plantations management, an increase of the current growing stock of about 15 million m^3 can be achieved, which is a 45% increase in comparison with current level.

Potential additional volumes are compared with the current level of growing stock in Figure 11.

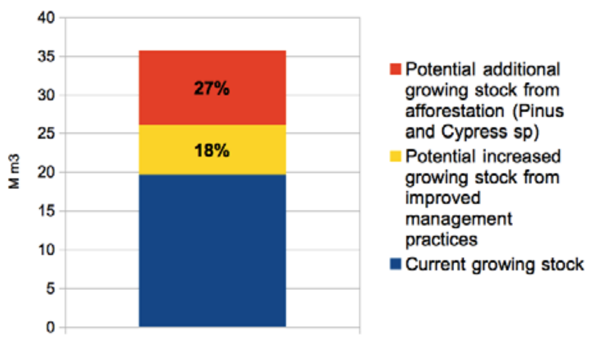

Figure 11: Potential additional growing stock from afforestation on public unstocked areas and improvement of public plantations management

PRIVATE PLANTATIONS

Opportunities in terms of afforestation-reforestation and/or improved management of growing stock could also be realized on private plantations.

Plantations which are intensively managed and owned by large corporations have largely already achieved the optimum yield rate, reducing the potential for further increase. Land availability and tenure were mentioned by the stakeholders as important limiting factors to expand further private plantations. Consequently, it seems that there is little room to increase the private intensively managed plantation area.

Small scale plantations and particularly trees in agroforestry systems have more promising prospects in terms of efficiency gains. It was mentioned above that there is a favourable policy environment for tree planting on farmlands. Kenya Forests Master Plan (KFMP), for example, estimated that trees on farms could be increased by 526,000 ha, Currently the average biomass of trees on farms is about 9.3 m^3/ha and this could be increased up to 27 m^3/ha without adversely affecting agricultural production. Promoting investments in tree planting in order to have an average biomass of 20 m^3 per hectare on additional 525,000 farmlands could result in 10.5 million m^3 growing stock increase. However, in promoting tree planting on farms, it will be important to also ensure that harvested products enter the market. For example, women and men both participate in agroforestry in Kenya, however on 20% of timber wholesalers are women (ICRAF 2011).

Measures for improving efficiency in harvesting operations and potential outcomes

This study is restricted to assessing opportunities arising from the improved harvesting operations in the costs and benefits analysis.

In Kenya, harvesting is usually done by chainsaw with varying levels of mechanization used in timber extraction depending on the scale of the operation, ranging from carrying timber by hand to use of machinery such as skidders and tractors.

Information on forest harvesting is very limited and neither statistics nor data allow benchmarking of harvesting techniques or a quantitative analysis of issue related to forest operations. Consequently, this study was informed from a literature review from which the following main problems were identified:

- Inadequate or ineffective planning of harvesting and other forest operations;
- Poor infrastructures and low performing forest machinery equipment;
- Unskilled chainsaw operators and/or inadequate supervision or operators, which can lead to log damage and/or difficultly in meeting product specifications, resulting in wastage or downgrading of timber; and
- Poor maintenance of equipment and machinery, which can lead to inefficient sawing (utilization) and fuel usage.

The issues above are source of inefficiencies, which result in log damage and/or difficulties in meeting product specifications, causing wastage, downgrading of timber at sawmill and inefficient sawing.

Notwithstanding the opportunity for improving the efficiency of forest harvesting fall within the realm of policy, training and technology, some potential areas with scope for potential REDD+ opportunities are outlined below.

IMPROVE HARVEST PLANNING

Kenya has regulations in place that govern timber harvesting in public forests (overseen by KFS) and community forests (overseen by county Governments). However, there is a need to refine harvesting systems and techniques so that they become fully compatible with the objectives of sustainable forest management. Moreover, appropriate harvesting techniques could be defined in a code of good logging practices, or similar framework for outlining best practices and oversight of timber harvesting. Developing such code could be an opportunity for improving harvesting efficiency and utilisation rates[11] through support for technicians and managers involved in wood harvesting and forest contractors. Relevant examples of best practices are available for the region and Kenyan context, see: FAO (2004).

IMPROVE EFFICIENCY OF HARVEST OPERATIONS

Vocational training in chainsaw use, tree felling and harvesting operations would help to ensure that skilled operators carry out harvesting and thereby reduce wastage and ensure optimum quality and value of logs. With correct supervision, improvements in forest sawing practices would help to ensure product specifications are met when cutting trees into logs and help to increase production rates of harvesting crews.[12]

IMPROVE EFFICIENCY OF SKIDDING AND HAULING

Planning and managing log skidding and in-forest transport is a potential area for improvement in relation to both forest management and fuel usage. Identification of efficient skidding and haulage approaches could improve recovery and lower the cost of operations.

An example of opportunities for efficiency improvements is the use of winch capability of skidders with synthetic rope (minimise movement of the skidder for extraction) and/or to use a tractor with a trailer to move full tree lengths (or long as possible) to a central processing point. In this scenario, the effective use of tractors minimises the number of people making key decisions on what products are cut and puts all products and residue in one spot for effective recovery.[13]

This type of actions can improve efficiency by reducing waste during logging and log processing and thus allowing higher recovery rates. This means that higher volumes of wood could be extracted from plantation resources and less waste will be left after harvesting.

The investments in a code of harvesting practices and vocational training for about 250 workers per year could increase the efficiency rate of logging operations by 5% (hence wood volume recovery from logging can be increased by 5%).

Capacities through vocational training have to be built progressively. The number of forest workers operating in Kenya is not known. Given that there are between 700 and 1,000 saw millers, it is reasonable to estimate a number of forest workers comprised between 2,000 and 3,000. Assuming training of between 200 and 300 forest workers per year, the whole forest worker force could be trained in 10 years time.

Table 21 shows the potential outcomes from improved harvesting practices, which is based on the above-mentioned assumptions.

Harvested timber volumes per year from public and private plantations (m^3)(*)	2,000,000
Number of forest operators trained per year	250
Average harvested volume by a forest crew made of 4 chainsaw operators per year (m^3)	5,000
Expected recovery rates increase (%)	5
Avoided wood waste from improved forest operations (m^3) over 10 years	859,375

Table 21: Potential outcome from improved efficiency brought about by training measures

(*) based on estimations presented on Chapter 3

The vocational training courses needed for loggers will have a structure and features similar to the training courses described in the Chapter 3.2.2 for saw operators. According to the experience from European training courses, the overall cost for training courses on harvesting techniques involving 10 trainees and having duration of 10 days is around 15,000 USD. Accordingly, the training of 2,500 forest operators would have a cost of about 3,750,000 USD.

Costs and benefits analysis

EMISSION REDUCTIONS

As explained above, improving harvesting operations through appropriate techniques could reduce wood waste from logging by about 5%. This would help increasing the production capacity in public and private plantations by reducing wastage. The objective of this Chapter is to determinate the REDD+ potential associated with these savings.

The following general equation is used to calculate the emission reductions associated with a given REDD+ measure aiming – in this chapter – at improving the efficiency of forestry operations to increase wood production, by reducing wastage(Source: adapted from IPCC, 2006):

$$ER = Bsavings \times fNRB \times BEF \times (1+RSR) \times Cf \times 44/12$$

Where:

ER = emission reductions (tCO_2e per year)
B savings = quantity of biomass saved per year (in tons) in the REDD+ scenario
fNRB = non-renewable biomass fraction
BEF = Biomass expansion factor (default IPCC values)
RSR= Root-shoot ratio (default IPCC values)
Cf = carbon fraction (default IPCC values)
Conversion factor from C to CO_2 = 44/12

The proportion of non-renewable biomass (also called "non-renewable biomass fraction") is an essential parameter to assess the emission reductions potential. It is calculated as follows:

$$fNRB = \frac{\text{Total biomass harvested per year - Sustainable yield per year}}{\text{Total biomass harvested per year}}$$

The fNRB can be calculated for each type of forest (natural vs. planted) and wood product (in this case, logs for timber processing). When fNRB is equal to 0, the annual harvested biomass is equal to the sustainable yield: in this case, there is no carbon stocks degradation. However, when the fNRB is between 0 and 1, it indicates a decrease in carbon stocks over time, e.g. forest degradation.

Improving the efficiency of harvesting operations is a relevant REDD+ measure if it reduces GHG emissions from deforestation and/or degradation in comparison to a business-as-usual scenario. The business-as-usual scenario must include the actual national trends to remain consistent with UNFCCC guidelines (GOFC-GOLD, 2013).

From a REDD+ perspective, emission reductions from improving the efficiency of timber processing operations in forest plantations may come from two sources: first, savings of non-renewable biomass in plantations, and second, alleviation of the pressure on natural forests due to an increase in total production.

Alleviation of pressure on natural forests to produce timber

The measures that are proposed above in terms of harvesting operations are addressed to formal operators harvesting in public and private plantations. Hence, these measures are not expected to affect illegal logging operators in natural forests.

There is no evidence that increasing wood supply from plantation harvesting will decrease the pressure on natural forests for timber production. From a REDD+ perspective, this assumption is crucial, because it affects the potential emission reductions of the proposed measures.

If such a link can be demonstrated, the biomass savings generated by the proposed measures might be converted into emission reductions using the equation above. Hereafter are presented some key-elements for further discussion:

- According to KFS (2007), since the 1999 ban, nationally most of the timber produced comes from plantations with most of the timber used in Kenya sourced from across the border. Timber trade between Kenya, Tanzania, Uganda, DR Congo, etc. remains informal and unregulated. Small, illegal saw millers rely mostly on timber from private farms and illegally accessed timber from forest reserves.
- Illegal logging for timber production is still occurring in forest reserves, especially through indiscriminate and uncontrolled selective cutting of rare species (KFS, 2007). However, construction material is not the only driver of illegal timber harvesting. Sandalwood (*Osyris lanceolata*), mainly use in the perfume industry and for its medicinal properties, is one of those rare species, exported to Tanzania, India, Europe and South Africa. Camphor (*Cinnamomum camphora*), is also illegally harvested with the bark used to produce oil.

At the moment, it is not possible to conclude based on evidence, that increasing timber supply from harvesting in plantations will decrease the pressure on natural forests for timber production. In this case, improving the efficiency of forestry operations would therefore not generate additional emission reductions in terms of REDD+.

The Kenyan R-PP (KFS, 2010) suggests to "*Undertake a comprehensive study to assess and analyse the existing information on the scope and extent of illegal logging and other forest crimes to provide a basis for regular monitoring and up-dating of information*". This recommendation remains valid.

Savings of non-renewable biomass in plantations

Increasing afforestation-reforestation on public and private lands is also a notable trend within the business as usual (BAU) scenario.[14] Public and private plantations are the main providers of timber for Kenya's small and medium enterprises (SME) and the total planted area increased following the logging ban in natural forests.

As described above, it is assumed that the annual harvesting is close to the sustainable yield (or mean annual increment) in public and private plantations. Therefore, the fNRB in the BAU scenario is close to null. Improving the efficiency of forest operations such as harvesting will therefore not generate additional emission reductions from non-renewable biomass savings. As such, increasing recovery rates might not have an impact on growing carbon stocks but rather on the overall wood supply (more production, less wastage – 86,000 m^3 RWE per year).

To conclude on REDD+ opportunities in forestry operations, it is expected that several measures that are out of the scope of this study might have significant impacts in terms of emission reductions, such as:

- Carbon sequestration by increasing the forest area through afforestation and/or reforestation (A/R). However, the annual A/R rate used in the REDD+ scenario must exceed the current trend as a result of these REDD+ measures to be considered as fully additional.
- Carbon stocks enhancement in forest plantations by improving the silvicultural practices such as thinning, pruning, extension of rotation age, etc. might also be a potential source of emission reductions, by increasing the mean carbon stock per ha.

BENEFICIARY MARGIN

Biomass savings are the quantity of wood biomass saved per year according to the implementation of the proposed measures. Biomass savings correspond to an increase of the total production from harvesting operations.

Considering the savings of 86,000 m^3 RWE per year from plantations, this would represent a total value of 1.1 million USD based on 1,400 KES/m^3 (based on the price paid by a company for harvesting in plantation forests - Vermeulen and Walubengo, 2006).

FORESTS TOTAL ECONOMIC VALUE (TEV)

As explained above, there is no evidence that increasing wood supply from harvesting in plantations will decrease the pressure on natural forests for timber production. In the absence of such a link, it would be imprudent to assume that improving the efficiency of forestry operations would help preserve natural forests and hence the economic value it represents according to the TEV approach.

JOBS, HEALTH AND SAFETY

In general, improving forest harvesting techniques is done through training that includes safety procedures. Operators are trained on several aspects, such as controlling tree-felling direction, delineating safety tracks on-site, team alerts and first aid. Thus, operator safety is a major co-benefit of training measures. Furthermore, if training targets both men and women, increasing gender equality could be an additional co-benefit from the action.

TIMBER PROCESSING INDUSTRY

Statistics

INTRODUCTION

Industrial timber sawing activity in Kenya started at the beginning of last century (1913), and progressively developed until World War II, during which the timber sawing activity increased as it supplied the armament industry through its 60 sawmills (Muthike et al, 2011).

Following independence country in the 1970's, and the implementation of 80 development plans, the number of sawmills increased to 450 in the 1990's, with an overall production capability of 200,000 m^3 of sawn timber products per year. The industry employed about 20 thousand long-term employees, in addition to seasonal workers (Muthike et al., 2011).

The first restrictions to the use and export of local timber started in the 1980's, but in 1999 a specific ban officially prohibited timber harvesting in public forests. Only a few large companies were able to obtain derogation and were authorized to continue their activity, while 90% of small and medium businesses had to stop or considerably reduce their activity. Some companies started to supply agricultural businesses or community forests, and timber was harvested in small private parcels.

The Forest Act passed in 2005 marked a turning point as it provided much more support to the timber sector. In 2011/2012 timber harvesting in public plantations resumed, while natural forests remained exclusively devoted to nature conservation.

As of the release of this report, registered sawmill companies number about 700, (according to the KFS Registry, with 32 producers of treated transmission poles, in addition to about 400 producers of firewood. The study estimates the existence of another 300 small businesses that are not registered, together with around 3,000 individual operators harvesting with chainsaw (Muthike 2015, informal report).

The 2030 Vision (Republic of Kenya, 2007) places sawmills, together with other SME, at the heart of the country development plan. However, small sawmills have to face a range of economic difficulties and structural deficiencies/weaknesses which puts them at a disadvantage compared to larger organisations. These include:[15]

- Difficulty/uncertainty in finding raw material,
- Difficulty accessing credit and high interest rates,
- Obsolete and limited efficiency equipment/machinery (over 75% of registered sawmills are equipped with circular saw, performance/yield ranging between 18% and 30%),
- High equipment purchase costs due to taxation on imported equipment/machinery,
- Difficulty in setting up production facilities due to barriers to authorizations and utilities,
- Unclear relationships and rights with the different local communities, and
- Presence of irregular operators and unfair competition.
- The timber processing business

Even though a registry of KFS authorized companies exists, statistical data on this sector are incomplete. With regards to equipment/machinery, KFS reports the following breakdown.

- 75% circular saws ;
- 15% woodmizer mobile saws ;
- 10% other band saws.

For this study, sawmills were classified according to the type of equipment and personnel they have into the following three groups:

- Industrial sawmills featuring varied outputs wood products, efficient sawing equipment and infrastructures, usually employing more than 100 employees (there are less than 5 in the entire country),
- Small and medium-size sawmills featuring poor efficient equipment and infrastructures and usually employing less than 100 employees,
- Individuals harvesting and processing timber with mobile equipment.

