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Full Length Research Paper

Analysis of woodfuel supply and demand balance in Kiambu, Thika and Maragwa districts in central Kenya

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This study was undertaken in Kiambu, Thika and Maragwa districts of Central Kenya and it aimed at developing micro-level wood energy plan that would act as a case study for future decentralized wood energy plans in Kenya. Primary data was collected from households, service/production institutions comprising of factories/industries, schools, restaurants, hospitals and prisons using structured questionnaires. The study established a deficit between supply and demand balance of -41.7, -45.6 and -50.1% of woodfuel in 2006 for Kiambu, Thika and Maragwa districts respectively. The strategies suggested in micro-level wood energy plans to curb these deficits include allocation of gazetted plantation forest to fuel wood production, increase of improved stove technology, increase of on-farm tree land area and use of alternative energy sources. The combination of all these strategies gave a surplus of 22,903, 46,947 and 32,409 tons of woodfuel in Kiambu, Thika and Maragwa districts, respectively by 2018. The study recommended implementation of the identified strategies aimed at reducing the huge deficit between supply and demand, enhancing inter-institutional collaboration in all sectors related to wood energy development, developing clear policies to guide charcoal and firewood production and marketing and having regular wood energy surveys.

Key words: Central Kenya, wood energy, planning, woodfuel deficit.

INTRODUCTION

It is estimated that about 90% of Kenyan rural households use woodfuel either as firewood or charcoal (MoE, 2002). Woodfuel meets over 93% of rural household energy needs whilst charcoal is the dominant fuel in urban households (Theuri, 2002; Kituyi, 2008). Besides being the standard cooking fuel for the majority of Kenyan households, fuel wood is also an important energy source for small-scale rural industries such as tobacco curing, tea drying, brick making, fish smoking and bakeries among others (Githiomi, 2010). Despite the importance of wood energy in the country's economic development, woodfuel data on supply and demand are scarce and characterized by a high degree of uncertainty that makes it difficult to undertake relevant wood energy planning and policy formulation. This has led to lack of integration of wood energy into national level planning exercises which are important in formulating national policies that are used in allocation of government investment and resources and prioritization of development objectives and targets. The scarcity and uncertainty of wood energy data is due to the fact that it is mainly handled in the informal sector and does not pass through monetized economy like in the case of liquefied petroleum gas (LPG), kerosene and electricity which are alternatives to wood energy. The national energy planning by ministry of energy concentrates more on these conventional fuels while forestry planning by Ministry of Wildlife and Forestry focus more on supply of commercial wood and conservation of protected areas (Republic of Kenya, 2002a). These two key sectors deny biomass energy the comprehensive consideration it deserves due to the role it plays in supply of energy to majority of Kenyans.

Lack of sustainable wood energy production planning has lead to scarcity and over-exploitation of natural resources and environmental degradation. This is

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Table 1. Sampled schools with feeding programme in Kiambu, Thika and Maragwa districts in 2006.

District	Division	Number of schools selected in each school category					
		PD	PB	PBD	SD	SB	SBD
Kiambu	Lari	16	-	-	22	06	-
	Kiambu municipality	11	03	-	04	03	02
	Kiambaa	16	02	-	10	04	02
	Limuru	13	-	-	11	05	01
	Kikuyu	30	-	02	16	07	01
	Githunguri	15	03	01	19	08	01
Thika	Municipality	-	1	-	-	09	-
	Ruiru	19	02	04	12	10	03
	Gatundu	06	-	02	19	11	04
	Kamwangi	-	-	-	18	08	-
	Kakuzi	-	-	-	22	08	-
	Gatanga				22	08	-
Maragwa	Maragwa	03	01	06	10	04	01
	Kandara	04	01	05	23	08	11
	Kigumo	-	-	02	15	02	04
	Makuyu	04	-	03	09	03	02

supported by past studies by Akinga (1980) and Ministry of Energy (2002) which despite being two decades apart showed widening gap between supply and demand as biomass resource was being depleted faster than the rate of replenishment. A decentralized area based approach to planning is essential to properly understand wood energy situations as dictated by varied socio-economic factors between the districts that lead to formulation of proper site-specific wood energy plans, policies and their implementation strategies to ensure sustainable supply. This study therefore aimed at generating data that will contribute to developing micro-level wood energy plan and its implementation strategies which will act as a case study for future decentralized wood energy planning in Kenya.

