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Kasese LEAP modelling technical report

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Key points

- Kasese municipality LEAP model data and methodology
- Kasese municipality energy characteristics for energy consuming sectors
- Potential energy savings for Kasese in future scenarios

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1. About this document

This document is a technical report describing the development of an energy systems model for the municipality of Kasese, Uganda. The methodology of data processing and modelling are described with supporting technical information. The model has been largely based on data collected in the field by Uganda Martyrs University (UMU) in collaboration with the Kasese Town Council (JMC) as a supporting partner (UMU, 2014) (UMU 2016) and supplemented by literature where required. The data collection and modelling exercises are both activities under the Supporting Sub-Saharan African Municipalities with Sustainable Energy Transitions (SAMSET) project The SAMSET project is a collaboration between the University College London (UCL) Energy Institute, the University of Sheffield, the Energy Research Centre, University of Cape Town, the Faculty of the Built Environment, Uganda Martyrs University, The Institute of Statistical, Social and Economic Research (ISSER), University of Ghana, the non-profit organisation, Sustainable Energy Africa (SEA) and the UK based consultancy Gamos. The project is co-funded by the United Kingdom government agencies the Department for International Development (DFID), the Engineering and Physical science research council (EPSRC) and the Department for Energy and Climate Change (DECC).

The SAMSET project also entailed the development of energy systems models for Jinja Municipality (also in Uganda), Awutu Senya East and Ga East in Ghana, and the cities of Cape Town and Polokwane in South Africa.

The model is intended for exploring the medium to long term evolution of energy demand in the municipality and the quantity of greenhouse gas (GHG) emissions arising from that. The results are however also highly relevant to the future costs and infrastructure challenges facing the municipality as a result of growing demand for energy. The report is organised by sector under which the data preparation and modelling methodology are discussed. A business as usual (BAU) scenario is contrasted with scenarios where energy is used more efficiently with a reduction in environmental impact and in most cases, cost.

2. General model data and methodology

Generally, the overall methodology employed was to create a bottom up model of Kasese which is calibrated to known energy sales values where possible.

The energy systems model for Kasese has been developed on the Stockholm Environment Institute's (SEI) Long range Energy Alternatives Planning System (LEAP) software platform. LEAP is a bottom-up accounting type simulation model but enables power system least cost optimization through a link to OseMosys and is widely used, particularly for national climate change strategy reporting to the IPCC (Bhattacharyya & Timilsina, 2010). The rationale for the selection of LEAP as a tool for the SAMSET project has been documented in another project output (Tait, et al., 2014) and the LEAP software tool itself is well documented by SEI (http://www.energycommunity.org).

The base year for this model is 2014, but much of the data used in the model is from 2015 and 2016 years. Work on the data and the model began in 2014 using data from small surveys of HHs and businesses in conjunction with the national census which at the time only had preliminary results available, but toward the end of 2015 and start of 2016 better data was collected and these were used with the 2014 base year. In this report, the data are presented with the years in which they apply to, but are used for the 2014 base year in the model. This is based on the assumption that between 2014 (population and household count from census data) and 2016 (when the HH, industry and commercial survey were conducted) the data does not vary significantly. Given the uncertainties involved and the variation that is inherent in this type of work, this was judged a reasonable compromise. Future work can include the rebasing of the model, particularly if any new survey data is collected.

Population

The population of Kasese was estimated to be 74000 people in 2010 by the Uganda Bureau of Statistics with an urbanisation rate of 4.2% per year. The provisional results of the Ugandan census for 2014 shows that the Kasese 'urban centre' population was 101 679 people with a growth rate of 5.3% (between 2002 and 2014).

Figure 1: Kasese town in Uganda, google maps

3. Kasese Fuel Sales

Presented in this section is the data obtained for fuel supplied to Kasese municipality which were used to calibrate the Kasese model.

3.1 Liquid fuels

The SAMSET municipal partners obtained data for liquid fuel sales volumes for the fuel stations in Kasese.

The volumes of liquid fuels data obtained is given in the table below:

Table 1: Monthly liquid fuel sales for Kasese in 2015.

Diesel	378 000	L
Petrol	550 800	L
LPG	858	kg
Kerosene	8 600	L

3.2 Electricity

The electricity sales for Kasese were obtained from UMEME national electricity distributor. The data obtained was for December 2014, January, June, and November of 2015. These are averaged monthly and estimated for a yearly[1] total for 2015 of 13 563 MWh:

[1] It should be noted that the energy consumption estimated here could be an over estimate since much of the industries – mainly millers would be seasonal.

Table 2 Electricity sales (kWh) by customer type for Kasese in 2015

	Average Monthly	Yearly est. for 2015
COMMERCIAL	435 600	5 227 197
DOMESTIC	465 953	5 591 439
INDUSTRIAL - LV	226 715	2 720 574
STREET LIGHTING	2 004	24 045
Total		**13 563 255**

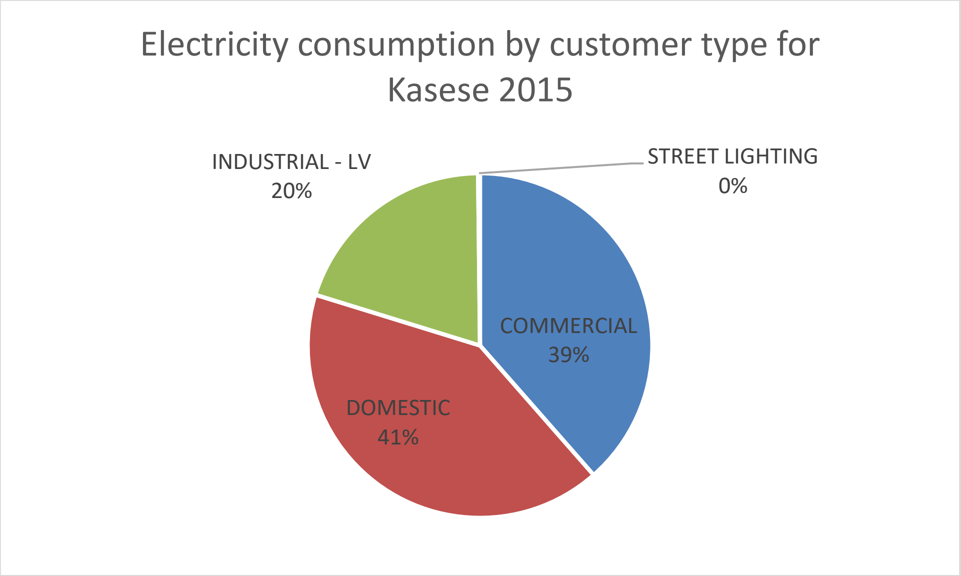


Figure 2 Electricity consumption by customer type for Kasese in 2015

Converting the liquid fuels and electricity to Giga Joules, the majority of energy consumed in the municipality is in liquid fuels:

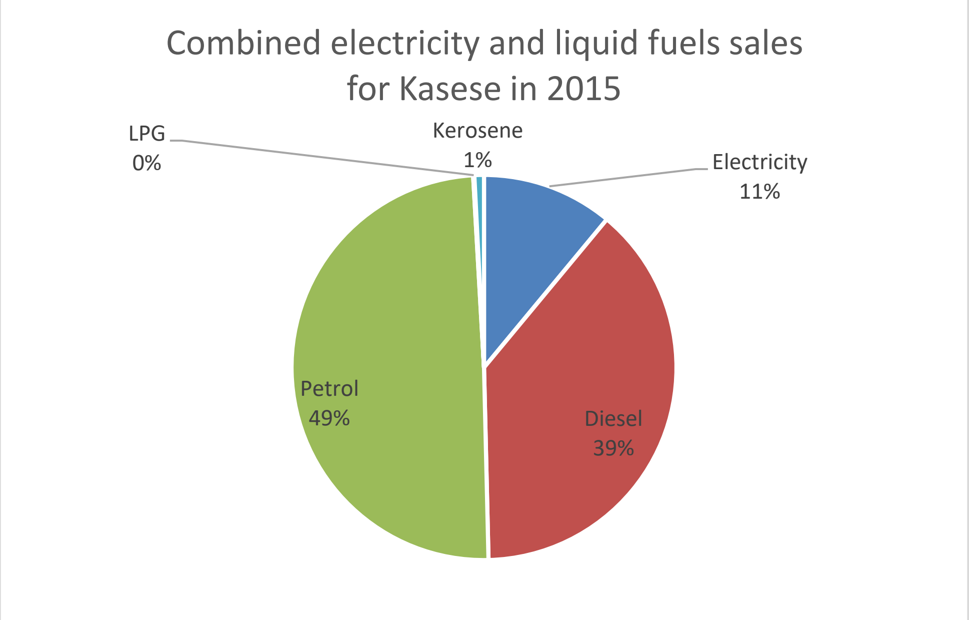


Figure 3 Share of energy consumption for 2015 from fuel sales data

4. Households

This section describes the data used and the methodology applied to it, for the household sector of Kasese.