The volumes of sawn logs can only be estimated according to the production capability of businesses assessed during the field study carried out in July 2015 and compared to the volume of timber sold from public plantations (KFS, interviews).

The volume of log processed by sawmills was estimated at about 1.8-2.0 million m^3. Average timber volumes processed per individual operator was estimated at 100 m^3 RWE volume annually, giving a total of around 300,000 m^3 RWE per year. Consequently, for the purpose of this study, we assumed that 2.1 to 2.3 million m^3 RWE are currently processed by the timber industry and individuals operators.

Several authors estimate that 70% of sawn and other timber products (timber-based panels and poles) rely on timber harvested in public plantations, while the remaining 30% come from private plantations and from the widespread "timber farming" business (Muthike et al 2011). Actually, it is likely that the timber coming from private landowners and/or other sources can be consistently higher reaching more than a half of total supply.

KFS data show about 0.9 million m^3 annually sold on the market from 2010 to 2014. As mentioned in Chapter 3.1 the sustainable annual yield from the currently stocked public plantations was assumed to be the average volume harvested from 2010 to 2014. There is little information available on private forestry, but it is likely that the estimated supply above has strongly increased in recent years. In 2009 the total productivity potential of private plantations forests was estimated at 1 million m^3 (PWC, 2014). Moreover, about 0.3-0.5 million m^3 of wood are supplied from community forest and farmlands (World Agroforestry Center, 2011). Reliable data on illegal logging and imported timber were not available, but it has to be noted that imports and illegal logging are other possible sources of timber supply, notably from public forests.

The study estimates that 20-30% of total consumption occurs in large facilities and the remaining 70-80% in smaller plants or individual operators (see hereafter). The breakdown of such volumes for assorted timber products is equally uncertain, but it could be represented as follows (Wanleys, 2013): 10% plywood and other wood panels, 15% poles for transmission, and 75% sawn wood.

By looking at these figures, it would appear that the sector, despite its challenges including being latent for several years, has steadily developed, far exceeding the production levels reached during the 1990's. In fact, considering the average performance of wood sawing equal to 33% of 2.1 million m^3, the annual sawn wood production may be estimated at 700,000 m^3 of products which is more than three times of the 1990's figures (200,000 m^3).

It is also worth noting that the small and medium sawmills are located close to harvested forest resources (a range of 70-100 km) and often close to cities and roads towards urban agglomerations (Nairobi and Mombasa) where the bulk of the demand of sawn timber comes from.

Timber sawing is also carried out on forest sites using chainsaws or portable sawing equipment by individuals who carry out this activity occasionally or according to private needs. This kind of activity is relatively widespread to carry out harvesting in agroforestry fields and it has increased since 1999. These operators are able to fulfil specific requirements, even for small quantity, and they supply local market demand, which, otherwise, would not be fulfilled by industrial timber sawmilling.

Chainsaw timber sawing is known to involve lower recovery rates. However this technique, if properly performed with the support of blade guiding equipment, can provide acceptable results for small scale splitting, with recovery rate up to 50% (Muthike et al., 2011). Operator's level of training plays an important role as they have to be able to assess the logs before sawing, master chain sharpening techniques and machine maintenance, and be able to use the chainsaw properly. There is need here to also create awareness among tree farmers and individuals operators on the benefits of "the improved framed chainsaw system".

SAWMILL PROCESSING

There are few industrial sawmills in Kenya and each one represents a case of its own (see Figure 11 for illustrative purposes). The observed field case study (Tim Sales) is dedicated to a productive facility organized with several production processes (timber treatment, drying, sawing, panel production, production of finished door and window frames), in order to use the raw material and offcuts in an integrated way, and thus maximizing recovery rates and optimizing production. Infrastructures and equipment are considerable, efficient, and recent, even if not last generation.

The scope of this study is focused on medium-to-small size sawmills, because they offer more opportunities for improvement and because they are quite widespread. Despite poor infrastructure and equipment, medium-to-small sawmills are very dynamic. Log and sawn timbers yards and storage areas for offcuts and cull wood are often insufficient as well as the area dedicated to the sawmilling per se. These deficiencies influence the possibility of rationalizing sawmilling processes, particularly incoming and outgoing material handling and its division by quality classes.

Logs (round wood) are not sorted according to quality in sawmills. Apart from non merchantable species, all the supplied logs are sawed. Sawing is carried out, in most sawmills, using old-style band saws (equipment dating back to the 1960's and 1970's) or new mobile saws of wood mizer type (15% of cases), which are becoming quite widespread now (TMA, interviews). This latter equipment has the advantage of being relatively cheap, has blades of limited thickness and thus allows greater recovery rates; it is highly flexible as it can cut large and small diameter size logs. Obviously, productivity is not comparable to the one of a fixed trolley-based saw.

Logs are fed into the machine by conveyor belt or by hand. Subsequent handling (i.e. unloading of sawn wood, maintenance works (quite rare) and stacking) is carried out manually. In some cases there are pit saw lines or other belt saws mounted on a bench designed to trim sawn woods into assortments of smaller thickness.

Figure 12: Band saw and wood mizer saw installed at Bufflo and Kelkos sawmills (Nakuru)

Sawn wood are sold with limited sorting: usually final products are not classified according to quality and/or size. The sale is done in bulk to resellers or to timber yards. According to the interviews, saw millers know little about the attributes required for the final use of their products, which, in most cases is related to the construction sector.

Mill wastes, such as offcuts and slabs, are limited as sawing is performed in order to optimize the timber log regardless of machine and labour time involved in the processing. Mill wastes are in the range of 30-40% and they are sold as firewood (see Figure 12 for illustrative purposes). No recycling or other internal valorisation of mill cull was observed. Chipping is performed by industrial sawmills but not in the medium and small size sawmills. Saw dust is removed manually in the sawing area, stocked on the yard, and sold in the market as biomass energy at very low price. Apart from firewood, mill cull are not so easily placed on the market.

Qualitative and quantitative performances of sawmills in which timber sawing is done with circular saw are even poorer (recovery rate being around 30%).

Sawing by chainsaw has low recovery rates, but in this case it is due to inexperience or to lack of ability from the operator, otherwise the recovery rates could exceed 50%, especially for thick products (Muthike, 2011). The use of a frame can considerably ameliorate the recovery and the quality of the sawn timber.

Figure 13: Sawdust and offcuts at Lanet sawmill and timber yards at Bufflo sawmill (Nakuru)

Table 22 below contains data from field interviews and estimations about the economic margins of the current sawmilling business (BAU) in a standard medium-size unit processing around 2,000 m^3 of log volume.

Item	Value
Cost of standing raw material	25-30 U$/m^3
Tree cull in the forest	(5-10% volume of the tree)
Mill cull (off cuts)	(30-40% volume of the trunk)
Mill cull (sawdust)	(10-15% volume of the trunk)
Value of sold sawn wood	220-250 U$/m^3 sawn wood
Value of off cuts	10-15 U$/tons
Value of saw dust	5-6 U$/tons

Table 22: Economic margins of the current BAU medium-size sawmilling businesses

Available technologies and measures to increase efficiency in timber processing

The actions recommended in the following sections concern both those intended to have a direct impact on efficiency at the processing site as well as actions concerning the sustainable development of the sector as a whole. In the final section, the outcomes from the potential efficiency improvement will be assessed in terms of potential raw material savings.

AVAILABLE EFFICIENT TECHNOLOGIES

A range of available technologies to support the previously suggested technical improvements is described below:

- *Chainsaw milling.* Inefficiencies arise from the wide kerf of a chainsaw and in inaccurate sawing when done free-hand. KEFRI has developed an improved chainsaw mill attachment that guides the chainsaw as it cuts, thus helping to reduce waste and improve the quality (straightness and dimensional accuracy) of the timber produced.
- *Sawmill.* Portable and semi-portable sawmill systems are available in Kenya for a variety of scales of operation, ranging from portable in-forest sawmills to medium sized operations. Some medium sized sawmills in Kenya have recently adopted Wood Mizer equipment which cuts with band saws. Other options, particularly for smaller operations, include Lucas Mills which are portable mills that cut with 'swing-blade' circular saws,
- *Multi blade saws.* The logs sourced from Kenyan plantations (mainly Eucalyptus) are generally of small diameter, difficult to efficiently process. Multi-blade circular saws are available that cut multiple boards in a single pass by the sawmill operator. Using such equipment could help maximise production yield from small logs,

- *Utilization of processing residues for energy.* There is potential to utilize mill cull, such as timber offcuts and sawdust, to generate heat and electricity that could run sawmills and processing equipment such as kiln dryers. Wood fired electricity generation systems exist that can be used in sawmill operations as well as in other industries such as tea production. Energy costs are then reduced for the sawmill,
- *Adding value to timber.* Drying timber is an important production step to ensure stability during use and therefore its quality and durability. Kiln drying systems can be developed that could be utilized by small-medium producers or perhaps groups of producers. Such technology could help to improve the wood quality and financial returns to small producers. Relatively simple systems can be constructed with a capacity of 15-20 m^3 using a shipping container and solar power,
- *Training* in chain sawing using framed chainsaw techniques as well as awareness raising among local enterprises to encourage investments in producing the frames to make them cheaper and readily available to operators.

POLICY MEASURES

Structural actions, such as improvement of the road network and access to the supply of electric power are important for timber processing as well as for other craft-related sectors.

In consideration of the situation of forests in the country, the most important measure to ensure a future of prosperity to the sector is to provide a constant and sure supply of raw material, both by acting on a better management of public plantations, and by promoting timber farming in private farms, especially small and medium size ones. Should this prerequisite not exist, any investment and corporate improvement policy by sawmills would be impossible, since there is no certainty that these investments will generate the expected returns.

Insufficient raw material force local sawmills to close or to become second-tier businesses dealing with imported sawn wood. Timber import seems bound to increase, but import of round wood faces increasing export limitations imposed by many African countries, to the advantage of local processing.

Another important aspect is the modality used to market the forest resources in order to ensure the following:

- Supply continuity for multi-annual purchasing contracts (at least three years),
- Purchasing and selling transparent procedures and completeness of information on volumes, timber quality and forest stands accessibility, and
- Regulatory mechanisms to avoid the concentration of resources and to grant incentives to the best players and avoid privileged positions.

TECHNICAL IMPROVEMENTS

Improvement recommendations for the sector mainly consist of actions on processing installations and vocational training for operators. The following types of investments could be supported:

Improvement of infrastructural equipment and machineries at company level:

- Improve corporate structures (yards, warehouses) to promote the quality of the product and improve personnel working conditions (safety and health),
- Improve recovery rates by purchasing portable belt saws to replace circular saws, or high-productivity sash gang saws in addition to belt saws (for short assortments),
- Improve the valorisation of offcuts and sawdust, for example by installing compacting systems to be used for saw dust as a raw material for briquettes making, and
- Improve the value of processing by for example drying the timber which can later be sold at a higher price, or by developing secondary processing lines for the production of finished products such as panels, floors, etc.

The values shown in the table 22 below refer to an average medium-size sawmill, processing 1,000 to 1,500 m^3 per year of round wood with about 15 employees allowing investments in saw equipment and briquette making devices. For the investment in drying equipment higher volumes of sawn wood would be required, at least 4,000 m^3 of round wood processed per year.

Public contributions can be delivered in various forms, in capital account at the end of the investment, as interest-rate subsidies, or in terms of tax relief. Public contributions are calculated as an average amount of 30% of the investment. Such percentage is normally applied to the sector in many countries of the EU in programs designed to support and develop forest activities.

Table 22 shows the average investments needed to support the suggested technical improvements as well as potential outcomes in terms of wood volume savings over 10 years. The calculations are based on the average expected increase of recovery rates and the number of industry participants willing to carry out this kind of investment. The estimated number of industry participants is based on the feedback received by local stakeholders during the field study and the inception workshop.

Vocational training for sawmill personnel:

Training courses are very important to allow technical improvement to be effective. Their goal is to improve human resource capacity enabling an efficient utilization of new technologies. According to the experience of vocational training courses for sawmilling operators in Europe, three types of courses could be put forward.

- Training courses on business management for sawmill owners,
- Training courses on wood technology and timber market for sawmill owners and production managers, and
- Training courses for saw operators and maintenance staff.

Currently sawmills tend to behave as performers of a processing work, rather than adding value to a raw material. Adding value on timber products according to the final use is left to resellers and whole sellers. They supply final consumers with the right product for the right use. Under these conditions, it appears that the higher margin is left to resellers who are in direct contact with final customers and who have the best knowledge of the market, products, and relevant needs.

This pitfall is exemplified by the poor ability to add value to best quality forest stands by non-industrial sawmills, which are not able to diversify their products on a qualitative basis and according to final destination of use. In order to provide added value to primary production and transformation, managers and marketing personnel as well as technical staff working in sawmills have to receive training.

Specified costs in Table 22 below refer to the organization and delivery of a relevant number of modules allowing the amortization of initial organizational costs. The above mentioned courses must be organized in short-term modular form and spaced over time so that attendance is compatible with operators' regular working activity.

Vocational training for individual operators:

When considering operators using portable chainsaws, it is possible to envisage short-courses (2-3 days) mainly focused on safety issues, chain sharpening and the use of bar-guide devices to be attached to the chainsaw.

The cost of importing a chainsaw frame would be about US$ 350-400, while producing it locally currently costs US$ 120-130. This should raise incentives to produce the frame locally. Awareness raising for local metalworkers could allow local enterprises to seize this opportunity.

Estimated potential outcomes from the improved alternative scenario

For the purpose of this study, the assessment considered only raw material savings. However, it has to be noted that the proposed measures will go far beyond raw material savings resulting in increased production and quality sawn wood which are beneficial for the entire wood supply chain from the forest resource to the carpentry sectors.

Table 23 shows the potential outcome from the recommended measures to improve efficiency in timber processing. Each measure has a specific target in term of number of operators involved ranging from 10 to 400 enterprises or individuals. Unit costs are based on the real costs of the investment and do not take into account transaction costs. Sawn wood and sawdust production parameters are based on an average small-medium size enterprise.

Concerning vocational training, experience from European countries shows that, initially, training must be delivered free of charge because it is not perceived as a real benefit by operators. Only in a secondary stage will operators understand the advantages and become willing to invest their own money.

The introduction of adequate supporting policies, infrastructural improvements, equipment investments and human resource training can contribute to increase recovery rates and allow raw material savings ranging between 5% and 10%.

Taking into account the current volume of processed sawn logs, the potential improved recovery rate would result in about 210,000 m^3 RWE saving per year and, prospectively, in 2,100,000 m^3 RWE savings over 10 years.

	Investments in infrastructure	Saw Equipment	Briquettes making equipment	Board drying	Vocational training (business management, wood technology, markets)	Vocational training (operators)	Vocational training (individual chainsaw splitters)
Unit cost (USD)	25,000	25,000	7,500	200,000	2,000	3,000	1,000
Current round wood consumption (m^3 per year)*	1,500	1,500	1,500	4,000	1,500	1,500	100
Current sawn wood production (m^3 per year)	500	500					30
Current sawdust production (tons)			180				
Potential sawn wood processed annually				2,400			
Expected increase of recovery rates (+%)	+7%	+20%		+5%	+5%	+5%	+20%
Valuation of waste as raw material (m^3 RWE)**			900				
Production increase from higher recovery rates (sawn wood – m^3 per year)	105	300		200	75	75	20
Raw material savings from higher recovery rates in 10 years (m^3 RWE)	1,050	3,000		2,000	1,500	1,500	200
N° of players	100	200	300	10	400	200	1,000
Overall savings calculated over 10 years of activity (m^3 RWE)	105,000	600,000	270,000	20,000	600,000	300,000	200,000

Table 23: Summary of efficiency measures in timber proces sing

** Estimations are based on the average size sawmill consuming around 1,500 m^3 of round wood per year. Statistics are not available to breakdown estimates according to industrial, medium-size and small sawmilling. Board drying technologies are assumed to be viable only for sawmill consuming more than 4,000 m^3 per year.*

*** assuming that the saw dust is used at 50%, 90 out of 180 tons per year are transformed and sold as briquettes during 10 years substituting around 540 m^3 RWE of fuelwood.*

Column 1 is about infrastructural investments related to the log and timber yards or to the sawmilling site such as the hangar or the pavement. Column 2 is about the investments in new equipment such as Wood Mizer type or multi-plank sawmill. Column 3 is about the investment in the equipment for briquettes making. Column 4 is about the investment in timber drying technologies.