METHODOLOGY

This study was carried out in Kiambu, Thika and Maragwa districts of Central Kenya. The districts were purposively sampled on the basis of various factors which include diverse wood production systems (farmlands, plantations, natural forests), diverse ecological conditions and population densities among others. The selected districts had rainfall range from 800 to 1400 mm, 500 to 2500 mm and 900 to 2700 mm for Kiambu, Thika and Maragwa districts respectively (Republic of Kenya, 1997a, 1997b, 2002b). The study was designed to generate and analyze the wood energy parameters that were essential in developing wood energy plans for the selected area. The study involved assessing the wood energy resource availability and supply through consideration of wood production systems (plantation forests, natural forests and trees on farms), woodfuel consumption by different sectors and utilization technologies. The target groups in this study were households, institutions, industries, service providers (for example, hotels and kiosks). The study on wood energy production, consumption and supply involved sampling techniques where the sample group was selected following appropriate sampling techniques to obtain information on variables of interest to a larger population. This permitted inferences as to the behavior of the studied variables within the population.

The data obtained from the sample was used to make future projections to forecast energy demand and supply which were used in obtaining demand-supply balances that were used in developing a sustainable wood energy plan for the study area. Sampling of the households was done using multistage stratified random sampling technique beginning with stratification sampling procedures as outlined by Lee-Ann and Martin (1997). Each of the three districts under study was stratified according to the weights in socio-economic and climatic activities as indicators. Following this procedure, at least 40% of the divisions with relatively homogeneous characteristics in each district were sampled. This ensured heterogeneity was well captured and represented. Similar procedure was followed for selection of administrative locations and sub-locations. In total, 200 households were sampled in each district. Primary and secondary schools with school feeding programme in each district of study were listed and clustered into primary day (PD), primary day and boarding (PDB), primary boarding (PB), secondary day (SD), secondary day and boarding (SDB) and secondary boarding (SB). Forty percent (40%) of the samples in each cluster were selected randomly from random tables. This facilitated selecting random sample units from each cluster while all the sampled schools had the same opportunity of being selected. Based on this sampling criterion, various categories of schools were selected from each of the three districts as shown in Table 1.

Sampling of local food processing services (food kiosks, butcheries and hotels) was done within each sampled division. A total of 80 questionnaires were distributed across sampled units per district based on preliminary reconnaissance survey. A total sampling procedure was employed for tea factories and service institutions like prisons and hospitals within each district as they were found to be few. The data was collected using different structured and semi-structured questionnaires for each sector to provide the required information. Supply/demand analysis of wood energy consumption was undertaken and the results used in forecasting several scenarios over time range of 10 years.

Formulas used in projections

Population projection

The following formula shown was obtained from district planning offices which were provided by Central Bureau of Statistics (Republic of Kenya, 2001) to project population data together with the relevant population percentage growth rate:

$P_{n+1} = P_n e^{rt}$

Where: P_n = base population; P_{n+1} = projected population; r = the population growth; t = the time period of projection.

In this formula the population growth rate for the three districts (Kiambu 1.8%, Thika 0.8% and Maragwa 0.8%) were again used to project growth as the new growth rate is expected after the next census in 2009.

Projected numbers of households (PNH)

This was computed by dividing the projected population and the household size of 1999 census that is:

PNH = PPG/HZ

Where: PNH is the projected number of households, PPG is the projected population growth and HZ is the household size.

Projected woodfuel consumption

This was computed using the following formula:

$$PWC = r * PNH$$

Where: PWC is the projected woodfuel consumption, *r* is the mean rate of consumption in tonnes of woodfuel per household and PNH is the projected number of households.