4.1 Data

The census provisional results (UBOS, 2014) indicate that there are about 25 631 households (HH) in Kasese, with a HH density of 3.97 people per HH:

Table 3: Provisional census 2014 results for Kasese town

	Households		
	Number	**Avg. size**	**population**
Kasese MC Bulembia Division	2770	4.7	13235
Kasese MC Central Division	7434	4.1	31635
Kasese MC Nyamwanba Division	15427	3.6	56809
Total	**25631**	**3.97**	**101679**

A large household survey for Kasese was conducted – a total of 450 Households were surveyed and information about the number of household occupants, how much fuel is bought per month, and the number of different appliances for each enduse used in the household were recorded. Also recorded, was how often each appliance used on a weekly basis in number of hours.

The households were classified in the survey as being one of three HH income groupings – Low, Medium or High income. Households were classified by the surveyor by noting what type of appliances, utilities, and infrastructure the household had access to.

The HH survey count and groupings by income and electrification from the survey are given by the table below:

Table 4 Household survey count by grouping for Kasese in 2016

Income	Electrification*	HH survey count	Share
High	Electrified	17	3.8%
High	Non-Electrified	7	1.6%
Middle	Electrified	98	21.8%
Middle	Non-Electrified	65	14.4%
Low	Electrified	100	22.2%
Low	Non-Electrified	163	36.2%
Total		**450**	

*Any HH that uses any electrical device which is not battery operated. See methodology section.

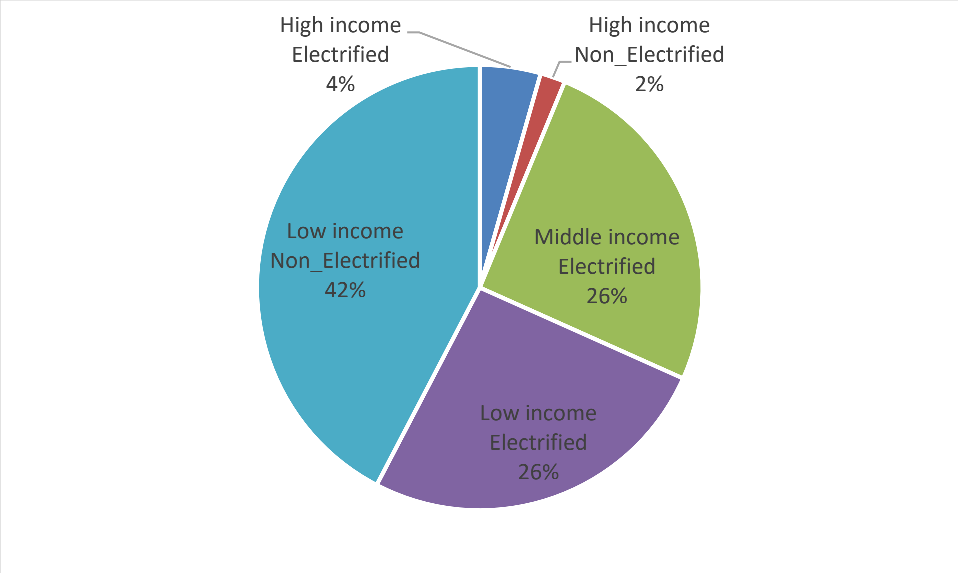


Figure 4 Kasese HH split by income and electrification based on Kasese HH survey in 2016

4.2 Methodology

Much of the survey data required cleaning – such as removing or replacing text were numbers should be, and making sense of large or very large numbers. Once the survey data was cleaned – into a large database, this database was fed into an R script[2] to process the data into useful summaries and groupings made easier by the R programming language. These summaries and groupings are then used as input into the LEAP model. Specifics about the R script are found in the Households section in the appendix.

Electrification

In this methodology we assume that any household that uses an electrical device that is not battery operated is electrified (such as electric light bulbs, TV's, DVD players or steroes etc.), this is done despite that the survey questionnaire included a question on whether the HH was connected to the grid because some HHs may not report any illegal connection they may have[3].

HH annual energy intensities and enduse shares

The R script grouped data by Household income group and by electrification, and summed the total number of appliances for each technology for each enduse listed in the survey (such as CFT bulbs or TV's etc.). Using this count of devices, the share of HHs that have each type of enduse (lighting, cooking etc.) was produced and is given in the table below:

Table 5 HH enduse percentage shares from survey data for Kasese 2016

		Appliances	Cooking	Cooling	Lighting	Refrigeration	Water Heating
High income	Electrified	100	100	6	100	53	
	Non-Electrified	100	100		100		
Middle income	Electrified	96	100	11	100	22	4
	Non-Electrified	74	100		82		
Low income	Electrified	82	100	4	100	12	

[2] R programming language for statistical analysis

[3] In developing countries, poorer communities are known to connect power cables illegally to neighbours or to distribution networks.

	Non-Electrified	75	100		92	1	

To obtain an energy intensity for each technology (CFT bulbs, fridges etc.) for each enduse for each HH income group and electrification, the R script calculated the total energy consumed by each device by multiplying the rating of the device (in Watts or L per hour etc.) by the average number of hours per week for this HH group (calculated from the survey data). For specifics about this process see the R script details in the Households section in the Appendix.

Also needed is the number (or share) of households that utilise each technology for each enduse. The R script was used to compute this as well – for example this would give the share of Low income non electrified HHs that use candles for lighting.

Calibration

In this methodology we calibrate the household sector to electricity sales, and do not calibrate the other fuels due to reliability of the data for the other fuels.

When calculating the total electricity consumed using the HH enduse shares and HH groupings (Table 4 and Table 5) and using the energy intensities calculated for each enduse for Kasese gives a consumption of electricity that is 40% more than reported sales for domestic (household) use. Thus to calibrate the household sector some assumptions on the usage of electrical devices are made:

Assumptions to calibrate electricity:

- Only half of the number of light bulbs in the household are used at any one time.
- And general appliances are used half of all weeks in the year instead of every week of the year.

With these assumptions the new consumption of electricity for HH is within 6.6% of the sales to Domestic users in Kasese.

The output of intensities by technology and their associated shares are given in Table 52 in the appendix.

Observation on 'efficient' stoves

The survey included a question on whether the HH used an efficient or regular stove to cook on. However, when computing the average consumption per household for an 'efficient' and 'regular' stove type it was discovered that the 'efficient' stoves often use more (sometimes substantially more) fuel than the regular stove counter parts. These results are presented in the tables below.