Cost-benefit analysis

EMISSION REDUCTIONS

From a REDD+ perspective, emission reductions from improving the efficiency of timber processing operations in forest plantations may come from two sources: first, savings of non-renewable biomass in plantations, and second, alleviation of the pressure on natural forests due to an increase in total production from plantations.

Savings of non-renewable biomass in plantations:

The proportion of non-renewable biomass (also called "non-renewable biomass fraction") is an essential parameter to assess the emission reductions potential in this sector. It represents the proportion of wood biomass harvested per year that is not renewable, e.g. exceeding the sustainable yield. As described above, we may assume that the annual harvesting is close to the sustainable yield in public plantations. Therefore, in absence of degradation in plantations in the BAU scenario, the fNRB is close to null and emission reductions equal to zero. We may also assume that private plantations are in the same situation - being even slightly better managed than public forests.

Biomass savings are calculated as the quantity of wood biomass saved per year according to the implementation of the proposed measures. From the saw miller's point of view, these savings may correspond to two situations.

First, these biomass savings may correspond to a reduction in the raw material consumption by saw millers to produce the same amount of wood products per year. In this case, the annual production of wood products would remain equal over time (Bsavings > 0). However, given the growth of the construction industry, the development of the first processing sector, and the subsequent demand increase in wood and timber from plantations (KFS, 2007 ; MEWNR, 2013), it seems difficult to adopt this assumption for all SMEs targeted by the measure.

Second, biomass savings may correspond to an increase in the saw mills' total production with the same amount of raw material used per year (Bsavings = 0). In view of the above, this hypothesis is more realistic in the Kenyan context. In this case, improving the efficiency of forestry operations would therefore not generate additional emission reductions in terms of REDD+.

Savings of non-renewable biomass in natural forests by substitution of firewood with recycled saw dust:

As stated earlier, saw dust may be used for cogeneration of heat and power at the mill, or transformed to briquettes to be sold on the market. If briquettes sold on the market replace firewood or charcoal from non-renewable forest sources, this may generate a REDD+ potential.

Assuming that, for a single saw mill, the saw dust will be used at 50% for cogeneration, 90 out of 180 tons of saw dust per year may be used as briquettes, substituting around 90 m^3 RWE of fuelwood per saw mill per year, e.g. 27,000 m^3 RWE per year considering 300 sawmills (see Table 22).

By using a fraction of non-renewable biomass equal to 92% in natural forests (default value for Kenya according to UNFCCC, 2012) and 5% leakages (conservative default value) for the equation above, the emission reductions are close to 46,300 tCO_2e per year.[16]

Alleviation of pressure on natural forests to produce timber:

As explained in Chapter 3.1.4 above, we cannot demonstrate clear evidence that increasing wood supply from harvesting in plantations will decrease the pressure on natural forests for timber production. In this case, improving the efficiency of timber processing would therefore not generate additional emission reductions in terms of REDD+.

BENEFICIARY MARGIN

Savings of 210,000 m^3 RWE per year would represent a total value of 2.8 million USD based on a price of 1,400 KES/m^3. Moreover, if briquettes are sold on the market at 6 USD/tons (Table 21), this would generate additional revenues estimated at 97,200 USD for the whole sector.

Forests total economic value (TEV)

In the absence of a link between wood processing and reduced drivers of forest loss, it would be hazardous to conclude that improving the efficiency of forestry operations would help preserving natural forests total economic value.

However, savings of 18,000 m^3 RWE of fuelwood from natural forests per year may be converted into forest ha-equivalent, based on the following hypotheses: (i) 92% is non-renewable (UNFCCC default value for Kenya, 2012), (ii) the mean growing stock in natural forests is 180 m^3/ha (FAO, 2015), (ii) the mean TEV produced is 323 USD/ha/year in natural forests. Therefore, the corresponding TEV preserved may be estimated at 44,198 USD per year.

Jobs creation, health and safety

As noticed by the Kenyan Timber Manufactures Association (KTMA), between 30,000 and 150,000 people lost employment directly or indirectly as a result of the logging ban (KFS, 2007). Hence, it is reasonable to think that increasing wood production will certainly generate more jobs, indirectly or downstream. However, according to PWC (2014), it has to be noticed that the potential job creations in the forestry sector relies more on increasing plantation area and forest maintenance. Improving timber processing techniques might include safety trainings ranging from accident prevention to first aid, through improved equipment usage and maintenance procedures. Furthermore, if training targets both men and women, increasing gender equality could be an additional co-benefit from the action.

CHARCOAL PRODUCTION

Statistics

The annual potential supply of charcoal from forests and farmlands in Kenya is estimated at 7.4 million m^3 RWE whereas demand in 2014 was estimated at 16.0 million m^3 RWE (Tables 24 and 25 below) leading to a production gap of around 8.7 million m^3 RWE per year. We assume that the production gap comes mostly from non-renewable wood harvesting in forests and farmlands, plus small imported volumes.

Forest ownership	Forest type	Charcoal	% by category
Public forests	Natural forests	285,187	6%
	Plantations	174,071	
Community and private forests	Natural forests	1,040,935	18%
	Plantations	280,116	
Trees on farms	n/a	5,578,407	76%
Total		7,358,716	

Table 24: Annual charcoal potential supply (m^3 RWE) in Kenya

As presented in table 23, trees on farms account in theory for 76% of the potential charcoal supply. Forest plantations account only for 6% of the potential charcoal supply, whereas natural forests account for 18%. In practice, there are no available data on the fuelwood origin countrywide and, as such, assumptions are mainly made based on literature review.

	Value	Unit	Source
Charcoal consumption per capita	0.3915	m^3 RWE/ year	MEWNR (2013)
Population (2014)	45,545,980	Inhabitants	Worldbank online database
Population using charcoal (%)	90%	-	Githiomi et al.(2002)
Total annual demand	16,048,126	m^3 RWE/ year	Calculated

Table 25: Annual charcoal consumption (m^3 RWE) in Kenya

Source: MEWNR, 2013

Once charcoal is produced, it is sold to wholesalers by transporters or brokers in bulk before being sold to retailers in bulk. Retailers also buy charcoal directly from producers and transporters and sell to consumers. In some cases both wholesalers and retailers might sell their charcoal directly to consumers. Retailers sell their charcoal in 35kg bags and smaller units of 'Debes' and 2kg Tins at retail markets.

While charcoal has been produced as a source of energy in Kenya for many years, it has been subject to various restrictions and even bans in production. Often considered an industry of the poor, one of the challenges that exists with regards to introducing new technologies into the sector is the need for it to be both affordable and able to offer optimal recovery of the wood fuel that is used (Monica et al, undated).

The identification of viable efficiency options for the charcoal sector is, however, desperately needed, as the combination of unsustainable harvesting of trees for charcoal production, increased charcoal consumption and the use of inefficient traditional kilns, form key threats to tree resources in Kenya (Kenya Forestry Research Institute, 2014). Furthermore, a 'cottage industry' largely driven by women producers has emerged to make use dust from charcoal breakage during packing and transit. Using charcoal dust, water, and binding agents charcoal briquettes are formed. These briquettes are sold at a lower price and burn cleaner than charcoal (ICRAF, 2013).

The charcoal supply chain involves about 2.5 million people in transportation and marketing. About 700 thousand charcoal producers are involved with their relevant families and most of the Kenyan population as consumers (2011, PAC pisces project).

From an economic point of view the charcoal sector generates an annual market value of 32 billion KES (Camco, 2013). From a fiscal point of view the generated revenue is quite low for the National Treasury due to the low compliance of law provisions, but it has significant potential if the system could be streamlined and standardized (2013, KFS NRCO).

Thus, charcoal supply chain improvement might have a tremendous REDD+ impact, particularly because of the amount of biomass involved.

Regulatory and legislative aspects

Charcoal production and transportation is subject to law authorizations. Marketing of charcoal and transportation of more than five bags of charcoal require a permit license to be acquired from KFS. The Traffic Act outlines the laws that need to be observed during transportation of charcoal and verification of charcoal movement permits.

Charcoal retailers are required by the county Governments to apply for business permits that allow them to sell charcoal to the end consumers. Under the Charcoal Rules (2009) a person engaged in wholesale or retail trade in charcoal is expected to keep a record of the sources of charcoal, and copies of relevant certificates. For charcoal imports and exports, the customs authorities provide import/export permits.

However, excessively complicated procedures, their different interpretations, overlapping competences and lack of mandate, together with historical and cultural motivations result in poor enforcement (Matthew Owen, 2013). Today only few producers are compliant with the law, while only part of the goods is transported with a regular permit (MEWNR, 2013).

Thus, those producing charcoal in compliance with good practices and environmental sustainability operate in the same context as those who are totally or partially resorting to illegal and abusive methods to exploit forest resources. The latter can obviously produce at lower costs.

An additional simplification of regulations and stricter controls on the ground, in production sites and in selling centres, could bring relevant advantages when addressing illegality in charcoal production.

The strengthening of producers' associations, launched with the Charcoal Rules in 2009, would help the sector to equip itself with a structure designed to disseminate good practices and raise awareness among operators. The cost of illegal practices accounts today for at least 20% of the finished product.

Finally, the implementation of product-related technical standards would contribute to market growth allowing market players to distinguish among different types of products in terms of purity, heating power and origin. These parameters are mainly impacted by the carbonization process and wood species.

Current efficiency rates

Production is mainly performed at small scale with informal modalities and very little involvement of entrepreneurs, and it is often related to subsistence needs. Furthermore, approaches are diversified across the country, depending on the vegetation, agricultural, social, and economic context.

In highly productive lands, the production of charcoal is a by-product or a secondary processing associated to other more profitable agricultural and forestry production. In such cases, charcoal accounts for secondary revenue resulting from the employment of tree branches and wood residues, while in poorer areas animal husbandry is often supplemented by charcoal production for consumption and sale.

In this context, following the entry into force of new laws after 2009, many producers' association have been formed and today they control 40% of charcoal production, with 60% still managed according to traditional methods and without any control.

Despite being few in number, some associations operate in full compliance with the law. Despite bureaucratic difficulties, and the fact that in some cases illegal productions or productions resulting from illegal imports are invovled, it is believed that the further promotion of producer associations is key to improvement measures in the sector.

Charcoal is mainly used in cities where there is no firewood. It is produced in wooded regions despite these areas have very poor infrastructures. For this reason, compared to firewood, charcoal processing appears to be the most adequate adding value for wood fuel. In fact, charcoal has, on average, a starting value at least 4 times higher that of firewood, with final consumer values sometimes 20 times higher.

Thus the production of charcoal is usually close to the forested areas where the raw material is found, particularly where mechanical transportation means and roads are very poor. Most of the production today is carried out with traditional charcoal kilns on the ground, close to the felling sites. Charcoal becomes a lighter and more valuable material and is transported from cutting areas to storage facilities by trucks. Traditional charcoal kilns have a very low recovery rate, featuring values ranging between 10% and 15%[17] (SalvaTerra, 2014). The result is a lower quality charcoal since this charcoal is contaminated with dirt and soil.

Available efficient technologies

While each charcoal production technology available for consideration has positive and negative attributes, a common set of rules can be adopted to improve the production of charcoal. These include:

- Dry wood for at least one month before carbonization. This recommendation is in general difficult to apply for small producers who cannot wait that long,
- Wood diameters must be quite homogenous. If necessary, largest wood logs must be split first or put in the middle of the wood pile,
- Mixing wood species should be avoided, because their pyrolysis time may be different, and
- Inner air content, temperature and humidity must be controlled to optimise charcoal production (pyrolysis occurs after 350°C: the hotter, the higher is the yield).

An opportunity exists across the sector to train charcoal producers to implement simple but basic good practices. In addition, a number of technologies are available for charcoal production ranging from simple traditional kilns for domestic production to advanced technologies that could be considered for industrial production. Figure 14 below illustrates the main groups of technologies available for charcoal production.

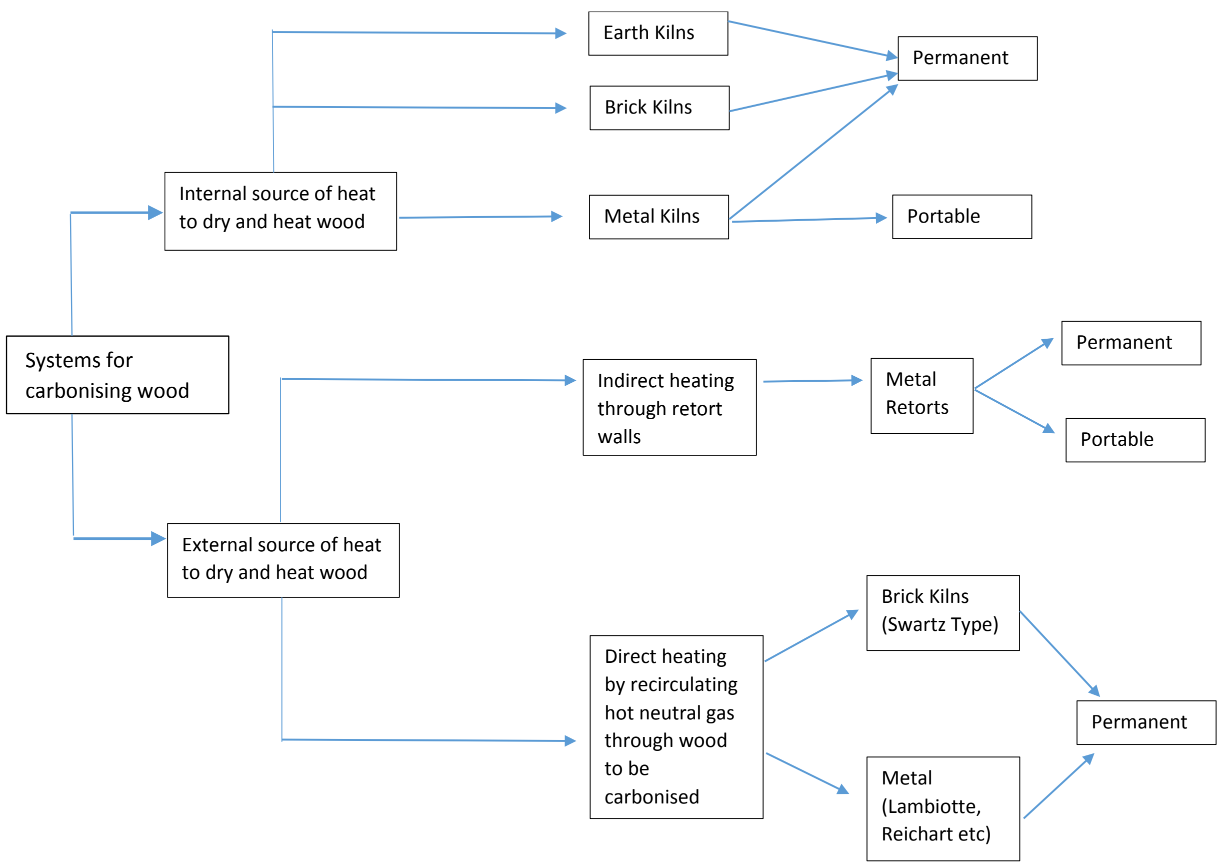

Figure 14: Charcoal production technology groups (adapted from FAO, 1987)

INTERNAL HEAT SOURCED KILNS - IMPROVED EARTH KILNS

The easiest way to improve traditional earth kilns (see Figure 14 below for an illustrative example) is to introduce rigorous construction rules in order to have a better control on the quantity of air penetrating the kiln to generate less ashes and a better homogeneity of inner temperature. An air corridor around and beneath the wood pile helps a best circulation of the air. Kilns are rather longer and larger than higher, to reduce risk of burns and facilitate surveillance. Surveillance time is reduced from 2 to 3 weeks to a few days because pyrolysis is much faster, and it becomes easier for the producer to pay attention.