Sustainable supply

Sustainable supply was computed using the formula:

$$SS = AAP * H$$

Where: *SS* is the sustainable supply of woodfuel from protected forests and farm lands, *AAP* is the average annual productivity of the forest stand which varied for example, closed forest- (1.3 m^3/year); woodlands (0.64 m^3/year), bushlands (0.44 m^3/year), wooded grasslands (0.25 m^3/year), grasslands (0.08 m^3/year), farmlands (1.44 m^3/year), forest plantations (19.9 m^3/year) (MoE, 2002). *H* is the land area in hectares under trees.

Expected area under trees

This was computed using the following formula:

$$EAT = \mu * p * NH$$

Where: *EAT* is the expected area under trees, *µ* is the mean area in ha under trees per given household, *p* is the proportion percentage expected to be under trees on the basis of individual household land size, *NH* is the projected number of households.

Amount of wood equivalent to carbonized charcoal

The formula used to calculate this was as follows:

$$Qtywd = \frac{AMTC}{r}$$

Where: *Qtywd* is the quantity of wood used for making charcoal, *AMTC* is the amount of charcoal carbonized, *r* is the rate of recovery (in this case the r for earth kiln is 20%).

Expected amount of wood to be saved under improved cooking technologies

This was computed using the formula:

$$ASWd = AUr - AUIr$$

Where: ASW_d is the expected amount of wood to be saved under improved use of cooking stoves, *AUr* is the amount of wood used under low efficiency (r = 10%) like in three stone stove, *AUIr* is the expected amount to be used under improved stoves with high efficiency (r = 30%).

Development of wood energy scenarios

In developing wood energy scenarios, the current situation at the time the survey was conducted in 2006 was first assessed and used as a base year. The factors likely to change in the future like the population were used to develop projections. The forecasting of wood energy demand and supply in the future was done as one of the processes of wood energy planning. Through these forecasts, a plan was developed with wood energy demand-supply balancing which proposes and determines a series of related developments and intervention strategies related to wood energy in order to sustainably bridge the gap caused by increasing wood energy demand. The approaches or strategies that were used to address the wood energy deficit were either aimed at reducing demand or increasing supply. These included increasing the land under trees for woodfuel production in both gazetted forests and farm lands, improving wood energy utilization technologies and encouraging fuel switch to conventional fuels. The wood energy demand and wood supply were built in this case study using projection formula shown earlier to develop various scenarios from the data that was taken in 2006 from Kiambu, Thika and Maragwa districts. First, an overview of the current situation in 2006 was created by specifying the data at the starting year and a basic scenario developed assuming a continuation of the same current trend.

A comparative consideration of different scenario combinations which gave the best options for wood energy demand and supply scenarios were considered and the interventions were evaluated using the developed scenarios.

RESULTS AND DISCUSSION

Woodfuel consumption among the districts was simulated

Table 2. Projections of population, supply of fuel wood and its consumption by different sectors in Kiambu district.

Year	2006	2008	2010	2012	2014	2016	2018
Projected population	843,917	874,852	906,920	940,164	974,627	1,010,352	1,047,388
Number of individuals expected to use charcoal	59,074	61,239	63,484	65,811	68,223	70,724	73,317
Expected area (ha) under trees on-farm	81,176	83,451	85,809	88253	90,787	93,414	96,138
Expected wood supply in tons from on-farm	116,894	120,169	123,565	127,085	130,734	134,517	138,438
Firewood consumption by households in tons	230,670	239,126	247,891	256,978	266,398	276,163	286,286
Equivalence of wood for charcoal consumed by households in tons	2,120	2,198	2,278	2,362	2,449	2,538	2,631
Firewood consumption by tea factories in tons	9,441	14,400	15,600	17,500	19,385	21,339	23,361
Firewood consumption by schools	23,102	24,882	26,689	29,502	32,315	35,128	37,941
Woodfuel consumption by prisons in tons	120	125	137	156	169	177	181
Woodfuel consumption by hospitals in tons	120	129	135	149	157	169	177
Woodfuel consumption by restaurants in tons	31	39	46	55	63	73	81
Farmland supply of woodfuel on basis of consumption	109,120	112,110	115,210	118,424	121,756	125,209	128,790
Total woodfuel expected to be used in ton	265,606	280,901	292,779	306,704	320,938	335,590	350,661
Sustainable supply of woodfuel	154,904	157,894	160,995	164,208	167,540	170,994	174,574
% deficit	-41.7	-43.8	-45.0	-46.5	-47.8	-49.0	-50.2

Table 3. Projections of population, supply of fuel wood and consumption by different sectors in Thika district.