Table 6 HH survey wood consumption by HH income group and stove type

Income group	Wood Stove type	Wood kg per person per month avg.	Count from Survey
H-Electrified	Regular	3.64	17
H-Non-Electrified	Regular	24.34	7
L-Electrified	Efficient	47.22	6
L-Electrified	Regular	8.23	94
L-Non-Electrified	Efficient	22.59	53
L-Non-Electrified	Regular	18.02	109
M-Electrified	Efficient	19.75	8
M-Electrified	Regular	9.06	90
M-Non-Electrified	Efficient	25.42	11
M-Non-Electrified	Regular	27.94	54

Table 7: HH survey charcoal consumption by HH group and stove type

Income group	Charcoal Stove type	Charcoal kg per person per month avg.	Count from Survey
H-Electrified	Efficient	12.89	11
H-Electrified	Regular	13.29	5
H-Non-Electrified	Efficient	12.02	3
L-Electrified	Efficient	15.19	40
L-Electrified	Regular	19.71	42
L-Non-Electrified	Efficient	23.98	25
L-Non-Electrified	Regular	9.19	65
M-Electrified	Efficient	12.84	33
M-Electrified	Regular	11.8	48
M-Non-Electrified	Efficient	12.33	17
M-Non-Electrified	Regular	9.58	20
M-Non-Electrified	Regular	5.04	38

5. Industry

Historically, Kasese's industry was largely centred on the copper and cobalt mines located in the nearby Kilembe hills. These mines had shut down in the 1980's, but are recently being refurbished to resume production. Other industries in Kasese involve Cotton production and grain processing.

5.1 Data

A survey of several industrial businesses and factories was conducted by the SAMSET team in partnership with the local municipal officials. The survey was conducted at 23 industrial businesses/factories:

- 2 X factories
- 3 X Ginners (Cotton)
- 1 X Construction company
- 6 X Millers (Cassava, maize etc.)
- 4 X Hullers (Coffee, ground nuts etc.)
- 3 X Bakers
- 4 X Small metal fabricator workshops

It is believed that this survey covered the majority of industrial activity in Kasese, with the exception that there would most likely be a vast number more of fabricators and workshops. This survey excluded the mines in Kilembe since they are not operating yet (more on this in the BAU scenario section – see section 9.5.2).

The survey at these industries entailed obtaining information about the number of appliances each site used – e.g. the number of light fittings and what rating they were (and what type of light), whether they used any cooling systems (and estimated ratings for these), what machinery is used, their number of motors (machinery) and their estimated power rating. Also included in the survey was an estimate given by the owners about how much fuel is bought per month (although not every surveyed entity provided this detail, nor did the numbers appear to be very reliable), and other useful bits of information such as how often the industry was running each year or how much they produced.

This raw data is too large to be presented here. Instead the results of the steps of applying the methodology are given in the methodology section next.

5.2 Methodology

The survey data was organised, cleaned and formatted to be processed into a dataset to create the industry sector model for Kasese.

The survey data provided an appliance/device count for each of the industries surveyed. And in some instances provided how often they are used. The appliances/devices include lighting, cooling and general equipment/appliances.

A bottom up model for industry was created by using the appliance/device count multiplied by the estimated annual usage for each industry group. This was done for each enduse for each industry, however, from the survey it showed that Hullers, Ginners and Millers all made extensive use of motors which were recorded in the survey. These motors required a separate analysis (this will be covered in the following sections).

The methodology employed for Industry is summarised as follows:

- Clean and format the survey data,
- Estimate annual working days for each industry using data and assumptions
- Estimate motors/machinery consumption for Hullers, Millers, and Ginners
- Estimate annual energy consumption by enduse and technology using annual activity estimates, and device ratings (where provided or assumed).

The estimated annual working days for each industry is given below using data provided:

Table 8: Estimated annual industry working days for Kasese

	Data	**Assumed**	
Industry	**Months/year**	**Days/week**	**Weeks/month**
Factory 1	11		
Factory 2	11	5	4
Ginnery1	4	5	4
Ginnery2	5	5	4
Ginnery3	5	5	4
Construction	11	5	4
Millers1	7	5	4
Millers2	5	5	4
Millers3	5	5	4
Millers4	10	5	4
Millers5	6	5	4
Millers6	7	5	4
Hullers1	4	5	4
Hullers2	4	5	4
Hullers3	4	5	4
Hullers4	4	5	4
Bakery1	12	5	4
Bakery2	12	5	4
Bakery3	12	5	4

NOTE: 'Fabricators' only provided annual estimates of energy consumption, thus are not included in this table.

Industry motors usage analysis

The Ginners, Millers and Hullers all provided a motors count along with their power rating. This is turned into annual energy consumption estimates by the analysis in the table below:

Table 9 Industries Motors analysis of survey data for Kasese industries

	Survey Data			Convert horse power to kW	Data or assumptions	Assumed using data (see Table 8)		Estimated total consumption
Industry	**Motor ID *****	**Horse Power**	**Number of motors *****	**kW**	**Hours/day**	**Days/week**	**Days/year**	**kWh/year**
Ginner 1	**1**	75	1	56	6*	6	96	31 968
	2	65	1	48	6*	6	96	27 706
	3	50	1	37	6*	6	96	21 312
	4	40	2	30	6*	6	96	34 099
	5	20	4	15	6*	6	96	34 099
	6	5	32	4	6*	6	96	68 198
Ginner 2	**1**	5	7	4	10*	6	120	31 080
	2	8	1	6	10*	6	120	6 660
	3	15	3	11	10*	6	120	39 960
	4	30	3	22	10*	6	120	79 920
	5	40	3	30	10*	6	120	106 560
	6	50	1	37	10*	6	120	44 400
	7	100	1	74	10*	6	120	88 800
Miller 1	**1**	50	1	37	5	6	168	31 080
	2	5	2	4	5	6	168	6 216
Miller 2	**1**	50	1	37	5	6	120	22 200
Miller 3	**1**	50	1	37	7	6	120	28 860
Miller 4	**1**	50	1	37	8	6	240	71 040
	2	50	1	37	8	6	240	71 040
Miller 5	**1**	400	1	296	8	6	144	340 992
Miller 6	**1**	25	1	19	8	6	168	24 864
Huller 1**	**1**							4 607
Huller 2**	**1**							622
Huller 3**	**1**							2 286
Huller 4	**1**	50	1	37	8*	6	96	28 416
	2	80	1	59	8*	6	192	90 931

*assumed daily operations.
**These hullers gave electricity bills (consumption) for the motors specifically.
*** Each factory indicated that there were groups of motors used for certain processes, but these were often the same type of motor with the same ratings.
NOTE: this analysis assumes the motors run at maximum capacity when operating, this may not be true if the motors have variable speed drives or do not operate at optimal performance, or do not operate all the time during work activities – although the information gathered the industries indicated that during peak season the motors run almost continuously.

Other enduse energy consumption estimates

The energy consumption for lighting, cooling and other enduses is calculated by multiplying the number of these devices by their rating (also given in the survey data) by the estimated working hours per year (from Table 8 and from data).

Table 53 in the Appendix gives the result of this enduse analysis from both the device/appliance count bottom up analysis and the motors analysis.

Summarising from Table 53 and converting the fuel from native units to Giga Joule, and grouping the industries into subsectors, most of the energy consumption from the survey was for diesel vehicles in the construction industry:

Table 10 Energy consumption (GJ) for the surveyed industries in Kasese

Industry	Lights	Cooking - Firewood	Cooling - Fans	Motors	Devices	Other Machinery	Other - Firewood	Diesel - Traction	Diesel - Genset
Construction		759			3			33173	
Cotton and Grains	193		2	5126	8		28	528	260
Food	3	3892		0		2			543
Manufacturing	37			295		9			6635

To compare the industries energy consumption, this fuel consumption is shown in the figure below to illustrate how the construction company dominates the energy consumption by the use of diesel.