Where traditional earth kilns mass-efficiency ratio is around 10-15 %, a ratio of 15-20% may be obtained with improved kilns (SalvaTerra, 2014). There are no additional costs for the producer, unless using metallic chimneys and air outlets (see Casamance kilns) – but small producers are generally reluctant to invest in this type of improvements. Furthermore, producers need to be trained properly to learn these new construction rules.

Figure 15: Improved tradition earth kilns in western DR Congo (Source: SalvaTerra)

The Casamance kiln is an improved earth kiln with special features, well described by KEFRI. The fuelwood is cut into lengths of 0.5 m stacked in a circular way with an air channel built across the centre. A chimney made of galvanised iron sheet is placed at the opposite of the lighting point, connected to the air channel. According to KEFRI, the mass efficiency ratio can reach up to 30%.

Internal heat sourced kilns - Brick or metal kilns, transportable or permanent

Controlling inner parameters such as air temperature and moisture is key to producing charcoal more efficiently. Improved earth kilns are limited in this respect, especially because a certain quantity of wood is partially burnt to release enough energy to start pyrolysis. Brick and metal ("Magnien") kilns are also limited (see Figure 15 below) even if they might have a slight better mass-efficiency ratio than earth kilns. But higher efficiency ratios do not counter the fact that wood has to be transported long distance to the kiln, which strongly increases transport costs.Hence, technologies using partial load combustion such as brick or metallic kilns should be avoided, and are not considered in the following evaluation.

Figure 16: Left - Metallic “Magnien” kiln. Right – brick kiln (Source: Projet Makala)

TECHNOLOGIES USING INDIRECT LOAD HEATING – RETORTS

Retorts are one option in a group of technologies using indirect load heating instead of partial combustion to initiate wood pyrolysis. Thus, the mass-efficiency ratio can reach up to 35-40% (C. Adam, personal communication) although experts consider these values very high and therefore recommend 30-35% as more realistic values. There are many models of retort kilns, with the “Adam retort” (see Figure 16 below) – a brick and metal based kiln –recently developed especially for developing countries. Each component can be built on-site with local material.

Retorts are typically composed of two chambers: one combustion chamber where biomass and waste are burnt to heat the load of the second chamber before pyrolysis. The gases emitted during the pyrolysis are sent back and burnt inside the combustion chamber to increase the inner temperature and accelerate pyrolysis. Thus this process also reduces GHG emissions and increases air quality compared to other kiln types.

However, there are additional costs linked to wood transport because the retort kiln is permanent. It is sometimes necessary to build several kilns because a single kiln can operate a maximum of 188 m^3 RWE per year. This is probably not adapted to the size of large-scale plantations but well adapted to farmlands with small woodlots.

Figure 17: Adam retort kiln (Source: Chris Adam)

The Adam retort type of kiln is protected by patent and costs approximately 1,700 USD/unit (construction and patent included). It operates with a small load of 1,875 m^3 RWE per production cycle (2 days per cycle). It has been tested in Kenya successfully, with a 3-month return on investment announced by the constructor (C. Adam, personal communication).

EXTERNAL HEAT SOURCED KILNS - TECHNOLOGIES USING DIRECT LOAD HEATING BY INERT GAS: METAL KILNS

A number of technologies have been developed in response to the need for high grade industrial charcoal that are more efficient in their conversion rates but less labour intensive and polluting than kiln and mound techniques. These include the Lambiotte and Reichert type kilns (FAO, 1987) and are described below.

Lambiotte System

Continuous carbonising systems such as Lambiotte provide a higher yield than the more simple technologies as well as providing savings in fuel required for. Production of charcoal using the Lambiotte process involves placing pre-dried wood at the top of the retort and then moving slowly down the retort where it will encounter an increasing counter current flow of inert hot gas which dried the wood and raises it to a carbonising temperature. This process takes about eleven hours (FAO, 1987).

One of the most important variables in the efficiency of the system is the moisture content of the timber entering the retort with an increase in energy use required as the moisture content increases. Corrosion is the other main problem with such steel-made systems, this can be overcome by using stainless steel, but this comes at a high cost.

Reichert Kilns

The Reichert retort uses recirculated heated gas through the load inside the retort. The gas is typically inert. While the Reichert Retort system has been used satisfactorily for many years, its efficiency and cost-effectiveness rely on mechanisation of the wood and charcoal loading system. In addition, as the investment costs are high, it is not considered appropriate in the Kenyan situation (FAO, 1987).

There is currently no industrial charcoal production in Kenya, given the high investment costs of industrial production systems such as the Lambiotte System and Reichert Kilns. Industrial operations also cannot compete with local charcoal producers who have a low opportunity cost for labour and typically no cost for the wood resource.

EXTERNAL HEAT SOURCED KILNS - TECHNOLOGIES USING DIRECT LOAD HEATING BY INERT GAS: BRICK KILNS

Schwartz Kiln

The Schwartz kiln is a brick, metal and iron kiln which uses hot flue gas from an external fire grate, passed through the kiln to supply heat for drying and heating the wood to start carbonisation. The overall yield of the Schwartz Kiln, when the wood is included in the accounting, is inferior to other kilns (FAO 1987). The major inconvenience of this kiln is that its door does not close completely during the cooling process, reducing its overall efficiency. Hence this type of kiln is also not considered applicable to the Kenyan scenario.

Technologies for analysis

Seven kiln types have been reviewed in this analysis of potential kiln technologies suitable for charcoal production. For the reasons explained above, of those seven technologies, only two – improved earth kilns and retorts are considered relevant to the Kenyan situation and hence applicable for further analysis. They are also the most affordable solutions. Table 26 below summarises the key features of these charcoal production technologies.

Technology name	Improved traditional earth kilns	Retort (example: Adam Retort)
Purchase cost (approximate)	0 – without chimneys 30 USD – with chimneys, 3 years lifespan (Casamance kiln)	1700 USD/unit Including patent Lifespan: 5 years
Operational costs (labour and others)	1-6 USD/m^3 RWE (mean value: 3.5) - same as traditional earth kilns	2-3 USD/ m^3 RWE (mean value: 2.5) – slightly inferior in comparison with earth kilns
Maintenance costs	0 – kilns are temporary	15% of operational costs per year
Training of charcoal makers associations	45 - 100 USD per capita (mean value: 64)	400 USD per unit
Efficiency in conversion (e.g. added value generation)	15-20% according to sources (17,5% for subsequent analysis) without chimneys 30% for Casamance (KEFRI)	30-35% seems more realistic (32,5% for subsequent analysis)
Skill set required for operation	Construction rules are easy to learn but training is required.	Training required for masonry work and operations. A constructor's manual has been developed.
Adoption challenges	Producers need to be convinced with demonstration. Construction rules are rigorous and affect directly the quantity of charcoal produced.	Relatively high investment costs for small producers and potentially high transport costs (permanent kiln). Small load per cycle
Viability assessment and approaches to enable adoption	Easiest way to improve charcoal production at no cost (except training costs) or low-cost (with chimneys)	Not adapted to large-scale plantations, but well adapted to small-scale plantations and farmlands.

Table 26: Outline of opportunities for improved carbonization

Proposed improvement measures

As is the case with any technology, efficiency gains will be realised when equipment is used appropriately and consistent procedures are followed. Charcoal production technologies are no different. As such, the implementation of training for the Kenyan charcoal production sector has the potential to impact its efficiency and effectiveness. Typical improvements that can easily be implemented include changing the stacking of the wood and managing air control to help the carbonisation process (KEFRI 2014).

The adoption of enhanced versions of traditional charcoal kilns would allow yield improvement from +5% up to +25% according to the type of technology involved. In view of concentrating production in fixed facilities, there are many construction solutions available for charcoal burners of various sizes, capable of increasing the yield to the point of even tripling (from 10% to 30-35%) production and thus reducing the corresponding need of wood.

However, kiln improvements are still rarely implemented. The major constraints to implementing improved kilns – except of course improved traditional earth kilns – is their high cost compared to the financial possibilities of the average operator in the sector. There are also difficulties in changing the supply chain organisation, which imply the sharing of costs and revenues among wood owners, charcoal makers, freight carriers and wholesalers. As such, along with the promotion of new charcoal technologies it is important to set up organizational, planning and training measures able to ensure production sustainability and efficiency improvement.

Three lines of action have been identified. The first two have a direct impact on efficiency having to do with production improvement. The third one has to do with the social and regulatory context and thus has an indirect impact on recovery rates from charcoal production processing. The third kind of action, however, is related to the reduction of the transaction cost of charcoal production and thus is not considered in the following cost-benefit analysis. Given that 75% of the charcoal production comes from dry areas (KFS, undated), dry forests are the focus of these interventions, in coherence with the Kenyan R-PP (KFS, 2010).

The results expected from the above improvements should first of all impact the environment – especially dryland forests - by providing savings in terms of wood biomass, and, as a consequence, a reduction of the area annually subjected to deforestation or forest degradation, together with better adherence to laws and regulations, and improved economic and social conditions for people working in this sector.

Action 1 (direct impacts): improvement of on-site production practices by providing vocational training, especially through Charcoal Producers Associations (CPA), as well as the promotion of Casamance kilns. These are considered as the most affordable solutions for charcoal makers.

Action 2 (direct impacts): enhance availability of fixed and semi-mobile high yield processing units (retorts) for the purpose of improving production yield in the carbonization process and achieving raw material savings in dryland forests (adoption of new charcoal production technologies). This option is less affordable but provides higher performances and co-benefits.

Action 3 (indirect impacts): review of the charcoal regulatory framework with the goal of facilitating producers willing to operate within the boundaries of legality (revision of regulations and legal framework). This would include:

- Introduction of a system of production licenses for professional and non-professional use (five year duration with relevant system for the payment of annual taxes; multi-level controls and inspections (national and local); requirements for the issue of titles for wood extraction, sustainable management plans, registration system for production control (simplified procedures for non-professional licenses);
- Adoption of professional licenses for the wholesale sector (and import);
- Measures addressed to encourage the establishment of producers' associations with the aim of de-fragmenting the market and aggregating the supply chain, by creating a social and economic fabric that facilitates the adoption and enforcement of rules and regulations;
- General policy measures to increase production quality (product standards, incentives for sustainable charcoal, fuel/charcoal consumption saving communication campaigns.

Cost-benefit analysis

EMISSION REDUCTIONS

As mentioned above, the potential supply of wood for charcoal production is lower than the national demand with an estimated shortage of 8.7 million m^3 RWE per year (adapted from MEWNR, 2013). The proposed actions aim to reduce the need to produce charcoal from non-renewable sources by increasing production efficiency (see the key-results summarised in Table 27 at the end of this chapter).

The overall production of charcoal remains equal to the BAU scenario, but fewer raw materials are consumed, which generates an opportunity to achieve REDD+ results. This is an important distinction with the two previous sectors (forestry operations and timber processing) where the overall production is expected to increase due to the measures proposed.

The emission reduction estimates are calculated as the difference between the biomass used in the BAU scenario and the biomass used in the REDD+ scenario, multiplied by the fraction of non-renewable biomass. The same equation as previous scenarios is used to convert the amount of non-renewable biomass savings into tCO_2e:

As explained in Chapter 3.1.4, it is necessary to determine the non-renewable biomass fraction (fNRB) of the biomass used to produce charcoal in order to estimate the potential emission reductions resulting from the proposed REDD+ measures. The biomass produced in forest plantations may not be qualified as non-renewable, given that the harvesting volumes are close to the annual yields (see Chapters 3.1 and 3.2). Moreover, the illegal production of charcoal in gazetted forests must be excluded from these estimations because the measures are not targeted towards these activities, but rather towards dry forest areas.

It is estimated that 75% of the charcoal produced in Kenya comes from dry forests (KFS, undated), representing an estimated 2,268,000 ha in 2010 (based on KFS data, 2013). The total charcoal demand is estimated at 963,000 tons per year, from which 722,000 tons are produced in dry forests (75%, equivalent to 12.0 million m^3 RWE). According to Mbugua (2000), sustainable production is estimated at 0.28 m^3/ha/year in dry forests. The total sustainable production from these forests may therefore be estimated at 635,000 m^3 per year, leading to a fNRB equal to 95%.

Action 1: Improvement of production practices on site in dry forests (improved traditional earth kilns) through CPA.

These estimations are based on the following hypothesis:

- 100,000 charcoal producers trained in good practices out of over 700,000 estimated countrywide and 280,000 estimated working in dry forests;
- An additional 50,000 charcoal producers trained to build Casamance kilns=. This reflects the fact that many producers cannot afford to pay 30 USD for metallic chimneys;
- Increased mass efficiency ratio from 10% to 17,5% with traditional earth kilns without chimneys and 30% with Casamance kilns; and
- Parameters for calculations: Root-shoot ratio = 0.56 (IPCC 2006 default value for Tropical dry forests, aerial biomass < 20 tms/ha) ; Biomass expansion factor = 1.9 (IPCC 2006 - Tropical dry forests, broadleaved, growing stock between 21 and 40 m^3/ha) ; Carbon fraction = 0.5 tC/t of dry wood ; C/CO_2e ratio = 44/12 = 3.67.

The quantity of biomass used in the BAU scenario by 150,000 charcoal producers in dry forests may be estimated at 3.4 million m^3 RWE, whereas the biomass consumed in the REDD+ scenario to produce the same amount of charcoal is rather equal to 1.7 million m^3 RWE. By using a fNRB equal to 95% and 5% leakages (conservative default value), the emission reductions are close to 4.8 million tCO_2e per year as illustrated in Table 27 below.

	Biomass consumed (m^3 RWE per year)	Non-renewable biomass savings (m^3 RWE per year)*	Emission reductions (tCO_2e/year)
BAU scenario – 150,000 producers	3,438,900		
REDD+ scenario – 100,000 producers trained to good practices	1,316,600	935,400	2,723,300
REDD+ scenario – 50,000 producers trained to build Casamance kilns	378,300	716,600	2,086,500

Table 27: Non-renewable biomass savings and emission reductions of Action 1 (charcoal production)
*fNRB = 95%

The costs of implementing Action 1 are mainly training costs because the technology used is fundamentally the same. Vocational training of this type is typically carried out using field demonstrations. The most efficient way to deliver this is to train representatives of charcoal makers associations who in turn train members of their constituency. This approach would work well in Kenya where the Forests Charcoal Rules (2009) require commercial charcoal producers to be in a registered CPA (KEFRI 2014).

The cost of such training may be estimated at $USD10,000 for 10-15 charcoal makers, who teach the techniques to 10-15 members of their association (estimations based on vocational training in similar conditions in DR Congo).