Year	2006	2008	2010	2012	2014	2016	2018
Projected population	682,905	693,919	705,111	716,483	728,039	739,782	751,713
Number of individuals expected to use charcoal	58,046	58,983	59,934	60,901	61,883	62,881	63,895
Expected area (ha) under trees on-farm	275,643	276,599	277,570	278,557	279,560	280,580	281,615
Expected wood supply in tons from on-farm	191,418	192,082	192,757	193,442	194,139	194,847	195,566
Firewood consumption by households in tons	330,741	336,075	341,496	347,004	352,601	358,288	364,066
Equivalence of wood for charcoal consumption in tons	5,583	5,673	5,764	5,857	5,952	6,048	6,145
Firewood consumption by tea factories in tons	7,709	10,002	13,901	13,490	14,500	16,484	18,569.0
Firewood consumption by schools	36,828	39,012	41,866	43,768	45,671	47,573	49,476
Woodfuel consumption by prisons in tons	547	555	564	578	590	600	612
Woodfuel consumption by hospitals in tons	84	108	128	142	165	205	230
Woodfuel consumption by restaurants in tons	318	376	434	473	523	580	626
Farmland supply of woodfuel on basis of consumption	177,062	177,676	178,300	178,934	179,579	180,233	180,899
Total woodfuel expected to be used in ton	381,812	391,803	404,155	411,314	420,003	429,779	439,726
Sustainable supply of woodfuel	207,627	208,291	208,965	209,651	210,347	211,055	211,774
% deficit	-45.6	-46.8	-48.3	-49.0	-49.9	-50.9	-51.8

from base year 2006 to 2018 using the principles of long range energy alternative program (LEAP). The simulation used percentage population growth rate of 1.8, 0.8, 0.8% and household hold size of 3.9, 3.8 and 4.3 for Kiambu, Thika and Maragwa districts, respectively (Republic of Kenya, 2001). The projection results are shown in Tables 2, 3 and 4. The population and wood energy consumption increased from base year 2006 to projected year 2018. Similar projections were done for schools, factories, prisons, hospitals and restaurants where all these sectors expected woodfuel shortage in the future. The trend on woodfuel consumption, sustainable supply and resulting deficits without any interventions (business as usual scenario) for both supply and demand show an overall increase in consumption of woodfuel in all the districts. By considering energy balances which involves matching energy demand and supply, several options for intervention were developed both at demand and supply sides. The supply and demand intervention strategies developed in section 3.1, 3.2, 3.3, and 3.4 are aimed at bridging the wide gap between the sustainable supply and consumption, and are based on the base case

Table 4. Projections of population, supply of fuel wood and consumption by different sectors in Maragwa district.

Year	2006	2008	2010	2012	2014	2016	2018
Projected population	410,315	416,933	423,657	430,490	437,433	444,489	451,658
Number of individuals expected to use charcoal	16,412	16,677	16,946	17,219	17,497	17,779	18,066
Expected area (ha) under trees on-farm	93,477	93,974	94,478	94,992	95,513	96,043	96,581
Expected wood supply in tons from on-farm	134,607	135,322	136,049	136,788	137,539	138,301	139,077
Firewood consumption by households in tons	201,951	205,208	208,518.	211,881	215,298	218,771	222,299
Equivalence of wood for charcoal consumption in tons	803	816	830	843	857	870	884
Firewood consumption by tea factories in tons	7,616	9,019	10,212	12,334	14,548	16,564	18,230
Firewood consumption by schools	30456	32,897	35932	39738	43545	47352	51158
Woodfuel consumption by prisons in tons	360	409	473	534	589	645	699
Woodfuel consumption by hospitals in tons	56	73	82	93	101	109	120
Woodfuel consumption by restaurants in tons	87	98	111	122	130	138	147
Farmland supply of woodfuel on basis of consumption	129,222	129,909	130,607	131,316	132,037	132,769	133,514
Total woodfuel expected to be used in ton	241,330	248,523	256,160	265,547	275,070.	284,451	293,541
Sustainable supply of woodfuel	155,204	155,562	155,925	156,295	156,670	157,052	157,439
% deficit of woodfuel	-50.1	-51.4	-52.7	-54.2	-55.7	-57.0	-58.2