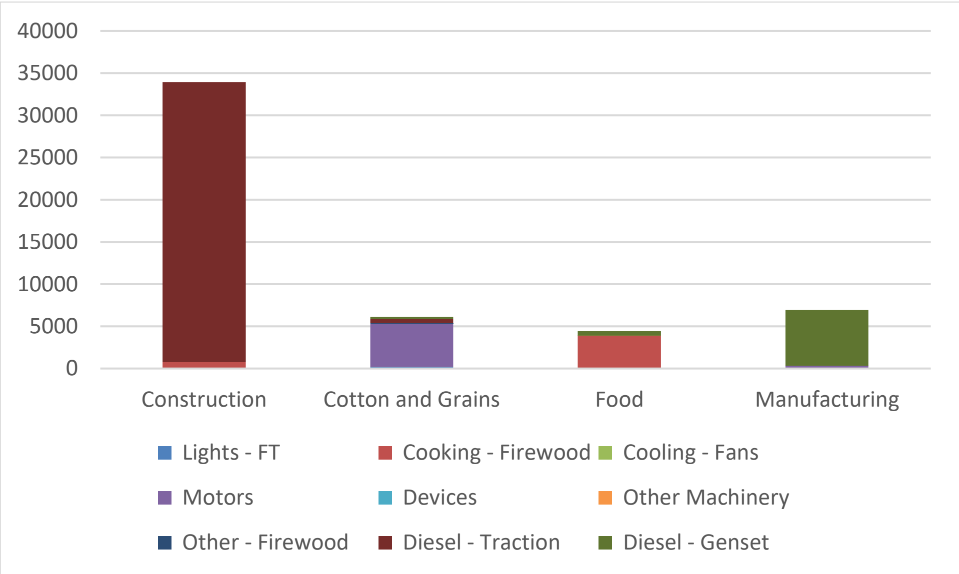


Figure 5 Industry subsector energy consumption (GJ) from survey data

The energy consumption characteristics varies for each of the subsectors, from some dominated by diesel consumption and others in electricity:

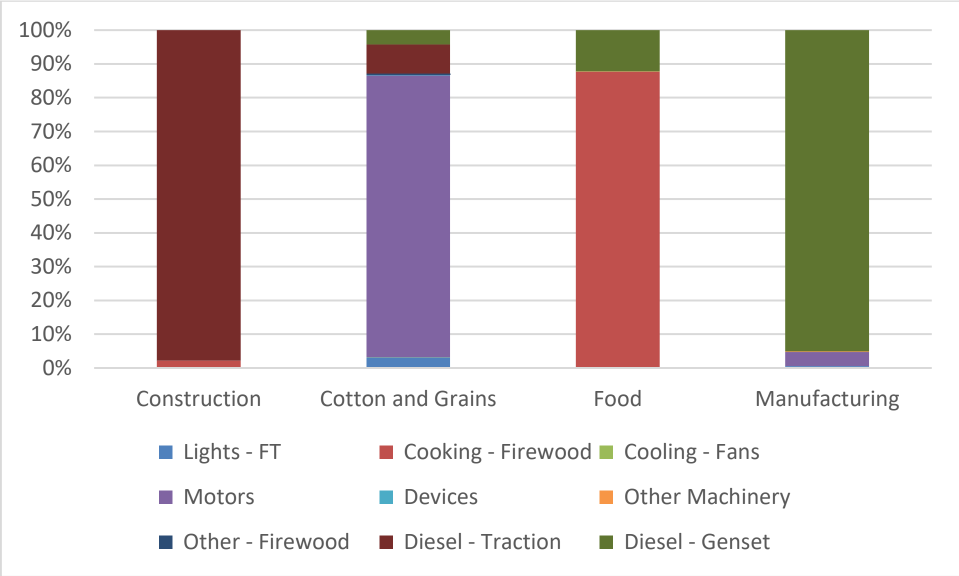


Figure 6 Industry energy consumption shares by fuel for each subsector based on the survey

Calibration and input to LEAP model

Calibration for industry is only done for electricity as this was the only data available for fuel supply to industry. The total electricity consumption for Industry was 2 720 574kWh (see Table 2).

The total electricity consumption from the survey, was 1 505 979kWh or about 60% of the sales. The remaining 40% of electricity sales is assumed to go to 'other industry'. Using the electricity consumed within the surveyed industries and a ratio to the amount of firewood used, the total firewood consumption for 'other industry' was estimated to be 176 tonnes (assuming a 50% elasticity).

The final industry energy consumption characteristics for Kasese is given in the table below:

Table 11: Kasese Industry energy consumption by enduse and technology

	Lighting			Cooking	Cooling		Machinery		Offic
	FL	MV	Kerosene	Firewood	Fan	AC	Motors	Other	Devi
	kWh	kWh	L	tonnes	kWh	kWh	kWh	kWh	kWh
Manufacturing	10210	0	0	0	0	0	81976	2525	0
Cotton and Grains	53671	9892	0	0	602	0	1424003	0	2320
Construction	0	0	0	55	0	0	0	0	800
Food	864	0	0	282	77	0	0	679	0

NOTE: Diesel for traction use is not included here, but under freight transport.

This is used as input into the LEAP model without the use of an industry model driver, along with the calibration sector of 'other sector':

<u>Other Industry consumption:</u>
Electricity – 1 132 956 kWh
Firewood – 176 tonnes.

6. Transportation

Modelling the energy demand from the transport sector on a local (city wide) scale needs to account for activity that is entirely within the defined boundary and activity that crosses the boundary or only enters the boundary to refuel before proceeding on a journey that has both an origin and ultimate destination outside the boundary. In this study we refer to the latter as "corridor" travel. In the case of small cities, the corridor component can be the largest demand for locally supplied fuel, particularly when the city is near or connected via a main route to a larger city or economic hub.

This section describes the data used and methodology applied to the transport sector of the model for Kasese. The data made gathered by Uganda Martyrs University from stakeholder engagement with municipal officials, a truck counting exercise at the fuelling stations and a transport section of the Household survey. A significant corridor component is included in the model in order to balance local fuel sales but no information was collected on corridor activity and this is simply assumed to be responsible for all fuel not consumed by the local fleet.

6.1 Data

Vehicle count and fuel sales were obtained by stakeholder engagement and municipal partners. Passenger transport activity was obtained through the HH survey that was conducted for the household sector – the HH survey included questions about each person's mode of transport and how long this normally takes for them.

A partial estimate of the numbers of vehicles operating in Kasese was obtained from stakeholder engagement. This would imply a total motorisation, including two wheelers, of only 15 vehicles/1000 persons. This is a very low figure and as will be discussed below, this did not agree well with the household survey results except in the case of boda-bodas

Table 12: Vehicle count data from stakeholder engagement for Kasese in 2015

Vehicle type	Vehicle count
Omnibus	123
Saloon Cars	176
Buses	17
Pickups	20
Lorries	30
Taxis	88
Boda-boda	1080

In this study, it was assumed that all the fuel sales subtracted from municipal truck usage and industry[4] usage are consumed within the transport sector:

Table 13 Kasese Fuel sales and assignment of fuel to Transport sector

	Diesel	Petrol
Supply/Sales	**4 536 000**	**6 609 600**
Consumption		
Municipal trucks	78 600	

[4] The construction industry within Kasese used about 800 000L of fuel, this is assumed to be captured within the transport freight subsector.

Industry	197 307	
Commerce		
Balance assign to Transport	**4 260 093**	**6 609 600**

Household (HH) survey transportation data

The HH survey captured data for commuting preferences and activity from individual householders in Kasese as follows:

- Preferred Transport Mode/Vehicle type used for typical daily commute to work / school / other
- Trip Destination Distance (km) for commute
- Typical Trip Travel time
- Number of trips/day
- Total daily travel time (including waiting)
- Number of trips/week

For the 450 households surveyed, a total of 2598 household members were indicated. Data fields were initiated for 852 and 844 of these were completed. A further 58 household members were included in a compound form, whereby the same travel behaviour was captured for multiple householders in a single line by, for example, indicating "2X' for two persons instead of "X" for one. Trip data for 900 householders or 35% of the residents in the households surveyed was therefore captured.

The data was processed as follows:

1. Data without an indicated mode preference was discarded
2. The number of trips per week and trip travel time were averaged for each mode after assessing and discarding outliers
3. Missing trips per week (12%) and missing trip time data (24%) were replaced with the average values per mode.
4. The number of trips per week per mode for the sample was summed and trip mode share calculated.
5. Total travel time per week was calculated from the product of trip time and trips per week. The average trip travel time per mode was calculated.
6. By assuming an average speed for each mode, the distance travelled per week for each respondent was estimated and summed to calculate the approximate passenger.km demand per mode for the survey sample.
7. The passenger.km mode share was calculated and validation checks done by calculating the average trips per day and distance per day per commuter.

The surveyed mode preference on a respondent and household basis and the weekly trips attributed to modes and the trip mode share are presented in Table 14 below.