For Casamance kilns, there is an additional 30 USD/kiln corresponding to the cost of chimneys (around 3,000 KES according to KEFRI), with an estimated lifespan of 3 years (e.g. 10 USD/year/producer).

Following the previous hypothesis, the cost of training 100,000 producers is estimated at 6,4 million USD and the cost of Casamance kilns chimneys at 500,000 USD per year – e.g. 2.1 USD/tCO_2e in total.

Action 2: Disseminating fixed or semi-mobile processing units (technologies using indirect load heating, adapted to small-scale interventions – "retorts").

These estimations are based on the following hypotheses:

- 10,000 small fixed or semi-mobile processing units disseminated countrywide (retorts) with a capacity of 188 m^3 RWE per year;
- Increased mass efficiency ratio from 10% to 32,5%;
- Parameters calculations: Root-shoot ratio = 0.56 (IPCC 2006 default value for Tropical dry forests, aerial biomass < 20 tms/ha) ; Biomass expansion factor = 1.9 (IPCC 2006 - Tropical dry forests, broadleaved, growing stock between 21 and 40 m^3/ha) ; Carbon fraction = 0.5 tC/t of dry wood ; C/CO_2e ratio = 44/12 = 3.67

In this scenario, the fixed and/or semi-mobile units have the capacity to produce 366,600 tons of charcoal annually with only 1.9 million m^3 RWE of biomass. The same amount of charcoal would be produced with traditional methods in the BAU scenario using 6.1 million m^3 RWE of biomass. By using a fNRB equal to 95% for dry forests and 5% leakages (conservative default value), the emission reductions are close to 11.7 million tCO_2e per year.

The costs of implementing Action 2 is composed of operational costs (343 USD/unit/year, including purchase and maintenance costs for a 5-year lifespan) and training costs estimated at 400 USD/unit.[18] Labour costs for these processing units are 1 USD/m^3 RWE, less than for earth kilns in the BAU scenario (see Table 26). Total costs may be estimated at 5.5 million USD, e.g. 0.5 USD/tCO_2e.

BENEFICIARY MARGIN

The overall beneficiary margin in the sector will increase due to the reduction in the use of raw material, estimated at 392 KES/m^3 (based on farm gate prices), e.g. 22.4 million USD in total for both actions considering the overall biomass savings from dry forests.

FORESTS TOTAL ECONOMIC VALUE (TEV)

Savings of 1.6 million m^3 RWE (action 1) and 4.0 million m^3 RWE per year (action 2) of non-renewable biomass may be converted into forest ha-equivalent, based on the following hypotheses:

- The mean growing stock in dry forests is 32 m^3/ha (FAO, 2015 – other wooded land),
- The mean TEV produced is 171 USD/ha/year in dry forests.

Therefore, the corresponding TEV preserved may be estimated respectively at 8.8 million USD per year (action 1) and 21.4 million USD per year (action 2).

JOBS CREATION, HEALTH AND SAFETY

Under the hypotheses chosen for these estimations, the number of charcoal producers would remain equal over time for Action 1 and would decrease for Action 2 because fewer producers are needed to produce the same amount of charcoal in comparison with the BAU scenario. However, Action 2 will generate the need for more qualified workers instead of maintaining "poor jobs".

From health and safety perspective, these actions will generate positive impacts such as the reduction of accidental burning due to traditional earth kilns collapses. Moreover, Action 2 will lower emissions of carbon monoxides by recycling and combustion of pyrolysis gas, which in turns generates less toxic smokes. Respiratory problems are indeed widely spread amongst charcoal producers and fuelwood consumers in general (charcoal and firewood), especially among women and children. Finally, if improved production methods are made available to both men and women, increasing gender equality could be an additional co-benefit from the action.

Hypotheses	per year
Number of charcoal producers	700 000
Number of charcoal producers working in dry forests	525 000
Population (2014) - Worldbank database	45 545 980
% of the population using firewood and/or charcoal	90%
Annual consumption of charcoal per capita (m3 RWE per year)	0,3915
Annual demand of charcoal at national level (m3 RWE per year)	16 048 126
Wood density	0,6
Proportion of fuelwood produced in dryland forests	75%
fNRB (non renewable biomass fraction)	95%
Root-Shoot ratio (no dimension)	0,56
Biomass expansion factor (no dimension)	1,90
Carbon fraction (tC/ton of dry wood)	0,5
tC to tCO2 ratio	3,67
Annual demand at national level (tons of charcoal)	962 888
Efficiency (output/input mass ratio)	10%
Annual potential sustainable supply from dry forests (m3 RWE per year)	635 040
Total charcoal production from dry forests (m3 RWE per year)	12 036 095
Total charcoal production from dry forests (tons)	722 166
Fuelwood - farmgate price (USD/m3)	3,7
TEV-Dry forests (USD/ha)	171
Growing stock - Other wooded land (m3/ha)	32

Action 1: Improved traditional earth kilns + Casamance kilns	per year
Efficiency (output/input mass ratio) - improved traditional earth kilns	17,5%
Efficiency (output/input mass ratio) - Casamance kilns	30%
Nb of producers in dry forests	525 000
Target (Nb of producers trained: improved earth kilns + Casamance)	150 000
Target Casamance kilns (Nb of producers trained)	33%
Biomass consumed by trained producers (m3 RWE) - BAU	3 438 884
Charcoal produced by trained producers (tons) - BAU and Action 1	206 333
Biomass consumed by trained producers (m3 RWE) - Action 1, improved earth kilns	1 316 601
Biomass consumed by trained producers (m3 RWE) - Action 1, Casamance kilns	378 277
Biomass savings (m3 RWE) - improved earth kilns	987 451
Biomass savings (m3 RWE) - Casamance kilns	756 555
Biomass savings (m3 RWE) - non renewable fraction - improved earth kilns	935 352
Biomass savings (m3 RWE) - non renewable fraction - Casamance kilns	716 638
Emission reductions (tCO2e/year) - assuming 5% leakages - improved earth kilns	2 723 312
Emission reductions (tCO2e/year) - assuming 5% leakages - Casamance kilns	2 086 517
Cost of one vocational training (USD/capita)	64
Cost of chimneys (Casamance kilns) - USD per year per kiln	10
Cost of chimneys (Casamance kilns) - USD per year	495 000
Total training costs (USD)	9 600 000
Cost per tCO2e (USD/tCO2e)	2,1
Beneficiary margin	6 535 852
TEV preserved (USD)	8 827 819

Action 2: Introducing more efficient carbonisation technologies	per year
Efficiency	32,50%
Dissemination target (number of units countrywide)	10 000
Annual biomass capacity per unit (m3 RWE)	188
Annual biomass capacity in total (m3 RWE)	1 880 000
Charcoal production with new technology (tons)	366 600
Biomass production from BAU scenario to produce the same amount of charcoal (m3 RWE)	6 110 000
Biomass savings (m3 RWE)	4 230 000
Biomass savings (m3 RWE) - non renewable fraction	4 006 820
Emission reductions (tCO2e/year) - assuming 5% leakages	11 666 005
Purchase and maintenance - duration: 5 years (USD/unit)	343
Cost of one vocational training (USD/capita)	400,0
Total costs (purchase, maintenance, vocational training) (USD)	7 426 550
Labour costs correction (USD) - 1 USD/m3 RWE inferior as compared to traditional earth kilns	- 1 880 000
Total costs (USD)	5 546 550
Cost per tCO2e (USD/tCO2e)	0,48
Beneficiary margin	15 852 390
TEV preserved (USD)	21 411 443

Table 28: Summary of findings – Charcoal production

FIREWOOD AND CHARCOAL CONSUMPTION AT HOUSEHOLD LEVEL

Statistics

FIREWOOD CONSUMPTION AT HOUSEHOLD LEVEL

Firewood is the main source of energy for cooking and heating for almost all households in rural areas in Kenya. Firewood is also used for lighting and operating home businesses. A study by Kenya National Bureau of statistics indicated that 87.7% of households – both urban and rural – in Kenya use firewood (Ministry of Planning and National Development, 2007). Rural families' preference for both space heating and cooking from the same source and the high cost of alternative fuel sources such as charcoal, electricity, liquid petroleum gas (LPG) and kerosene often makes firewood the only viable source of energy.

According to the 2013 Ministry of Environment, Water and Natural Resources study on wood demand and supply, the annual potential supply of firewood is 13.7 million m^3 RWE while current demand is 18.4 million m^3 RWE, leading to a sustainable production gap of 4.7 million m^3 RWE per year (see Table 29 and 30 below).

Forest ownership	Forest type	Firewood	% by category
Public forests	Natural forests	529,634	6%
	Plantations	323,276	
Community and private forests	Natural forests	1,919,224	18%
	Plantations	520,215	
Trees on farms	n/a	10,361,673	76%
Total		13,654,022	

Table 29: Annual firewood potential supply (m^3 RWE) in Kenya

	Value	Unit	Source
Firewood consumption per capita	0.4485	m^3 RWE/year	MEWNR (2013)
Population (2014)	45,545,980	Inhabitants	Worldbank online database
Population using firewood (%)	90%	-	Githiomi et al.(2002)
Total annual demand	18,384,635	m^3 RWE/year	Calculated

Table 30: Annual firewood consumption (m^3 RWE) in Kenya

Encouraging farmers to plant more trees could increase the supply of fuelwood from farmlands (Vermeulen and Walubengo, 2006). However, scarcity of land and competing land uses limit the extent to which people are willing to put most of their land under trees for fuelwood.

CHARCOAL CONSUMPTION AT HOUSEHOLD LEVEL

The urban population represents 25% of Kenya's total population according to the World Bank database. Most of the charcoal in Kenya is consumed in urban areas: it is estimated that 82% of urban households use charcoal as source of domestic energy (Mugo and Gathui, 2010). Furthermore, a study by FAO (FAO, 2007) found that among the women interviewed fuelwood ranked as the most important forest product, while among men it ranked eighth. While the majority of charcoal consumers are households, others are commercial businesses such as hotels, restaurants, Jua Kali shades (e.g. informal sector), and institutions including schools and hospitals.

Regulatory and legislative aspects

Charcoal production and consumption are regulated while the consumption of fuelwood is taken into account under various regulatory frameworks related to energy and environment. Households can burn and produce their own charcoal as guided by the Charcoal Rules (2009) under the Forests Act 2005. The Environmental Management and Coordination Act of 1999 (EMCA) regulates the supply of fuelwood and charcoal indirectly via an environmental conservation perspective. In particular, the Act requires tree cover of 10% in farms.

Important policy frameworks for charcoal and firewood consumption are the Energy Policy (2004) and Energy Act (2006). Some of the objectives of the energy policy are:

- Increasing the rate of adoption of efficient charcoal stoves from 47% in 2004 to 80% in 2010 and to 100% by 2020 in urban areas; and to 40% by 2010 and 60% by 2020 respectively in rural areas;
- Increasing the rate of adoption of efficient firewood stoves from 4% in 2004 to 30% by 2020;
- Promoting inter-fuel substitution;
- Increasing the efficiency of the improved charcoal stoves from the 2004 level of 30-35% to 45-50% by 2020; and
- Offering training opportunities for Jua Kali artisans at the village level for the manufacture, installation and maintenance of renewable energy technologies including efficient cook stoves.

The Energy Act, 2006 regulates production, distribution, supply and use of renewable energy and other forms of energy. It also provides for promotion of the development and use of renewable energy technologies which include charcoal and firewood.

Furthermore, the Gender Policy on Forestry and the Environment, 2006 recognizes the disproportionate exposure to smoke inhalation among women and advocates for the use of improved cook stoves and the modernization of power systems.

Current efficiency rates

Many Kenyans use traditional consumption methods for firewood, such as "three-stone open fires". These have very low thermal efficiency of about 10% and high health hazards; however, they are popular for most households as they are cheap and contribute to house warming (Githiomi et al, 2007). Apart from the "three stone" cooking method, there are many other traditional ways of cooking which have been improving over time without any additional costs, e.g by surrounding the area with wood, ash or cow dung to reduce losing heat. It is hard to estimate their thermal efficiency without proper assessment (water boiling tests).

The efficiency of regular charcoal-based stoves may be estimated at 20%. Indeed, some ICS are already being used in Kenya like the Kenya Ceramic Jiko (KCJ). This stove was developed in the 1980s and is widely produced by local artisans who use the clay liner as an insulator to preserve heat.

However, the large majority of Kenyans still do not use ICS technology. Studies have estimated that 30-40% of the population has access to an improved stove of some type; however the actual number could be somewhat lower due to the potentially high numbers of broken, poor quality and unused stoves (USAID, 2011).

The real use of ICS may be estimated at 25% countrywide, but sources are contradictory on that matter. For example, Energising Development (2012) indicates a percentage of 13% countrywide. Furthermore, penetration of improved stoves is high in urban areas - as much as 80% in Mombasa and 47% in Nairobi.

Available efficient technologies

The key technology available for improving the efficiency of consumption of firewood and charcoal are improved cook stoves (ICS), which are stoves that have been modified to use less fuel, cook faster and reduce smoke (SNV 2015). For example, a traditional metal charcoal stove can be improved by adding clay as insulating material which helps conserve heat and save fuel while cooking. ICS have been developed for use with either firewood or charcoal, or even biomass briquettes. According to sources, modern stoves can save up to 70% in fuelwood in comparison to open fires.

Kenya has been at the forefront of ICS technology development over the last 30 years (see Figure 17 for an illustration of the Kenya Ceramic Jiko). One of the first ICS to be produced on a commercial scale was the widely known KCJ, a ceramic charcoal stove (see Figure below). The successful local production and uptake of the KCJ led to the spread of training programs and business models for similar products in several other countries (USAID 2011), and to the continuing evolution of ICS development in Kenya.

Figure 18: The Kenya Ceramic Jiko

Since the development of the KCJ many donor organisations, international NGOs and local social organisations have contributed to further technological developments and awareness-raising around the use of ICS (see for example the Global Alliance for Clean Cook Stoves). More recently, carbon finance projects have led to the development of more mass produced and imported ICS (USAID 2011).

The bulk of stove manufacturing is still done by artisanal producers despite imported stoves increasingly entering the market. Some of the common technologies introduced in Kenya are outlined in Table 30 and include:

- Envirofit wood stoves, operating on a rocket principle (see Figure 18 below);
- Jiko Kisasa: a firewood stove promoted by GIZ. Has an insulating ceramic chamber that is mudded in allowing for better airflow around fuel;
- Jiko Upesi: a firewood stove promoted by Practical Action. Similar to Maendeleo (below) and Jiko Kisasa but with slightly different pot-stove interface and the addition of chimney (see Figure below);
- Kuni Mbili: a portable firewood stove that consists of an insulating ceramic chamber (the same type used in Maendeleo, Kisasa and Upesi) encased in metal;
- Jiko Poa: a locally manufactured firewood rocket stove, similar in performance to the Envirofit;
- Maendelo Jiko: for use with firewood. A ceramic liner provides insulation while the raised fireplace allows for better airflow around burning sticks. Similar in nature to Jiko Kisasa and Upesi;
- CO_2 Balance: a firewood stove made entirely of fired ceramics, operating with the rocket principle and restricting greatly the size and amount of fuel used.

There are hundreds of ICS models that are potentially available, although there are around 10 main types that have been used in Kenya. Attributes that can be used to differentiate between the various different models are:

- Household-level (small) or institutional level (large) ;
- Whether cook stoves are fixed i.e. permanently built into a kitchen, or portable ; and
- Whether cook stoves are designed for use with firewood or charcoal, or both (most cook stoves are usually designed for use with one single fuel type).