scenario. The base case scenario assumed all existing parameters influencing wood energy consumption remained unaltered. The analysis used 2006 as the base year for projection purpose as the data used was collected in that year. Energy demand dynamics such as response to scarcity and prices were not considered in making projections. The supply/demand of wood energy across all sub-sectors has been marked by an acute imbalance.

The simulations as provided in Tables 2, 3 and 4 showed for instance in 2008 total sustainable supply of woodfuel was 157,894, 208,291 and 155,562 tons for Kiambu, Thika and Maragwa, respectively. Similarly, on the same year, the expected consumption was 280,901, 387,826 and 248,523 tons resulting to a deficit of -43.8, -45.6 and -51.4% for Kiambu, Thika and Maragwa districts, respectively. The household sector was found to be consuming the highest amount of fuel wood followed by schools. The consumption is projected to increase further to 350,661, 439,726 and 293,541 tons of fuel wood by 2018 as compared to 174,574, 211,774 and 157,439 tons of the expected sustainable supply in the same year leading to a deficit of -50.2, -51.8 and -58.2% for Kiambu, Thika and Maragwa districts, respectively by 2018. The stated projections provide a clear indication of high deficit of fuel wood if all energy sectors continue using woodfuel without any interventions. If the “business as usual” remains as indicated in projected years, the implication is that various sectors would obtain their woodfuel from other sources outside the district or will over-harvest the available stock which will likely accelerate deforestation in the district leading to high insufficiency of fuel wood supply in future. This would not only impact on their economic activities but also environmental degradation and low land productivity as the trees are very valuable in stabilizing soil, reducing water runoff, providing habitats and carbon dioxide fixation. The woodfuel deficit may also lead to households using farm wastes which would further lead to soil degradation.

Results of demand and supply of wood energy provided an opportunity to identify possible gaps in wood energy which can be addressed through development of appropriate interventions to sustain the ever increasing demand of woodfuel. In development of efficient wood energy plan, analysis of demand and supply balance of woodfuel was used to create possible scenarios from base value (business as usual). The scenario strategies were aimed at mitigating the difference between sustainable supply and consumption. Therefore, in this study, four scenarios were identified and simulated to provide possible alternatives of developing an effective wood energy plan for each of the three districts. These were: allocation of 16, 19 and 21% of gazetted plantation forests in Kiambu, Thika and Maragwa districts, respectively for fuelwood production. The second strategy was establishment of woodlots on household farms depending on their farm sizes. Third strategy was to increase adoption of efficient technology devices used in households as well as other sectors of wood energy. Finally, the fourth strategy was to increase use of other alternative sources of energy like LPG, kerosene and electricity. It was envisaged that a combination of these strategies/scenarios involving supply and demand strategies would provide correct interventions in meeting the woodfuel gaps and to some extent provide a surplus if the plan was to be implemented.

The descriptions of these strategies/scenarios and their projected contributions in reducing the woodfuel deficits in each of the three districts are presented in the subsequent sections.

Intervention strategy based on increasing plantation for woodfuel production in Kiambu, Thika and Maragwa districts

The first strategy suggested allocation of 16, 19 and 21% of the gazetted plantation forests in Kiambu, Thika and Maragwa districts, respectively. The strategy envisioned sustainable supply of firewood through increase of plantations for woodfuel development at an equal proportionate rate which is equivalent to 299 ha for the next 10 years from 2009 (two years needed for necessary planning), will inject about 5,790, 2,985 and 5,510 tons of fuel wood annually in each of the three districts, respectively. This will imply that in 2018 about 47,689, 23,880 and 44,080 tons of fuel wood could have been produced for use by various sectors leaving a deficit of -36.6% (128,397.9 tons), -46.4% (204,072 tons) and -43.2% (126,669 tons) for Kiambu, Thika and Maragwa districts, respectively. This may be attained if fast growing and well managed plantation trees species like *Eucalyptus species*, *Acacia mearnsii*, *Acacia melanoxylon*, *Grevillea robusta* among others are planted. This strategy can be achieved through leasing out forest land to private investors like Kenya Tea Development Agency (KTDA) who have been expressing interest of leasing land for firewood supply to their factories.