Table 14: Passenger transport Trip Based mode data from HH survey for Kasese 2016

Mode	Count of Respondents Using Mode	Count of Weekly Trips	Mode Share (% of Trips)[1]	Count of Households Using Mode	θ_M - Share of Households Using Mode[2]
Walk	506	5200	57%	302	67%

Bicycle	20	168	2%	19	4%
Motorbike (personal/work)	24	360	4%	22	5%
Boda Boda	243	2457	27%	169	38%
Taxi (Special hire)	1	2	0.02%	1	0%
Minibus taxi	43	351	4%	34	8%
Bus	3	12	0%	3	1%
Company minibus/bus/truck	24	223	2%	15	3%
Own Car	38	332	4%	24	5%

1: Totals 100%
2: Does not Total 100% because householders within households indicated different mode preferences

The average trips per week and average trip time per mode which were combined with assumed average speeds to estimate the demand for passenger.km per mode are presented below in Table 15 and Figure 7.

Table 15: Passenger transport trip frequency, trip time and estimated passenger.km based mode data from HH survey for Kasese 2016

Mode	Average Trips/Week	Average Trip Time (min)	Assumed Mode Speed	pkm per week	pkm Mode Share
Walk	10	28	4	10120	23.4%
Bicycle	8	27	10	745	1.7%
Motorbike (personal/work)	15	19	35	4032	9.3%
Boda Boda (Motorcycle taxi)	10	13	35	19359	44.7%
Taxi (Special hire)	2	-	30	0	0.0%
Minibus taxi	8	25	30	4755	11.0%
Bus	4	77	25	401	0.9%
Company minibus/bus/truck	9	21	30	2202	5.1%
Own Car	9	9	30	1714	4.0%

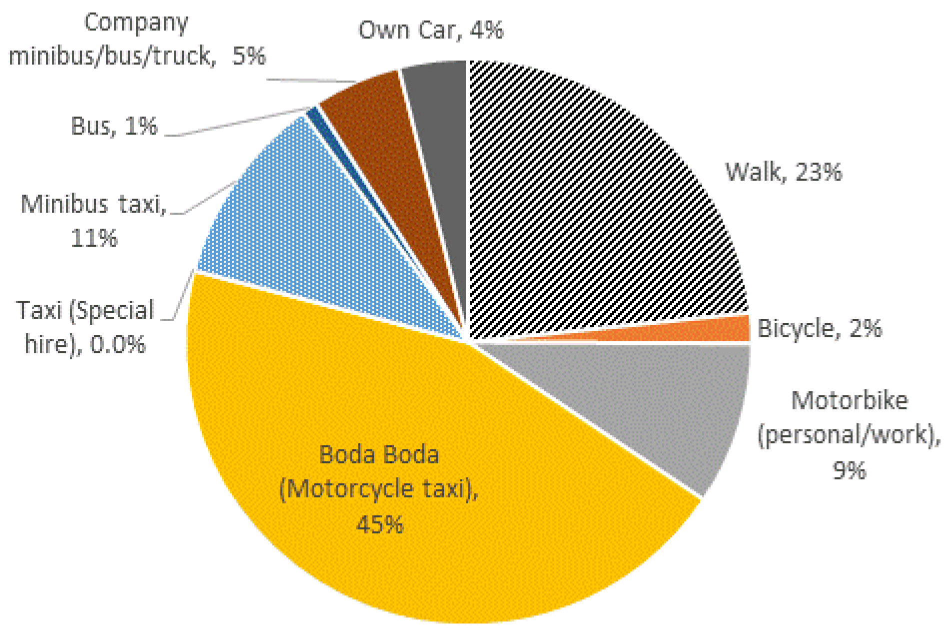


Figure 7: Surveyed passenger km based Mode Share for Kasese

As expected, walking dominates trip mode share (57%) followed by boda-bodas with significant minority shares for private cars and minibus taxis. On a passenger km basis walking accounts for a lower share because of its low speed and the dominance of boda-bodas is greater, accounting for 45% of all passenger km demand. Trip times are short on average suggesting low levels of congestion, except for buses where it seems longer distance trips have been captured.

As shown below in Table 16, disaggregating the trip based and passenger km based mode share by income group indicated significant differences in preference, with lower walking shares and higher private car use for higher income respondents evident as anticipated.

Table 16: Mode Data by Income Group and Commuter Survey Summary Data

Income Group	High		Medium		Low	
Mode	**Mode Share (pkm)**	**Mode Share (trips)**	**Mode Share (pkm)**	**Mode Share (trips)**	**Mode Share (pkm)**	**Mode Share (trips)**
Walk	5%	21%	18%	50%	31%	67%
Bicycle	0%	0%	1%	1%	2%	2%
Motorbike (personal/work)	5%	2%	13%	6%	7%	3%
Boda Boda (Motorcycle taxi)	31%	32%	48%	34%	44%	21%
Taxi (Special hire)	0%	0%	0%	0%	0%	0%
Minibus taxi	10%	7%	12%	5%	11%	3%
Bus	0%	0%	2%	0%	0%	0%
Company minibus/bus/truck	26%	12%	5%	2%	2%	1%
Own Car	23%	27%	2%	2%	3%	2%
Summary Data	**km**	**trips**	**km**	**trips**	**km**	**trips**
TOTAL/week (sample)	3523.3	604.7	18829.2	3645.5	20937.8	4844.8
TOTAL/person/day	8.6	1.5	8.9	1.7	7.3	1.7
Average Trip Length (km)	5.8		5.2		4.3	

Respondents	68	353	478

As was the case for the survey in Jinja, the preference for the boda-boda mode was consistently high across income groups. The higher income respondents tended to undertake longer trips (arises because we assumed motorised trips are faster) and be supplied with company transport. In general, assuming 6 travel days a week, the respondents travelled around 7 - 9 km a day over approximately 2 trips.

While the transport system could be modelled on a purely passenger km basis, it is useful to disaggregated this into the contribution of a specific count of vehicles for each mode. In this way a realistic check can be kept on the evolution of the vehicle fleet in scenarios of the future. The implied demand for vehicles from the bottom up survey data can be contrasted with the top down vehicle count data in Table 12 above on a household basis and on a trip basis as follows:

1. On a household basis:

$N_M = (\theta_M H_D V_H)$

Where:

N_M = Number of Vehicles used in Mode M
θ_M = Share of Households using Mode M in District (Survey)
H_D = No. of Households in District (18,936 for Jinja)
V_H = Assumed No. of vehicles servicing each household (close to 1 for private vehicles, much less than 1 for public vehicles). Also usefully expressed as $1/V_H$ the number of households preferring a mode that are serviced per vehicle.

2. On a trip basis:

$N_M = (P_D/ p_S) \times T_{S,M} / (O_{V,M} \times R_{T,V})$

Where:

N_M = Number of Vehicles used in Mode M
p_S = survey sample population (900 for Kasese)
P_D = Population of District (101,679 for Kasese)
$T_{S,M}$ = Trip demand per day for mode M in survey sample
$O_{V,M}$ = vehicle occupancy for mode M
$R_{T,V}$ = assumed number of trips per vehicle per day

These two approaches were used to estimate the numbers of vehicles required to supply the mode preference and trip demand observed in the survey, calibrating to the top down values in Table 12 where relevant and possible as presented below:

Table 17 Vehicle count estimate from HH survey

Mode	Assumed No. of Households serviced per vehicle ($1/V_H$)	Share of Households Using Modes (θ_M)	Estimated Vehicle Count (N_M) - Method 1	Trips/Day (scaled up from survey to District)	Assumed Occupancy ($O_{V,M}$)	Assumed Trips/Vehicle/day ($R_{T,V}$)	Estimated Vehicle Count (N_M) - Method 2
Motorbike (personal/work)[3]	1.0	5%	1310	6781	1.5	3.5	1310
Boda Boda (Motorcycle taxi)[1,2]	8.9	38%	1080	46263	2.5	17.1	1080

Taxi (Special hire)	12.1	0%	5	38	2.0	4.0	5
Minibus taxi	35.2	8%	55	6601	12.0	10.0	55
Bus[2]	30.0	1%	6	235	20.0	2.0	6
Company minibus/bus/truck[2]	7.3	3%	117	4199	17.9	2.0	117
Own Car[3]	0.9	5%	1543	6244	2.0	2.0	1543

1: Occupancy includes driver because drivers appear to be captured in survey data. Often more than 1 passenger
2: Assumptions have been used to calibrate vehicle count to stakeholder estimates(company transport assumed to be all large buses – Bus + Company Bus = 123)
3: Used survey data to estimate vehicle counts for these modes. While these are estimates they are not rounded off to the nearest 100 because these figures were adopted into the model from earlier generations of the analysis. This analysis serves to confirm them as broadly reasonable which is sufficient given that the model is driven by passenger.km per mode which is based on the trip data from the survey, not numbers of cars.