Portable		Fixed
Firewood	Charcoal	Firewood
Envirofit M5000 Kuni Mbili Jiko Poa	Kenya Ceramic Jiko Envirofit CH5200	CO_2 Balance Upesi Maendeleo Jiko Kisasa

Table 31: Examples of available ICS in Kenya

Figure 19: Envirofit M5000 cook stove

Figure 20: Upesi cook stove

With the high number of ICS potentially available, it is important to recognise the role of a market-based approach and consumer preferences in selection of an 'appropriate' technology. In promoting further uptake of ICS, consideration should be given factors such as: cooking comfort, convenience, portability, affordability, as well as their efficiency (Ghitiomi and Oduour 2012). Table 32 below is not complete, but intended to illustrate a variety of ICS that are on the market.

	Kenya Ceramic Jiko	CO_2Balance	Envirofit household wood and charcoal stoves	Envirofit EFI 100L Institutional wood stove suitable for cooking in e.g. Schools
Purchase cost (approximate)	USD 4-10	USD 2 (cost of installation, subsidised by CO_2Balance)	USD 23.5 (subsidised)	USD 100 (subsidised)#
Efficiency in conversion (e.g. added value generation)	30-40%	35%	60%	up to 80%
Maintenance costs	No maintenance cost, however the lifespan is limited (efficiency decreases over time)			
Skill set required for operation	No technical skills required			
Adoption challenges	User perceptions and awareness Availability and distribution can be limited	User perceptions and awareness Availability and distribution can be limited	User perceptions and awareness Price is dependent on subsidies. Full price is around USD 100*.	Price is dependent on subsidies.
Viability assessment and approaches to enable adoption	Most suited for use with charcoal or briquettes, rather than firewood.	Suitable for use with wood Continued distribution at this price dependant on funding availability	Models available that are suitable for use with either wood or charcoal. Need to establish distribution networks.	Need to establish distribution networks.

Table 32: Opportunities for improved efficiency in consumption of firewood and charcoal
Source: Clough (2012) and other references
**Price taken from* http://www.evansoutdoorstore.com/m-5000---rocket-stove.html
#Cost is estimated based on comparative costs of smaller Envirofit cook stoves for households

It is also important to recognise that the cook stoves efficiency is determined by the amount and quality of fuel that is used as well as their technical specifications. Bentson et al (2013) conducted tests on a number of charcoal cook stoves and found a high degree of variation in efficiency. Most stoves were more efficient when relatively less fuel was used.

Proposed improvement measures

Use of ICS, especially local portable cook stoves, is critical to enhancing charcoal consumption efficiency. There are many types of ICS that are more efficient than the KCJ. Some of these include Improved Envirofit Charcoal Cook Stove and Jikopoa.

According to a report by Stockholm Environment Institute (SEI, 2014), fuelwood collection and use is a traditional activity that has received relatively limited attention from researchers, development practitioners, development partners (donors) and policy makers. This has led to a general lack of knowledge on how to move to more sustainable practices associated with the use of fuelwood such as the use of improved firewood stoves. These stoves not only improve efficiency and reduce health hazard but they also reduce the time used in fuelwood collection since they consume less.

Two lines of actions are suggested:

Action 1: introduction of firewood-based ICS to replace traditional firewood-based cooking methods, such as the three-stone open fire, mostly in rural areas;

Action 2: introduction of charcoal-based ICS to replace regular charcoal stoves, mostly in urban areas;

Both actions are in line with the Energy Policy (2004) and Energy Act (2006) and should be carried out so as to target men and women equally in support of the Gender in Forestry and the Environment Policy (2006). The potential impacts of such actions are described below.

Costs and benefits analysis

EMISSION REDUCTIONS

The actions proposed aim at reducing the demand for fuelwood – both firewood and charcoal – at household level by increasing the efficiency of cooking devices. This will contribute to reducing the overall production of charcoal and firewood, leading in turn to reducing the non-renewable harvest of fuelwood.

As explained in Chapter 3.3.6, emission reductions estimates are based on the quantity of non-renewable biomass saved by implementing the proposed measures. The same equation as used above is used to convert the amount of non-renewable biomass savings into tCO_2e.

Action 1: introduction of firewood-based ICS at household level.

These estimates are based on the following hypotheses:

- 75% of the population live in rural areas (World Bank database, figures for 2014) where almost 90% of the population use firewood (estimations by author), mainly in three-stones open fires ;
- The actual dissemination rate of firewood-based ICS is around 30% and the dissemination target is 3.5 million devices (around 80% of the total rural population);
- The number of people per household may be estimated at 5;
- The efficiency of the ICS is 30% over its lifespan (5 years) compared to 20% for traditional cooking methods (this default value is recommended for CDM and Gold Standard methodologies for small-scale project on efficiency measures in thermal applications of non-renewable biomass);
- The non-renewable biomass fraction is estimated at 92% for natural forests in Kenya (default value given by UNFCCC, 2012). In this scenario, we consider natural forests as a whole, not only dry forests (as in the previous chapter) because consumers cannot differentiate the origin of the fuelwood they consume;
- The proportion of firewood produced from forests is not known. According to Table 27, the potential supply of firewood from natural forests is estimated at 18% of the annual demand. This figure is used as conservative value in the following. This hypothesis is key, because the higher this parameter is, the higher the REDD+ impacts are; and
- Calculations are based on: RSR = 0.37 (tropical dense forests, IPCC 2006) ; Biomass expansion factor = 1.3 (tropical dense forests, IPCC 2006) ; Carbon fraction = 0.5 tC/t of dry wood ; C/CO_2e ratio = 44/12 = 3.67.

The total non-renewable biomass savings from forests reach 390,000 m^3 RWE per year, generating 726,000 tCO_2e emission reductions per year (including 5% leakages).

The costs of implementing Action 1 are mainly linked to the ICS acquisition. They can be estimate at 10 USD per ICS for a duration of 5 years, e.g. 2 USD/year. However, the transaction costs necessary to develop a market-based approach to allow the dissemination of 3.5 million new ICS, including artisan capacity building, cannot be estimated easily. As a consequence, the abatement cost may be estimated at 9.6 USD/tCO_2e, but it is probably underestimated by not considering the additional transaction costs.

Action 2: introduction of charcoal-based ICS in urban areas.

These estimations are based on the following hypotheses:

- 25% of the population live in urban areas (World Bank database, figures for 2014) where almost 82% of the population use charcoal, mainly in regular charcoal-based stoves;
- The actual dissemination rate of charcoal-based ICS is around 30% and the dissemination target is close to 100% (1.5 million ICS);
- The efficiency of the ICS is 30% and 20% for the regular charcoal-based stove;
- In the previous chapter, we estimated the proportion of firewood produced from dry forests at 75%; and
- The non-renewable biomass fraction is estimated at 95% in dry forests (see previous chapter). Hence, the constants used for Equation 2 in the previous chapter are used here.

The total non-renewable biomass savings from forests would represent 570,000 m^3 RWE per year, generating 1.7 million tCO_2e emission reductions per year (including 5% leakages).

The costs of implementing Action 2 are also mainly linked to ICS acquisition. With the same hypothesis as above (e.g. 2 USD/year) the abatement cost may be estimated at 1.8 USD/tCO_2e (including 5% leakages), but it is probably underestimated because transaction costs are also difficult to estimate.

BENEFICIARY MARGIN

Households would reduce their fuelwood expenses by reducing their consumption of raw material (firewood and charcoal). Considering the savings of 1.0 million m^3 RWE biomass per year from natural forests, this would represent a total value of 3.8 million USD based on 392 KES/m^3 (farm gate prices).

FORESTS TOTAL ECONOMIC VALUE (TEV)

Savings of 390,000 m^3 RWE non-renewable biomass from natural forests and 570,000 m^3 RWE non-renewable biomass from dry forests per year may be converted into forest ha-equivalent, based on the following hypotheses:

- The mean growing stock in natural forests is 180 m^3/ha and 32 m^3/ha in dry forests (FAO, 2015), and
- The mean TEV produced is 323 USD/ha/year in natural forests and 171 USD/ha in dry forests.

Therefore, the corresponding TEV preserved may be estimated at 3.5 million USD per year.

JOBS CREATION, HEALTH AND SAFETY

Developing a market-based approach for ICS dissemination would require many competencies, from building efficient devices, to marketing, etc., unless these ICS are imported from abroad. Disseminating five million cooking devices would generate hundreds, if not thousands, of jobs.

The main health and safety benefits are linked with the reduction of acrid smokes that are responsible for many breathing diseases and deaths, especially amongst women and children.

Hypothesis	per year
Population (2014) - Worldbank database	45 545 980
% of population using firewood and/or charcoal	87,7%
Rural population (2014) - Worldbank database	75%
Urban population (2014) - Worldbank database	25%
Annual consumption of charcoal per capita (m3 RWE)	0,3915
Annual consumption of firewood per capita (m3 RWE)	0,4485
Proportion of firewood from forests	18%
Wood density	0,6
Ratio: tCO2e = x tons of dry wood	1,8
fNRB (non renewable biomass fraction)	92%
Root-Shoot ratio (no dimension)	0,37
Biomass expansion factor (no dimension)	1,3
Carbon fraction (tC/ton of dry wood)	0,5
tC to tCO2 ratio	3,7
BAU devices thermal efficiency (BAU)	20%
BAU Charcoal-stove efficiency (BAU)	20%
Household composition (n° of people per household)	5
TEV-Natural forests (USD/ha)	323
Fuelwood - farmgate price (USD/m3)	3,7
Growing stock - Natural forests (m3/ha)	180
Action 1: Introducing firewood-based efficient cookstoves (ICS) to replace 3-stones stoves	**per year**
% of firewood consumed in rural areas	90%
Quantity of ICS disseminated to reach target	3 500 000
Current dissemination rate	30%
Project dissemination rate	81%
ICS efficiency (annual mean over lifespan)	30%
Number of days stoves are used per year	365
Firewood - Non-renewable biomass savings (m3 RWE) from forests	389 926
Firewood - Emission reductions (tCO2eq) including 5% leakages	725 709
Cost of one ICS (USD/unit)	2
Total cost of disseminating ICS under Action 1	7 000 000
Cost per tCO2e (USD/tCO2e)	9,6
TEV preserved (USD)	643 724
Beneficiary margin	1 588 359
Action 2: Introducing efficient cookstoves (ICS) to replace regular charcoal-based stoves	**per year**
% of charcoal consumed in rural areas	82%
Quantity of ICS disseminated to reach target	1 500 000
Current dissemination rate	30%
Project dissemination rate	96%
ICS efficiency (annual mean over lifespan)	30%
Number of days stoves are used per year	365
Charcoal - Non-renewable biomass savings (m3 RWE) from dry forests	570 173
Charcoal - Emission reductions (tCO2eq) including 5% leakages	1 660 079
Cost of one ICS (USD/unit)	2
Total cost of disseminating ICS under Action 1	3 000 000
Cost per tCO2e (USD/tCO2e)	1,8
TEV preserved (USD)	2 886 103
Beneficiary margin	2 255 804

Table 33: Summary of findings - Firewood and charcoal consumption at household level

FIREWOOD AND CHARCOAL CONSUMPTION IN AGRICULTURAL & INDUSTRIAL PROCESSING

Statistics

Firewood and charcoal are essential sources of energy in the agricultural and agrifood sectors in Kenya. As shown in Figure 20 below, according to MoE (2002), the indirect contribution by the forestry sector to the agriculture and manufacturing of food, beverage and tobacco sectors in Kenya is around 20% in terms of value added generated.

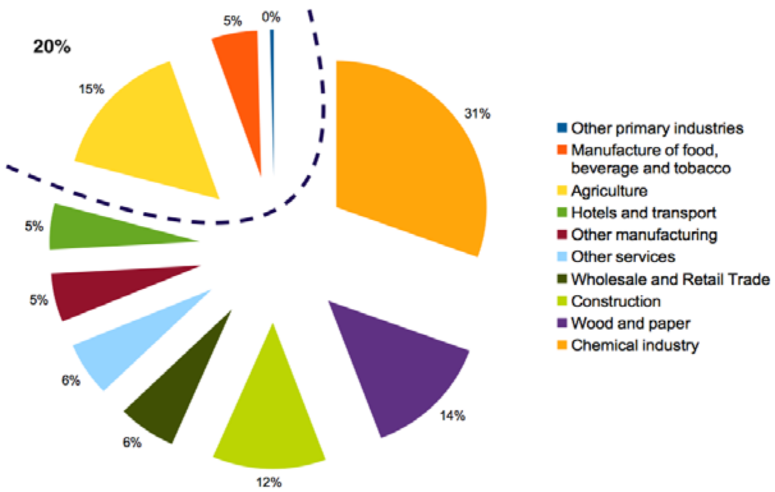

Figure 21: Contribution of the forestry sector to value added in the different industries, annual average (as share of total value induced) (by UNEP, 2012)

Types of businesses included range from the cottage industry to industrial sectors such as agrifood industries (milk, fish drying and smoking, lime processing), labs for the production of food products such as bakeries/restaurants, and public places where food and drinks are served. It is made of small-to-medium scale operations, located in rural areas or in secondary urban centres.

It was estimated that, on average, between 20% and 30% of the total operation costs for energy comes from wood (MoE, 2002). In sugar factories, firewood is burnt along with cultivation processing residues (bagassa), a biomass residue derived from sugar cane. In many other cases, firewood or charcoal are preferred for economic reasons and because they are easy to find compared to electric power, liquefied petroleum gas (LPG) or fuel oil. Restaurants and luxury hotels, instead of firewood and charcoal, integrate LPG for image reason and use firewood or charcoal for the preparation of traditional dishes only.

Available statistics on firewood and charcoal consumption are shown in Table 34 below according to the type of businesses. It shows the consumptions in agricultural industries and in the so-called cottage industries split between firewood and charcoal.

Biomass Demand	Qty of fuelwood in tons/year	Qty of charcoal in tons/year	Qty of charcoal in (RWE tonnes/year)	Total biomass consumption (RWE tonnes/year)
Tobacco farmers	140,000			140,000
Tea industry	800,000			800,000
Restaurant/Kiosks	1,276,000	428,025	1,945,568	3,221,568
Bakeries	20,000	622	2,827	22,827
Agrifood industries (jaggary, milk, fish, etc.)	223,000		2,455	225,455
Total agroindustry and cottage industry	2,459,000	428,647	1,950,850	4,409,850

Table 34: Firewood and charcoal consumptions by type of activity in the framework of agricultural industries and cottage industry.
* Data obtained from literature;
** data from interview.

FOCUS ON THE TEA INDUSTRY

Tea represents one of the main products in Kenya, with an annual production in 2014 of about 445,000 tons.[19]

Tea industrial facilities are fitted with large boilers for the production of steam. Firewood is burnt in large quantities accounting for 70% of the overall energy used (by integrating fuel oil, and other renewable energies such as thermal solar and hydroelectricity). As presented in Chapter 3.2 tea companies often have their own plantation resources from which firewood is sourced. They also rely on external supply by strongly supporting the firewood production without grower schemes (see Figure 21 for an illustrative example from Finlays).

Figure 22: Firewood stock under greenhouses for drying and boiler fed by woody biomass at Finlays estate (Kericho)

Firewood demand is increasing rapidly because of the increase of tea production. Companies have to seek high efficiency by investing in the latest boiler technology. Concerns about future firewood supply prompt these companies to find new way to scale down over reliance on firewood, for instance, by using briquettes (bagasse, sawdust, coffee husks, rice husks) or introducing Bamboo for firewood. KTDA is also training farmers in their supply area on domestic energy, especially energy efficient cooking stoves.