In other parts of the world, planting of plantations for supply of energy has been done in some countries like India, Indonesia and South Korea in Asia and Rwanda, Sudan and Ethiopia in Africa (FAO, 2001). This is supply-side intervention which is aimed at enhancing supply of woodfuel from plantation forests.

Intervention strategy based on increasing the farmland area under tree production in Kiambu, Thika and Maragwa districts

Strategy two aims at establishing on-farm woodlots which depends on household land sizes. The strategy envisages that for those households with less than two acres of land, at least 0.1 acres will be under trees throughout the years providing an average sustainable supply of wood biomass of about 6,571, 20,586 and 17,064 tons per year for Kiambu, Thika and Maragwa districts, respectively. On the other hand, for those farmers who have 2 to 3 acres of land, it was anticipated that 0.2 to 0.3 ha will be under trees resulting to sustainable supply of 27,024, 21,235 and 17,640 tons annually for each of the three districts in that order. Equally for farmers that will be having at least 4 acres of land size, it was envisioned that at least 0.6 ha will be under trees resulting to sustainable supply of wood biomass at an average of 25,223, 59,765 and 21,517 tons per year for Kiambu, Thika and Maragwa, respectively. Overall, this strategy may be achieved if annual planting programme is keenly introduced to the mentioned categories of land sizes among the various households. This may drastically reduce woodfuel deficit from 128,397 (-36.6%) to 31,746 tons (-9.1%) in Kiambu district, 204,072 (-46.4%) to 81,730 tons (-18.6%) in Thika district and 131,051 (-52%) to 35,125 tons (-12%) in Maragwa district by 2018. Thus, the summation of all sustainable wood biomass less industrial wood biomass (20%) shows that this scenario of woodlots development/increase of tree planting on farm will reduce a lot of pressure on wood energy. The government intends to increase the forest cover to 10% by 2030 (Republic of Kenya, 2007) and there are efforts to enact law requiring land owners to plant trees on at least 10% of their land holdings. If enacted, the increase of land area under trees will be easily implemented. This intervention strategy is supply oriented as it aims to increase woodfuel supply from farmlands.

While promoting the tree planting on farms, the preference of tree species and obstacles to tree planting which were identified in this study should be considered. The introduced farm forestry technologies should reflect the needs of diverse farm units. This is due to the fact that different households have different needs and therefore introducing different strategies will allow farmers to choose an appropriate option instead of having to decide whether or not to adopt a single technique (Raintree, 1981). The farm forestry technique to be promoted for the household production should incorporate local knowledge on tree growing to maximize benefits. The tree planting in the farms would diversify the productivity of the farm making the ecosystem more resilient and sustainable therefore improving the livelihoods of the households. One of the obstacles to tree planting identified in this study is lack of seedlings. It is important that nurseries are responsive to the local requirements through producing seedlings that are in demand. To increase the on farm tree planting to meet the demand from various sectors, a strategy of outgrower tree schemes can be developed by tea factories and other service institutions. The schemes will involve contractual partnership between the partners (land owners and the tea factories/service institutions). The scheme can be arranged such that the growers are provided with technical advice on forestry practices which are essential to the success of outgrower schemes (Arnold, 1997) and the planting material.

Following a contractual agreement, a clear management plan is essential to ensure effective implementation aimed at achieving the target for longterm viability. This will ensure guaranteed market for the farmers and stable source of woodfuel by the tea factories and service institutions.