The survey data supported the top down estimates of boda-bodas and (large) buses if we assume that most of the company transport uses this mode. The high occupancy of the boda-boda mode includes the driver because the survey data includes respondents with very high trip rates suggesting that boda-boda taxi drivers have been captured. The number of cars (176 saloon cars) suggested by stakeholders didn't accord with the mode share observed in the survey and this was recalculated. Far fewer taxis (special hire) are implied by the survey data than was indicated by the stakeholder number but far more minibus taxis although the distinction between 'bus' and 'taxi' in this data wasn't clear. Broad numbers of vehicles were therefore estimated for the local fleet which yield a motorisation including two-wheelers of 40 vehicles per 1000 people[5], a more reasonable figure for an urban centre in Uganda than that suggested by the stakeholder data. The model is driven by passenger km scaled up to district level from the survey data so moderate errors in the number of vehicles have a small effect on the outcome. The assumed growth of the vehicles types within the fleet however has a significant effect on the demand for passenger.km from different modes in the future projections.

Other sources of data

Table 18: Vehicle fuel type splits for Uganda (Mutenyo et. al., 2015)

	Engine size	Petrol	Diesel
Light duty	500_1200CC	96%	4%
	1201_1500CC	99%	1%
	1501_2000CC	98%	2%
	2001_2500CC	45%	55%
	2501_3000CC	23%	77%
	3001_3500CC	35%	65%
Heavy duty	3501_4000CC	8%	92%
	4001_5000CC	10%	90%
	>5000CC	1%	99%

[5] Motorisation in Uganda (urban and rural) in 2009 was 10.6 vehicles/1000 people (Gwilliam, 2011)

Table 19 Average fuel efficiency (L/100km) for Uganda by weight category and year (Mutenyo et. al., 2015)

	Diesel				Petrol			
Weight Category	2005	2008	2011	2014	2005	2008	2011	2014
Light Duty	11.6	11.7	11.9	13.4	10.6	10.8	11.1	11.8
Heavy Duty	24.2	24.9	27.7	29.3	22.2	21.4	21.5	22.9

6.2 Methodology

In this section, the passenger and freight transport model representations are described.

6.2.1 Passenger

The passenger transport model is constructed by using vehicle count data and the passenger demand by mode to estimate total vehicle-km (mileage) travelled by each vehicle type to obtain energy consumption characteristics by mode for passengers.

The fuel type split for these vehicles are adapted from Mutenyo et. al. (2015):

Table 20 Fuel split by transport mode for Kasese

Vehicle type	Diesel	Petrol
Omnibus	55%	45%
Saloon Cars	2%	98%
Buses	100%	0%
Pickups	55%	45%
Lorries	100%	0%
Taxis	55%	45%
individual	1%	99%
Boda boda	0%	100%
Motorbikes	0%	100%

The fuel economies for the various vehicle types in this model are given in the table below, and come from

Table 21 Fuel economies (L/100km) for vehicles in this model – adapted from (Mutenyo et. al., 2015) and SATIM (ERC, 2013)

Vehicle type	Diesel	Petrol
Omnibus	11.4	13.5
Saloon Cars	13.4	11.8
Buses	31.2	
Pickups	13.4	11.8
Lorries	29.3	
Taxis	11.4	13.5
individual	13.4	11.8
Boda		1.9
Motorbikes		1.9

Passenger occupancy of the vehicles is an assumption:

Table 22 Vehicle occupancy for passenger transport

Vehicle type	People per vehicle
Omnibus	4
Saloon Cars	1.5
Buses	20
Pickups	
Lorries	
Taxis	12
individual	1.5
Boda boda	2
Motorbikes	1

Using **Error! Reference source not found.** and the total passenger demand (of 218 248 341 pass-km) then the split of pass-km over each vehicle type is calculated:

Table 23 Pass-km demand by vehicle type

Vehicle type	% share	Pass-km
Omnibus	3.2%	6 983 947
Saloon Cars	0.0%	-
Buses	2.4%	5 237 960
Taxis	9.5%	20 817 444
individual	4.1%	9 049 148
Boda	40.5%	88 462 734
Motorbikes	8.4%	18 328 954
Walk	29.6%	64 574 974
Bicycle	2.2%	4 743 251

Using the assumed occupancy per vehicle, then the total mileages for each vehicle type is calculated:

Table 24 Pass-km and veh-km by vehicle type for Kasese

	All vehicles		Per vehicle	
Vehicle type	pkm/year	veh-km/year	pkm/year	veh-km/year (mileage)
Omnibus	6 983 947	1 745 987	56 780	14 195
Saloon Cars	-	-	-	-
Buses	5 237 960	261 898	308 115	15 406
Taxis	20 817 444	1 734 787	236 561	19 713
individual	9 049 148	6 032 765	6 619	4 413
Boda	88 462 734	44 231 367	81 909	40 955
Motorbikes	18 328 954	18 328 954	13 991	13 991

Using the fuel economies (Table 21) the fuel consumption is calculated for Kasese by vehicle type:

Table 25 Estimated fuel consumption for passenger transport for Kasese

	Total Litres/year	
Vehicle type	**Diesel**	**Petrol**
Omnibus	108 897	106 752
Saloon Cars	-	-
Buses	81 712	-
Taxis	108 198	106 067
individual	7 388	705 361
Boda	-	840 396
Motorbikes	-	348 250
Total	**306 195**	**2 106 825**

6.2.2 Freight

The SAMSET team undertook a truck counting exercise at two main petrol stations in Kasese and observed the number of trucks passing through the stations in 2015. This survey data is presented below:

Table 26 Truck counting survey in Kasese in 2015 – vehicles observed per day

	Pickups/ Double cabins	Small trucks (Dianas, Toyota elf, Canter)	Medium sized Trucks (Forward, Couler)	Big trucks (Hima cement trucks etc.)	Trailers/buses
Station 1 average	61	78	41	32	25
Station 2 average	56	19	13	22	15
Combined	117	97	54	54	40

NOTE: We assume here that a typical vehicle would not fuel more than once a day nor would be double counted between the two stations in the same day.

We use the total number of vehicles observed as an approximate to the population of freight vehicles.

Table 27: Freight vehicle count and assigned vehicle class for Kasese

Vehicle type	**Vehicle count**	**Vehicle class**
Pickups/ Double cabins	117	Pickups
Small trucks (Dianas, Toyota elf, Canter)	97	LCV
Medium sized Trucks (Forward, Couler)	54	MCV
Big trucks (Hima cement trucks etc.)	54	HCV

Using data from Mutenya et. al. (2015) the diesel and petrol split for these freight vehicles assumed is given below:

Table 28 Diesel Petrol fuel split for freight vehicles assumed in Kasese transport model

	Diesel	Petrol	Adapted from Mutenya (2015) Average size of engine
Pickups	66%	34%	2000 to 3000CC
LCV	65%	35%	2000 to 3500CC
MCV	65%	35%	3000 to 3500CC
HCV	100%	0%	

In this methodology we use an assumed vehicle-km travelled and load for each vehicle class to estimate the total freight demand. These are given below:

Table 29 Assumed freight vehicle mileages and loads for Kasese

	Vehicle activity	Avg. load
	km/year	tonne
Pickups	30000	0.5
LCV	30000	0.5
MCV	75000*	5
HCV	75000*	10

* Based on an average for 'Truck Mileage' for Ethiopia, Camerooon and Kenya from Teravaninthorn (2008)