On average for each kilogram of tea as a finished product, the average firewood consumption is estimated at 2.5 kg. Some time ago the average consumption was 4 kg, but some companies - thanks to technical innovation - have drastically reduced their needs. Firewood reduces tea preparation costs up to 40% compared with fuel oil. Conversion of the energy source towards firewood is underway and this shift is only limited by the availability of forest resources.

Focus on tobacco industry

Tobacco cultivation has been introduced relatively recently in Kenya, but it is spreading rapidly and, in 2011, was practiced by a very high number of small producers (about 50,000) on a surface of 23,000 ha (Kibwage, 2012). Tobacco can provide much higher incomes than other crops. On the other hand, this labour-intensive crop requires great attention to cultures, fertile and irrigated soils and use of phyto-pharmaceuticals, both pesticides and fungicides.

The heat necessary for the fermentation and drying of leaves is mainly obtained from firewood, with a consumption rate depending on equipment's type. It ranges from 10 to 12 kg of wood per kg of finished product in traditional systems commonly used by small farmers (traditional barn); 5 kg for rocket barns, widely tested but not very widespread; and 2.5 to 3 kg for the most modern installations (modern barn) (Nyer, 2008).

In terms of green product, a ton of green leaves require 0.5 to 2 tons of wood depending on the cycle and efficiency of the treatment plant. In Kenya, 2.5 ha of Eucalyptus plantation are needed to dry the production of 1 ha of tobacco (Musoni et al, 2013).

Other energy consumptions reported by MoE (2002) would appear today strongly diminished or even stopped, in relation to technological changes, as it is the case of brick factories for the production of bricks, in which wood has been replaced by other biomasses and by oil.

Research on improving energy efficiency conversion in agricultural industry

AVAILABLE TECHNOLOGIES

There is a large range of combustion systems available on the market. Many aspects impact the type of system that is suitable for a given plant, including both the end use of the heat and the size of the wood being used in the combustion system. Deciding on which parameter to use as the primary determinant for the selection of the combustion system is made on a case by case basis (FAO, 1990).

The most appropriate biomass furnaces for Kenya are the pile burners, which burn fuel in piles on a refractory floor or gate. Combustion is enhanced with air coming from under and above the grate. While this is a simple technology and allows for flexibility in the type of fuel used, its low combustion efficiency and the need to manually remove the ash mean that it is not often used in commercial plants unless the ash content is very low (Goble and Peck 2012).

Pile burners can be divided into two main types – heaped pile burning furnaces and thin pile furnaces. In heaped pile burning furnaces, fuel is continuously fed from the top of the furnace in batches via chutes located across the grates. Thin pile furnaces burn hogged fuel as a thin bed spread across the grate (FAO, 1990).

IMPROVED AGRICULTURAL AND COTTAGE INDUSTRIES ALTERNATIVE SCENARIO

Based on experiences from European countries, the purchase and installation of furnaces/boilers with improved yield can be promoted through incentive campaigns with diversified technical and administrative procedures.

In the case of large installations, the contribution is released directly to the investing company, following a short administrative procedure aiming at verifying the feasibility of the intervention and the existence of admissibility pre-requirements.

In the case of smaller installations, a contribution to the boiler producer could be envisaged, aiming at reducing the purchase cost by the final user, similarly to the incentive in some European countries for low-emission vehicles. The amount of contribution must be of at least 20% of the purchase cost to boost the company and achieve 30-40% for smaller installations including micro-enterprises or individuals. Any contribution adjustment can be envisaged according to geographical, social or economic factors (disadvantaged areas). The overall investment needed to bring about the alternative scenario is estimated at US$ 114,300,000.

Table 35 below shows the current fuelwood consumption and potential outcome from investments in improved boilers. The outcome is estimated in terms of tons of wood saved per year.

Fuelwood demand	Total fuelwood consumption (tons/year)	Estimated quota of the energy demand potentially engaging efficiency improvements measures	Increase in energy conversion	Savings per year (tons/ year)
Restaurants/kiosks*	3,221,568	25%	from 20 to 40%	402,696
Tea industry**	800,000	50%	from 20 to 50%	240,000
Tobacco farmer*	140,000	50%	from 10 to 20%	35,000
Agrofood industry (jaggary, milk, fish, etc.)*	225,455	25%	from 20 to 50%	33,818
Bakeries*	22,827	25%	from 20 to 40%	2,853
TOTAL	4,409,850			714,367

Table 35: Consumption and estimated potential wood savings from efficiency improvement in agricultural and cottage industries

Biomass demand	Part of energy consumption potentially involved in improvement measures	Average consumption of firewood by operator (tons/year)	Number of operators	Number of operators potentially involved in the improvement measures	Average investment for more efficient boilers (USD)	Totals investments (USD)	Percentage of public funding (USD)	Public funding (USD)	Public funding per saved RWE m^3 over 10 years time (USD/tons)
Agrofood industry (jaggary, milk, fish, ecc.)	25%	1,000	225	56	100,000	5,600,000	30%	1,680,000	4,97
Bakeries	25%	50	457	114	10,000	1,140,000	30%	342,000	11,99
Restaurants/ kiosks	25%	50	64,431	16,108	5,000	80,540,000	30%	24,162,000	6,00
Tea industry	50%	4,000	200	100	200,000	20,000,000	20%	4,000,000	1,67
Tobacco farmer	50%	30	4,667	2,334	3,000	7,002,000	40%	2,800,800	8,00
Total			69,980	18,712		114,282,000		32,984,800	

Table 36: Public investments and contributions for the purchase of improve efficiency boilers in agricultural and cottage industries

Costs and benefits analysis

EMISSION REDUCTIONS

The exact origin of the firewood consumed in agricultural and cottage industries is not known. According to Vermeulen and Walubengo (2006), KTDA firewood supply depends partly on its own plantations. The authors indicate that it is not clear whether the other part is supplied by private farms, State plantations or public land. It is however a highly needed parameter to estimate the proportion of non-renewable biomass that is used in the processes and to assess the potential emission reductions from deforestation and degradation.

As discussed in previous chapters, the fraction of non-renewable biomass is a key-factor to estimate the potential emission reductions of a given REDD+ measure. When fNRB is equal to 0, fuelwood production is considered sustainable (harvested volumes are equal to the yield). As discussed above (Chapters 3.1 and 3.2), we may assume this is the case for private plantations that are grown to supply tea factories (such as KTDA tea factories for example). In such scenarios, no emission reductions are expected from increased recovery rates in the agricultural and cottage industries, because the fuelwood that is used in the BAU scenario is assumed to be 100% renewable (trees being replanted).

Fuelwood supplied from trees on farmlands that do not qualify as forests under the national definition presented in Chapter 2.1 is not eligible for reducing emissions from deforestation and degradation because these lands may not be considered as "forests".

On the contrary fuelwood supplied from natural forests may be eligible. Considering fNRB is equal to 92% in natural forests in Kenya (UNFCCC, 2012), saving one ton of firewood in natural forests represents approximately 2.9 tCO_2e of emission reductions from deforestation and degradation.[20]

The measures proposed to increase efficiency in the agricultural and cottage industries are expected to reduce fuelwood consumption by up to 714,000 tons per year (e.g. 1,2 million m^3 RWE), generating up to 2.0 million tCO_2e per year of emission reductions (including 5% leakages). The total emission reductions will depend on the proportion of fuelwood sourced in natural forests.

Other measures that are outside of the scope of this study might be undertaken to increase the potential GHG net removal and be included in the Kenyan REDD+ strategy: (i) increasing planting on both public and private land in order to sequestrate carbon (afforestation/reforestation), and (ii) improving silvicultural practices to enhance fuelwood production yield in farmlands so that these plantations meets the Kenyan definition of forest, making them eligible to REDD+ as potential carbon sinks (enhancement of carbon stocks).

During the final workshop KTDA explained that they give improved cook stoves to their farmers so that they save on their energy and have excess firewood that they can supply KTDA with. To assess the potential REDD+ opportunities linked to this activity, one must determines:

First, whether the firewood that is used by the farmers comes from forest lands or non-forest lands, according to the Kenyan definition of forests (see above). The amount of biomass saved from forests thanks to the improved cook stoves distributed by KTDA to the farmers is noted Bsavings (f).

Second, the proportion of non-renewable biomass from forests that is used by KTDA in the BAU scenario, noted fNRB (k).

There is a REDD+ potential only if it can be shown that the biomass from forests saved on farms replaces non-renewable biomass from forests used by KTDA. The emission reductions may be derived from the proportion of non-renewable biomass that is saved from burning at KTDA facilities (Bsavings (f) x fNRB (k)). On the contrary, there is no REDD+ potential if KTDA uses renewable biomass in the BAU scenario.

BENEFICIARY MARGINS

Industrial fuelwood consumers would reduce their fuelwood expenses by reducing their consumption of raw material. Considering the savings of 1.2 million m^3 RWE biomass per year from natural forests, this will represent a total value of 4.5 million USD based on 392 KES/m^3 (based on farm gate prices).

FORESTS TOTAL ECONOMIC VALUE (TEV)

Savings of 1.1 million m^3 RWE of non-renewable biomass from natural forests per year may be converted into forest ha-equivalent, based on the following hypotheses: (i) the mean growing stock in natural forests is 180 m^3/ha (FAO, 2015), and (ii) the mean TEV produced is 323 USD/ha/year in natural forests. Therefore, the corresponding TEV preserved may be estimated at 2.0 million USD per year.

JOBS CREATION, HEALTH AND SAFETY

Increasing the efficiency of furnaces and boilers will reduce the total biomass consumption for the agricultural and cottage industries, thus having positive impacts on health from reduced smoke inhalation, but a potential negative impact on employment.

Key-findings

MATRIX OF COSTS AND BENEFITS INDICATORS

The balance between costs and benefits is calculated as the sum of socio-economic benefits (beneficiary margins) plus environmental benefits (direct benefits [carbon value] and indirect benefits [TEV preserved]) minus the substitution costs as outlined in Table 37.

x 1,000 USD	Forestry operations	Timber processing	Charcoal production	Firewood and charcoal consumption at household level	Firewood consumption at industrial level
Benefits					
Emission reductions (tCO_2e/year)	0	46	16,476	2,386	2,040
Hyp1: carbon price 1 - 5,6 USD/tCO_2e		259	92,265	13,360	11,427
Hyp2: carbon price 2 - 8,4 USD/tCO_2e		389	138,397	20,041	17,140
Hyp3: carbon price 3 - 111 USD/tCO_2e		5,136	1,828,818	264,822	226,494
TEV preserved (USD/year)	0	44	30,239	3,530	1,966
Beneficiary margins	1,166	2,946	22,388	3,844	4,462
Costs					
Substitution costs (annualised)	375	1,415	15,642	10,000	11,430
Abatement costs					
USD per tCO_2e	n/a	4.9 (briquettes substitution only)	0.9	4.2	5.6
Benefits – Costs (balance)					
Hyp1: carbon price 1 - 5,6 USD/tCO_2e	791	1,834	129,251	10,734	6,424
Hyp2: carbon price 2 - 8,4 USD/tCO_2e	791	1,964	175,383	17,415	12,138
Hyp3: carbon price 3 - 111 USD/tCO_2e	791	6,712	1,865,803	262,196	221,491

Table 37: Balance of costs and benefits (x 1000 US$)

CONCLUSIONS

This study assessed whether increased efficiency in forestry operations and forest product processing in Kenya may be a potentially interesting REDD+ policy or measure (PAM) as the government moves towards REDD+ implementation. Specifically five types of efficiency measures were identified and compared for their economic and environmental costs and benefits. The link between REDD+ opportunities, increased efficiency and reduced pressure on forests has been discussed for each sector and wood product.

Plantations were established in Kenya to provide timber materials and offer a buffer for natural forests, with the underlying assumption that all timber materials would come from plantations instead of natural forests. At the moment, there is no clear evidence that increasing efficiency in forestry operations and timber processing will help alleviate pressure on natural forests from illegal harvestings for timber production. However, this assumption seems realistic for fuelwood (firewood and charcoal) production.

Forestry operations (harvesting): Increasing efficiency in forestry operations, such as improved harvesting techniques in public and private plantations, will increase the national timber production for a limited amount of volumes (85,900 m^3 RWE per year). However, as there is no evidence that increasing timber supply from harvesting in forest plantations will decrease the pressure on natural forests for timber production; and that the fraction of non-renewable biomass in public and private plantations is close to null, these measures are unlikely to generate emission reductions from deforestation and forest degradation. Regardless, these measures might have socio-economic positive impacts, such as increasing the safety of harvesting operations and harvested timber quality as well as improved gender equality depending on who receives training.

Timber processing (including briquette production): Increasing efficiency in timber processing will also increase national timber production for an amount estimated at 210,000 m^3 RWE per year. For the same reasons as described above, these measures are unlikely to generate emission reductions from deforestation and forest degradation, except the production of briquettes with saw dust for fuelwood substitution (46,000 tCO_2e per year, TEV preserved equal to 44,000 USD). However, it is reasonable to think that increasing wood production will create more jobs in this industry and increase the industry's profitability.

Charcoal production: Increasing efficiency in charcoal production in dry forests can lead to 5.7 million m^3 RWE of non-renewable biomass savings per year, generating more than 16.5 million tCO_2e per year of emission reductions from deforestation and forest degradation. Additionally, the forests total economic value that is preserved is estimated at 30.2 million USD per year. The overall balance of costs and benefits is positive (assuming a hypothetical carbon price of at least USD 5.6/tCO_2e), and the profitability of the sector is increased. Moreover, these measures will generate positive impacts such as the reduction of accidental burning and respiratory problems among charcoal producers. These measures can also generate more qualified jobs in the sector and may improve gender equality in the charcoal sector. Lastly, efficiency improvements in charcoal production could go a long way towards meeting Kenya's ambitious climate target. Therefore, considering these measures is strongly encouraged as they are directly relevant for the Kenyan REDD+ strategy, generating both emission reductions from deforestation and degradation and positive co-benefits.

Fuelwood consumption at household level: Increasing efficiency in the consumption of firewood and charcoal from natural forests can lead to 960,000 m^3 RWE of non-renewable biomass savings per year, generating 2.4 million tCO_2e per year in terms of emission reductions from deforestation and forest degradation. While the reduction potential is lower than efficiency measures in charcoal production these are nonetheless very relevant from the perspective of Kenya's climate change target. The forests total economic value that is preserved is estimated at 3.5 million USD per year, the overall balance of costs and benefits is positive, and the profitability of the sector is increased. Moreover, these measures will generate positive impacts such as the reduction of respiratory problems amongst the charcoal and firewood consumers (affecting mainly women and children). Finally, these measures can contribute to create jobs in the improved cook stoves manufacturing sector and can contribute to the achievement of Kenya's Gender in Forestry and Environment Policy. Therefore, considering these measures is strongly encouraged as they are directly relevant for the Kenyan REDD+ strategy, generating both emission reductions from deforestation and degradation and positive co-benefits.

Fuelwood consumption at industrial level: Increasing efficiency in the wood usage in industrial processes may represent up to 1.1 million m^3 RWE of non-renewable biomass savings per year, generating more than 2.1 million tCO_2e per year in terms of emission reductions from deforestation and forest degradation. The forests total economic value that may be preserved is estimated at 2.0 million USD per year. The overall balance of costs and benefits may also be positive. However, more data on fuelwood origin by sectors (tea, tobacco, restaurants and kiosks, etc.) is necessary to refine this conclusion. Indeed, it is yet not clear whether a significant amount of non-renewable biomass from natural forests is used in these industrial processes, or if they rely only on renewable biomass harvested in forest plantations.