Intervention strategy based on increasing adoption of efficient utilization technologies in Kiambu, Thika and Maragwa districts

The third strategy (adoption of efficient technology devices) will contribute to reduction of woodfuel deficits by assuming that the households that were using three stone fire with an efficiency of 10% will slowly shift to more efficient technologies like improved firewood and charcoal stoves (like kuni mbili and Kenya Ceramic Jikos). These improved technologies are reported to have an efficiency of over 30% (Kammen, 1994), which means if adopted; there will be a substantial reduction in the demand of woodfuel. This scenario envisaged that by 2018, 80% of the households will have adopted the mentioned improved technologies at an increasing rate of 10% each year as from 2011. This implies that a significant amount of woodfuel will be saved hence reducing the consumption projected. This is a demand side intervention strategy as it aims at reducing consumption of woodfuel. Implementation of this strategy in combination with the earlier two strategies (strategy 3.1 and 3.2) will reduce consumption of woodfuel by at least 53,558, 70,427 and 51,974 tons leading to 21,811 (surplus of 7.3%), 70,427 (deficit of -2.6%) and 16,848 (surplus of 5.7%) in Kiambu, Thika and Maragwa, respectively, by 2018. This projected reduction of firewood consumption as a result of adoption of efficient technologies forms a realistic approach.

In addition to savings in woodfuel consumption, the improved stove has an added advantage of reducing smoke and health hazards like acute respiratory infection (Kammen, 1994). This strategy needs creation of awareness on indoor air pollution, particularly for women and children which can be achieved through organizing capacity building programmes like trainings aimed at developing stove production skills. A practical example of a successful case of building capacity in women groups in western Kenya has been reported where 11,000 improved Upesi stoves are made and sold per year (www.practicalaction.org/household_energy).

Intervention strategy based on promotion of increased use of alternative sources of energy in Kiambu, Thika and Maragwa districts

Finally, the demand oriented option which aims at reducing the amount of woodfuel consumed through use of alternative sources of energy was considered. If the rural and urban households slowly combine the use of LPG, kerosene stoves and electrical appliances, the use of woodfuel would be reduced thus minimizing the pressure on wood biomass for domestic use. This will reduce the consumption of wood biomass by 8, 16 and 11% in Kiambu, Thika and Maragwa districts, respectively, by 2018. If this scenario is applied in combination with the other stated three intervention strategies, a surplus of 22,903, 46,947 and 32,409 tons in the three districts respectively will be realized. This strategy is supported by the energy policy of 2004, which promotes the use of cleaner fuels like LPG through subsidies (MoE, 2004). As an example the government removed ‘value added tax’ on LPG in the Kenya Government budget of June 2004 to encourage the use of LPG. The government has also enforced harmonization of different types of LPG regulators which previously reduced competition in the market by restricting a customer to using one brand of LPG. While the use of alternative fuels sounds fairly realistic, it is likely to be faced with difficulties in price fluctuations of LPG, kerosene and electricity bills which have been on the increase in the recent times. Other barriers that hider their wider use include supply distribution, high initial cost of appliances among others.

The switch to conventional fuels like kerosene and LPG will occur as a wider change on social and economic conditions. This decentralized wood energy planning case study intends to provide bases for future wood energy planning in other Kenyan districts which should be integrated to district development committees (DDCs). District planning committees should be involved in monitoring wood energy plan implementation. This study was aimed at getting solutions to wood energy deficit through matching demand and supply in the three districts. The strategies suggested to meet the deficits were either demand-oriented (like the improving utilization technologies to reduce demand) or supply-oriented (through increasing the area under trees or substituting supply with alternative fuels). The combinations of both supply and demand oriented solutions were adopted to give a sustainable supply of the woodfuel. The production, distribution and consumption of wood energy are site specific as the demand and supply vary per region. The spatial variation among the districts should be taken into account for decentralized wood energy planning. With decentralized planning, the specific and unique characteristics of the demand and supply of energy per district are considered. For effective planning, there is need for wood energy database development which should have wood energy resource data, and supply/demand data that are useful in developing wood energy plans. There is also need for technical and financial support for development of capacity in wood energy data collection.

The capacity building can be done to the existing government structures in Kenya Forest Service (KFS), Ministry of Energy and Ministry of Agriculture through training in wood energy data collection.

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