The fuel economy for freight vehicles is

Table 30: Fuel economies for freight vehicles (L/100km) used for freight model in Kasese

	Diesel	**petrol**	**Comment**
Pickups	13.4	11.8	Adapted from Mutenya (2015)
LCV	13.4	11.8	As above
MCV	33.3	28.1	From SATIM (ERC, 2013)
HCV	37		As above

Since Kasese is located near the border with Congo, and according to municipal officials, much of the transport is long distance/through fair, the following assumption is used to account for fuel sales:

- 50% of these vehicles freight transport is serviced by Kasese municipality

Using this assumption, the fuel economy, the assumed vehicle mielages and loads, and vehicle counts leads to an estimate for freight transport in the Kasese Municipality and the fuel consumption for these vehicles:

Table 31: Freight transport demand and fuel consumption for Kasese freight model

	Tonne-km		**Fuel consumption (L)**	
	Diesel	**petrol**	**Diesel**	**petrol**
Pickups	578 762	301 953	155 108	71 261
LCV	475 653	252 382	127 475	59 562

MCV	6 477 313	3 553 937	431 389	199 731
HCV	20 357 143		753 214	
Total	**27 888 871**	**4 108 272**	**1 467 187**	**330 554**

6.2.3 Into the model

The LEAP model is set up where passenger-km and tonne-km are the drivers for passenger and freight demand in transport. Using the fuel consumption for each vehicle category and the total demand serviced by each vehicle category, the energy intensities are calculated – and are used in the model inputs. These are summarised below:

Table 32 Passenger transport input into LEAP model

Vehicle	Public or Private	% share of Public or Private	Energy intensity MJ/pkm
Omnibus P	Public	2.6%	1.15
Omnibus D	Public	3.1%	1.02
Taxis P	Public	7.8%	0.38
Taxis D	Public	9.4%	0.34
Boda Boda	Public	72.8%	0.32
Bus	Public	4.3%	0.56
Individual Car P	Private	32.8%	2.69
Individual Car D	Private	0.3%	3.20
Motorbikes	Private	66.9%	0.65

Table 33 Freight transport input into LEAP model

Vehicle	% share of tkm	MJ/tkm
Pickups P	0.9%	8.1
LCV P	0.8%	8.1
MCV P	11.1%	1.9
Pickups D	1.8%	10.2
LCV D	1.5%	10.2
MCV D	20.2%	2.5
HCV	63.6%	1.4

Calibration

Summing up the fuel consumptions for the freight and passenger transport sections leaves most (about 60%) of the fuel unused in this model:

Table 34 Fuel consumption in the transport sector of LEAP model

	Diesel - L	Petrol - L
Passenger sector	306 195	2 106 825
Freight sector	1 467 187	330 554
Total	1 773 382	2 437 379
Sales	4 457 400	6 609 600
Balance	**-2 684 018**	**-4 172 221**

To calibrate the model to the fuel consumption, the remaining balance of fuel is simply allocated to 'Corridor' transport in the model without any assumptions as to what vehicles would be using this or whether this is passenger or freight.

7. Municipality

7.1 Data and methodology

Some data was obtained by municipal officials in partnership with the SAMSET team:

- The total electricity bill for the municipality was 1377kWh per month.
- The municipality has 15 vehicles which all run on diesel, consuming about 6550 L per month.

These energy consumption values for electricity and diesel are input to the model as absolute numbers.

8. Commercial

This section describes the commercial sector representation of Kasese, which is largely derived from survey conducted by the SAMSET partners in Uganda.

8.1 Data

A survey of commercial entities was carried out by the SAMSET team in Kasese, and surveyed:

- 4 X Primary schools
- 2 X secondary schools
- 1 X tertiary institute
- 4 X banks
- 2 X Micro finance institutes
- 6 X hotel
- 6 X guest houses
- 6 X guesthouse/bar
- 5 X restaurants
- 3 X health centres
- 1 X clinic
- 3 X radio stations
- 2 X NGO offices

The municipality provided information about the total number of schools in Kasese – a total of 24 Public and 40 private primary, 18 Secondary schools, and 12 Tertiary institutes. Thus the survey (of the schools) covered 6%, 11% and 8% of Primary, Secondary and Tertiary schools respectively.

This survey did not cover shops, informal commercial activities or general business offices which would also constitute a significant part of the commercial sector of Kasese. This is an area for improvement in understanding Kasese commercial sector.

The survey collected data on the total number of appliances owned and used, how often the surveyed business was active during the year, and occasionally, where available, monthly bills for energy such as electricity – but these were often not reliable. The methodology employed to determine the energy consumption of commercial entities in Kasese is described next, see Table 54 for a list of the appliances types that were counted in the survey.

8.2 Methodology

The methodology taken here, is to first calculate the total fuel consumption for each appliance for each type of commercial entity from the survey (except for cooking – this is given as fuel consumed monthly or daily – see below). This is outlined below:

- Calculate the sum of the number of appliances for each group from the data. For cooking enduse, the total fuel used as indicated in the data is used and summed for each entity.
- Make an assumption of number of hours a working/active day each group type would use each appliance type
- Make assumptions (in combination with actual data given) for the total yearly activity each group is active for (in total number of months)
- Using an average rating for each appliance (such as the wattage for a CFT bulb), calculate the total yearly consumption for each group for each appliance by multiplying total number of hours per year for each appliance by the rating.
- Use an assumption on sample survey size to estimate total energy consumption for these subsectors
- Calibrate commerce sector to Electricity sales

The assumptions and data for this methodology approach are presented below.

	Days/week	**Weeks/month**	**Months/Year**	**Adjustment factor***	**Days/year**
Schools	5	4	9		180
Tertiary	5	4	11		220
Banks	6	4	12		288
Banks small	6	4	12		288
Hotels*	7	4	12	46%	154
GuestHouses*	7	4	12	63%	213
Restuarants	7	4	12		336
Hospitals/clinics	7	4	12		336
Offices	7	4	12		336

* Based on Hotel and guesthouse occupancy numbers given.

The assumptions on appliance hourly usage per active/work day are too large a dataset to fit into this document, but as an example some of those used are presented below:

Table 35 Example extract of assumptions on appliance usage for each commercial entity

		Compact Flourescent 6 - 18W	Open wick light	Computer -desktop	Refrigerator	TV	Fan - ceiling mounted
Hours of use/day	Schools	8	4	5	6	4	6
	Tertiary	12	4	5	6	4	6
	Banks	16	4	6	6	4	6
	Banks small	16	4	6	6	4	6
	Hotels	16	4	3	6	4	6
	Guest Houses	16	4	3	6	4	6

	Restuarants	16	4	3	6	4	6
	Hospitals/clinics	16	4	6	6	4	6
	Offices	16	4	6	6	4	6

For energy ratings of each appliance used in this methodology see Table 54 in the appendix. These ratings are used in conjunction with the assumed yearly activity (a combination of hours per day and number of work days in a year – the tables above) to obtain an estimate for energy consumption by each appliance type for each commercial subsector. This result is given in Table 55.

To obtain an energy consumption estimate for the full commercial population of Kasese, a sample size estimate is used. For schools, this is known (see data section), but for the other subsectors of the commercial sector this is assumed:

Table 36 Assumed sample size of survey for commerce in Kasese

Subsector	**% sample size**	**Comment**
Schools	7%	Known
Tertiary	8%	Known
Banks	20%	Assumed
Banks Small	20%	Assumed
Hotels	50%	Assumed
Guest Houses	10%	Assumed
Restaurants	5%	Assumed
Hospitals/clinics	5%	Assumed
Offices	10%	Assumed

Thus the total energy consumption by fuel after scaling Table 55 using Table 36 and summing by fuel, the total fuel consumption[6] is presented below:

Table 37 Commercial sector fuel consumption by subsector for Kasese based on Survey

		Schools		Offices		Hospitality			Health	Offices	
		Schools	Tertiary	Banks	Banks Small	Hotels	Guest houses	Restaurants	Hospitals / clinics	Offices	**Total**
Elec	kWh	912367	65166	1026095	115111	575142	819150	375836	954699	612326	**5455893**
LPG	kg	0	0	120	30	6036	742	0	0	0	**6928**
Kerosene	L	39360	0	23040	0	0	2128	0	0	0	**64528**
Charcoal	tonnes	0	0	32	0	28	229	874	0	0	**1162**
Firewood	tonnes	12668	432	0	0	576	844	3132	0	0	**17652**

Calibration

To calibrate the model, the only known fuel consumed within this sector is electricity (see Fuel sales in section 3). However, the electricity consumption here after scaling up – 5 455 893kWh is within 5% of the total electricity sold to commercial entities in Kasese.