It is also expected that several measures that are out of the scope of this study might have significant impacts in terms of net GHG removal, such as increasing the forest area through afforestation and/or reforestation. Carbon stocks enhancement in forest plantations by improving the silvicultural practices such as thinning, pruning, extension of rotation age, may also be a potential source of net GHG removal, by increasing the mean carbon stock per ha.

Potential outcomes from alternative improved scenarios and costs and benefits indicators presented in the previous chapters are aggregated in figure 22 below, which shows the potential biomass savings rising from achieving the efficiency improvement goals proposed for the five areas of research falling within the scope of this assessment.

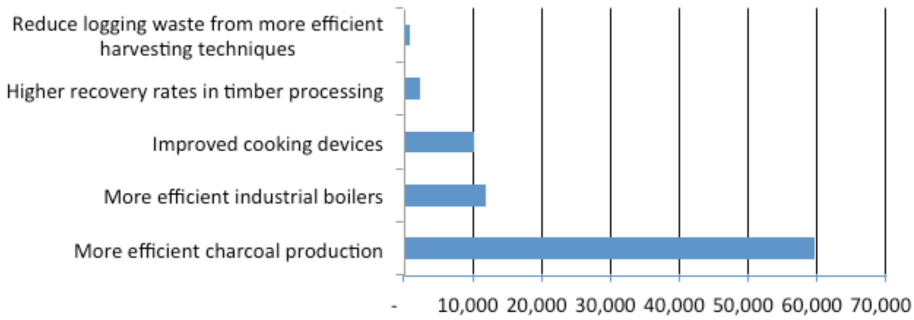

Figure 23: Potential biomass saving from improved alternative scenarios over 10 years (x 1,000 m^3 RWE)

The potential biomass savings from alternative improved scenario based on the above assumptions and a time period of 10 years are presented in Figure 22 above with the overall prospective biomass savings reaching more than 85 million m^3 RWE. This outcome is almost six times higher than the potential biomass production from increasing the growing stock of public plantations from afforestation and improved management techniques, which was estimated in Chapter 3.1.1 at 15 million m^3 RWE. Moreover, it has to be noted that the potential outcome from growing stock increase in public plantations can be achieved over a much longer timeframe because the expected effect of improved management techniques take place during the whole rotation period, which for pine and cypress species is around 30 years. Afforestation has to be progressive in order to properly integrate new establishments with the ages of previous plantation stands. The options discussed in this report may potentially lead to immediate, short-term results.

Figure 22 above shows that biomass savings can be more easily achieved in the agricultural and cottage industries, charcoal production and firewood/charcoal consumption sectors. These activities involve both large wood supply volumes as well as great efficiency improvement potential from technological innovation ranging from 10% to 50%. In the field of harvesting and timber processing efficiency improvement, one cannot expect to achieve more than 5% to 20% increase from the current recovery rates levels, which is limiting the potential of total biomass savings.

Financial figures shown in Chapter 4.1 gives additional insights into the cost and opportunities involved in the alternative scenarios. For each sector, the proposed measures have a positive cost-benefit balance, although they are not all eligible for REDD+ activities. The lowest abatement cost was found in the charcoal production sector (0,9 USD/tCO_2e) and the highest in the fuelwood/charcoal consumption at industrial level (5.6 USD/tCO_2e. The abatement costs from the production of briquettes made of recycled saw-dust are estimated at 4.9 USD/tCO_2e and 4.2 USD/tCO_2e for the use of improved cook stoves at household level. In the charcoal production sector especially, efficiency can be strongly improved at a relatively low cost, as compared to other sectors.

End notes

1 Reducing Emissions from Deforestation and Forest Degradation (REDD) is a concept to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

2 Fuelwood designates firewood and/or charcoal

3 The Kenyan definition of forests used by KFS to carry out a wall-to-wall mapping at national scale in 2013 is based on the following characteristics: "Land spanning more than 0.5 ha with trees higher than 5 meters and canopy cover of more than 15%". In its FRA 2015 country report, the FAO uses the following definition: "Land spanning more than 0.5 ha with trees higher than 5 meters and canopy cover of more than 10% - or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use".

4 It has to be noted that in 2009 Pan Paper mill stop operating, but the above statistic refers to the four companies.

5 See FAO Unasylva n°229, special edition on "Forests and Water".

6 Montane forests represent 1,140,000 ha * 1,240 m^3/ha/year = 1.4 billion m^3/year, which is 75% of the total water availability. The 2,902,000 ha of other natural forests (including dry forests and plantations) represent 25% of the total amount of available water (approximately 162 m^3/ha/year).

7 The effect of the deforestation of 100 ha would be 100 times the effect of the deforestation of one ha

8 This report was commissioned by the French Prime Minister in 2008.

9 KFS definition of indigenous forest: a forest which has come about by natural regeneration of trees primarily native, and includes mangrove and bamboo forests.

10 KFS definition of woodland: an open stand of trees of 10 to 30% of tree canopy cover and trees growing to 2m tall which has come about by natural regeneration.

11 Relevant examples of best practices are available, see: Regional code of practice for reduced-impact forest harvesting in tropical mois forests of West and Central Africa (FAO, 2004).

12 See: Silayo (2014); Pasiecznik and Carsan (2006).

13 See: Melemez et al (2014)

14 +5,400 ha/year between 2005 and 2010 and +1,400 ha/year between 2010 and 2015 according to FRA (2015).

15 Adapted from Wamukoia & Associates, 2007

16 Parameters used for Equation 2: RSR = 0.37 (tropical dense forests, IPCC 2006) ; Biomass expansion factor = 1.3 (tropical dense forests, IPCC 2006) ; Carbon fraction = 0.5 tC/t of dry wood ; C/CO_2e ratio = 44/12 = 3.67

17 Mass efficiency ratio: charcoal (output) / dry wood (input)

18 10,000 USD to train 25 charcoal makers.

19 Source: http://www.teaboard.or.ke/statistics

20 See Equation 2 with RSR = 0.37 (tropical dense forests, IPCC 2006) ; Biomass expansion factor = 1.3 (tropical dense forests, IPCC 2006) Carbon fraction = 0.5 tC/t of dry wood ; C/CO_2e ratio = 44/12 = 3.67 ; fNRB = 92% and leakages = 5% (default value).

Bibliography

Methodology

Arino, O., Ramos, P., Jose, J., Kalogirou, V., Bontemps, S., Defourny, P., Van Bogaert, E., (2012). Global Land Cover Map for 2009 (GlobCover 2009). European Space Agency (ESA) & Université catholique de Louvain (UCL).

CIA, (2015). The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/

Ecosystem Marketplace, (2013). Covering New Ground - State of the Forest Carbon Markets 2013.

Quinet, A. (2009). La valeur tutélaire du carbone - Rapport de la commission présidée par Alain Quinet. Rapports et documents N°16-2009. Centre d'analyses stratégiques.

Emerton, L. (1997). An Economic Assessment of Mount Kenya Forest. EU/African Wildlife Foundation, Nairobi.

Food and Agriculture Organization (FAO) (2007). Unasylva – Forests and Water (vol.58, 2007/4, 229). FAO, Rome.

Food and Agriculture Organization (FAO) (2010). Global Forest Resources Assessment 2010 – Country report – Kenya. FAO, Rome.

Food and Agriculture Organization (FAO) To be published. Global Forest Resources Assessment 2015 – Country report – Kenya. FAO, Rome.

Ireri, P. (2012). Ecotourism investment opportunities in Kenyan forests. Kenya Forest Services (KFS).

KAFU (2000). [Quoted in Mbugua, 2000. Reference not found]

KFS (2013). Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. Submitted by Pasco Corporation.

Mbuga, D. (2000). Forest Outlook studies in Africa (FOSA), Kenya.

Ndegwa, G.M. (2010). Fuelwood value chains in Kenya and Rwanda - Economic analysis of the market oriented fuelwood sector. Cologne University of Applied Sciences Institute for Technology and Resources Management in the Tropics and Subtropics (ITT).

Peltorinne, P. (2004). The forest types of Kenya. In: Pellika, P., Ylhäisi, J., Clark, B. (2004). Taita Hills an Kenya, 2004 – seminar, reports and journal of a field excursion to Kenya. Expedition reports of the Department of Geography, University of Helsinki 40, 8-13.

Prime Africa, LTS International (2009). Classification of Kenya's forest regulating services. UNEP.

TEEB. (2010). The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. (P. Kumar, Ed.) London and Washington: Earthscan.

UNEP (2012). The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy. UNEP/UN-REDD/Republic of Kenya/KFS, Nairobi.

Vermeulen, S., Walubengo, D. (2006). Developing partnerships for sustainable management of forests in Kenya - Review of existing models and set of options for further support.

MEWNR (Wanleys Consultancy Services) (2013). Analysis of demand and supply of wood products in Kenya. Ministry of Environment, Water and Natural Resources.

Forestry operations

Business daily (2015). Corporate news: KTDA factories roll out plan for reliable wood.

Kiptot E. and Franzel S. (2011). Gender and agroforestry in Africa: are women participating? ICRAF Occasional Paper No. 13. World Agroforestry Centre

FAO (2007). Gender Mainstreaming in Forestry in Africa – Kenya. Food and Agriculture Organization of the United Nations.

FAO (2004) Regional code of practice for reduced-impact harvesting in tropical moist forests of west and central Africa. Food and Agriculture Organization of the United Nations.

Finlays (2015). Website: www.finlays.net. Consulted on 08/31/2015.

ICRAF (2014) Sustainable firewood access and utilisation; achieving cross-sectoral integration in Kenya. World Agroforestry Centre and Stockholm Environment Institute.

Institute for Law and Environmental Governance (ILEG) (2011). The ban on logging and its impact on the forest sector and the economy.

IPCC (2006). IPCC Guidelines for national greenhouse gas inventories – Volume 4: Agriculture, forestry and other land-use – Chapter 4: Forest Land.

KFS (2007). Forest Law Enforcement and Governance in Kenya: A paper prepared for the East African Community-led regional process in the framework of the Ministerial Declaration, Yaoundé, Cameroon, October 16, 2003 on the Africa Forest Law Enforcement and Governance (AFLEG)

KFS (2011). KFS Strategic Plan 2009/2010 – 2013/2014.

KFS (2012). KFS Annual Report.

Melemez, Tunay and Emir (2013). A comparison of productivity in 5 small scale harvesting systems. Small Scale Forestry

MEWNR (2013). by Wanleys consultancy services. Analysis of demand and supply of wood products in Kenya.

Pasieczsnik and Carson (2006). Turning Trees into Timber: a Chainsaw demonstration/training course. World Agroforestry Centre

PWC (2014). Discussion paper: Meeting the wood supply challenge: the need for commercial forestry in Kenya.

Silayo, D.S. (2015). Modelling productivity and cost of timber harvesting in plantation forests using two man crosscut saws under learning experiments, Tanzania. American Journal of Operational Research 5(2): 29-38

GOFC-GOLD (2013). A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP19-2, (GOFC-GOLD Land Cover Project Office, Wageningen University, The Netherlands).

Timber processing

KFS (2007). Forest Law Enforcement and Governance in Kenya: A paper prepared for the East African Community-led regional process in the framework of the Ministerial Declaration, Yaoundé, Cameroon, October 16, 2003 on the Africa Forest Law Enforcement and Governance (AFLEG)

Muthike et al. 2011 - Sawmilling in Kenya.

World Agroforestry Centre (2011) - An assessment of farm timber value chains in mountain Kenya area – The application of the filiere approach to small and medium scale farm timber businesses.

Wamukoya and associates (2007) – Support to forest sector in Kenya: analysis of policy, regulatory and fiscal framework for small and medium enterprises development in sawmilling.

Wanleys consultancy services (2013) – Analysis of demand and supply of wood products in Kenya. MEWNR.

PWC (2014). Meeting the wood supply challenge: the need for commercial forestry in Kenya. Discussion paper.

Kenya Forest Service (2010). Revised REDD Readiness Preparation Proposal for Kenya submitted to the Forest Carbon Partnership Facility. The World Bank.

Charcoal production

FAO (2010): Global Forest Resources Assessment: Kenya Country Report. Food and Agriculture Organization of the United Nations Roma, 1987.

FAO (1987). Simple Technologies for Charcoal Making. Forest Industries Division FAO Forestry Department. FAO Forestry Paper 41. Food and Agriculture Organization of the United Nations Roma, 1987.

Monica, K., John, N., Clement, N., Simanto, O., Odour, N. (Undated). Available Charcoal Production Technologies in Kenya. UNDP and Kenya Forest Service.

Kenya Forest Service (KFS) and Miti Mingi Maisha Bora (2013). Support to forest sector reform in Kenya, carried out by Matthew Owen consultant. The Legally Compliant Charcoal Industry and its Barriers to Growth in Kenya, Draft Version.

MEWNR (2013). Analysis of demand and supply of wood products in Kenya. Wanleys consultant services.

SalvaTerra (2014). Production and marketing of sustainable charcoal made from forest plantations in the periphery of Kinshasa, DR Congo. GIZ.

ICRAF (2013). Charcoal briquetting in Nairobi relieves poverty, environmental stresses. World Agroforestry Centre

Firewood and charcoal consumption at household level

Bentson, S., Still, D., Thomson, R. and Grabow, K. (2013) The influence of initial fuel load on Fuel to Cook for batch loaded charcoal cookstoves. Energy for Sustainable Development 17 153-157

Clough, L. (2012) The Improved Cookstove Sector in East Africa: Experience from the Developing Energy Enterprise Programme (DEEP). GVEP International.

Githiomi J. K., Mugendi D. N. and Kung'u J. B. (2011): Analysis of household energy sources and fuelwood utilisation technologies in Kiambu, Thika and Maragwa districts of Central Kenya,

Githiomi J.K and Oduor N, (2012): Strategies for Sustainable Wood fuel Production in Kenya, International Journal of Applied Science and Technology Vol. 2 No. 10; December 2012 21

ICRAF (2014) Sustainable firewood access and utilisation; achieving cross-sectoral integration in Kenya. World Agroforestry Centre and Stockholm Environment Institute.

Ministry of Environment, Water and Natural Resources (2013): Analysis of the charcoal value chain in Kenya.

Ministry of Planning and National Development (2007). Kenya integrated household budget survey 2005/06 Revised Edition. KNBS, Nairobi, Kenya, pp. 96

SalvaTerra (2014) – Production and marketing of sustainable charcoal made from forest plantations in the periphery of Kinshasa, DR Congo. GIZ.

SEI (2014): Sustainable firewood access and utilization Achieving cross-sectoral integration in Kenya

SNV (2015) ICS Business Toolkit: Starting, Managing and Growing and Improved Cookstoves Business in Uganda. SNV Netherlands Development Organisation, Integral Advisory Ltd.

USAID (2011) The Kenyan Household Cookstove Sector: Current State and Future Opportunities. Winrock International, E+Co and Practical Action Consulting East Africa.

World Bank (2015). The World Bank Open Data. Consulted Aug. 15, 2015. Link: http://data.worldbank.org/.

Firewood and charcoal consumption in agricultural and industrial processing

UNFCCC (2012). Default values of fraction of non-renewable biomass. https://cdm.unfccc.int/DNA/fNRB/index.html Consulted on August 15th.

Vermeulen, S., Walubengo, D. (2006). Developing partnerships for sustainable management of forests in Kenya - Review of existing models and set of options for further support.

Republic of Kenya
Ministry of Environment, Natural Resources and Regional Development Authorities

KENYA
Forest Service

UN-REDD
PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP
Empowered lives. Resilient nations.

UNEP