Thus no further calibration is done on this sector.

[6] By technology energy consumption detail is used in the model, the summation here is for illustrative purposes.

NOTE: Despite the survey not including informal commercial actives and shops, the electricity consumption comes pretty close to the sales. It is not unreasonable that informal activities may not be consuming a lot of electricity however, and with the uncertainty inherent with making assumptions about the sample size (as is done here) this leaves room for error in how much of the commercial sector is actually represented, which may be the case here.

Into the LEAP model

The energy consumption data (as in Table 55 except after scaling up) is input into the model as absolute numbers and not as an intensity.

9. Business as Usual scenario (BAU)

9.1 General

The base year used in this model is 2014, and set the end year as 2030 – ie. Running scenarios (this one and others) to 2030.

9.1.1 Population

The population of Kasese MC in 2002 was 53 907 in 2002 and 101 679 in 2014 (UBOS, 2014). This gives an annual growth rate of 5.43%. This annual growth rate is used as the growth rate for Kasese to 2030.

9.1.2 Economic activity - GDP

The economic activity is assumed to be proportional to the country's economic activity. This is done since there is no data currently on the economic activity of Kasese itself. The country's economy grew on average 5.98% between 2009 and 2013:

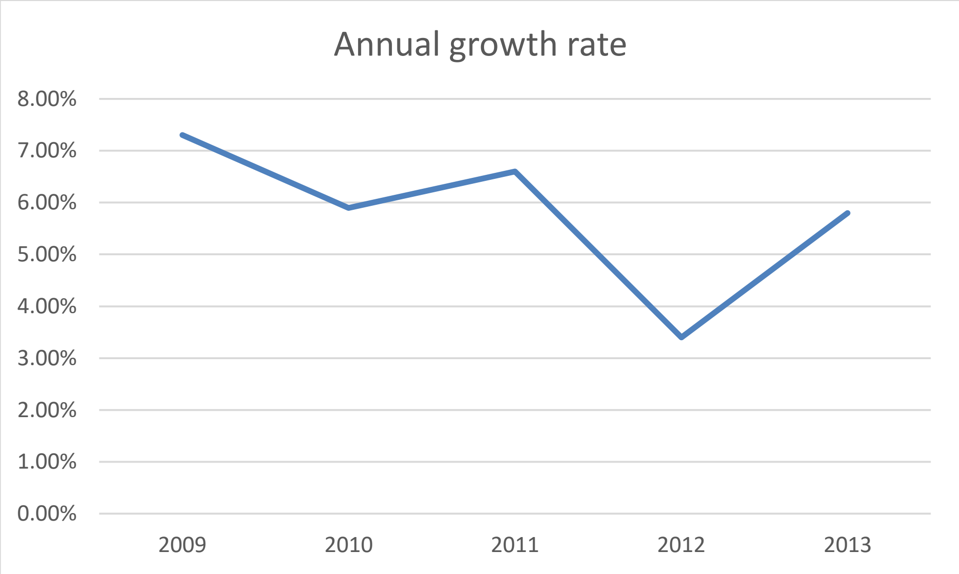


Figure 8 Annual average GDP growth rate for Uganda – source: Worldbank country indicators

In this model, we use unity as the reference base year value with a growth rate of 5.98% per year and an elasticity of 0.8 – inherently presuming that due to Kasese's distance from main economic centres like Kampala, the economic growth is a bit lower. It is assumed that this growth rate is constant to 2030.

9.2 Fuel costs

From the HH survey, questions on how much each month the HH bought of each fuel, and how much they spent on that fuel were included. The resulting analysis of fuel costs are given in the table below:

Table 38 Fuel costs from the HH survey for Kasese

	LPG	Kerosene	Charcoal	Firewood	Elec
UGX per	*kg*	*L*	*kg*	*kg*	*kWh*
Min	3 600	383	160	80	469
Mean	17 754	3 531	615	434	636
Median	8 000	2 797	529	250	640
Max	100 000	33 333	2 000	2 880	640

The mean and median as well as the maximum values are presented in order to show the variation that HHs were reporting their costs for fuels. Some HHs may not have correctly given their monthly figures, and thus skew the results. In which case the median value is used to avoid this.

Fuel retail prices were obtained from the Ugandan SAMSET team from various petrol stations[7] and are presented below in *UGX per L*:

Petrol – varies between 3000 and 3200. Assume 3100 in BAU

Diesel – varies between 2250 and 2500. Assume 2375 in BAU.

Kerosene – varies between 2150 and 2500. Using HH survey median of 2797in BAU.

9.3 Households

The number of households is assumed to be the formula: population/household size. The household size (in people per HH) is 3.97 in 2014, and is assumed to remain constant to 2030.

9.3.1 Electrification and income groups

Interviews with UMEME distribution engineers in Kasese indicated that new electricity connections were growing at about 10% per year. Although this may include commercial and industrial users, we assume this rate for the HH sector. This would result in an electrification rate of 85.5% by 2030.

For the income groups splits for HHs, we assume the income groups splits do not change between the base year and 2030. Also, it is assumed that the HH energy characteristics do not change from the Base year.

9.4 Commerce

In the BAU scenario, it is assumed there is no change in the energy characteristics of the commercial sector of Kasese.

The drivers for the commercial sector are the economic activity of Kasese, and the population. For schools, the growth in activity (and thus energy consumption of schools) is assumed to be proportional to population growth in Kasese.

For Offices, Hotels, guesthouses and restaurants, these are assumed to expand at the same pace as the economic growth of Kasese.

9.5 Industry

9.5.1 General industry

In Kasese, the industries such as Ginners, Hullers and Millers, as well as smaller industries like metal fabricators and food producers are assumed to grow at the same rate as Kasese's economic growth. The absolute energy consumption numbers are used are assumed to scale in proportion with the growth in economy in Kasese.

9.5.2 Mines

In Kasese there is an old copper mine in the Kilembe hills which are part of the Kasese municipality. These mines are in the process of being rehabilitated and restored by a Chinese owned firm (New Vision, 2014), but according to the SAMSET municipal partners, as of writing these mines had not restarted yet but were in the stage of testing equipment. The mines, are expected to process 1500 tonnes a day and eventually a target of 5000 tonnes (EastAfrican, 2015). This amount of production, if copper, however would make it the largest copper producer in the

[7] These fuel prices are for Jinja and are taken from the work done for the Jinja LEAP model.

world, thus it is assumed this is meant to be ore that is processed not copper production. Either this is the case, or presumably the source mistook annual production for daily production.

We assume that the production will start in 2020 at 1500 tonnes per day, scaling up to 5000 tonnes per day by 2022 and continuing this level of production to 2030.

The stakeholders also indicated that the consortium running the mines will upgrade the hydro plant - Mobuko I - from 5MW to 12MW and then 19MW around the year 2020. They indicated that the power will all be consumed for the mining operations (and presumably for processing as well).

From data obtained from the Electricity Regulatory Authority (ERA), the 5MW power plant has been operating at about 62% capacity factor between 2006 and 2010. Thus, 12MW operating at the same capacity factor of 62% would generate 66 060 MWh, and 19MW would generate 104595MWh per year.

We assume that the upgraded hydro plant is specified to meet the requirement of the mine at full operation of 5000tonnes per day. This would equate to 95.1kWh/tonne of processed ore.

In the LEAP model we use 95kWh/t as the energy intensity of the mines, and the following production schedule:

	2020	**2021**	**2022**
t/day	1500	3250	5000
t/year*	330 000	715 000	1 100 000
kWh/t	**95.1**	**95.1**	**95.1**

*assuming 11months a year and 20 working days a month.

After reaching 2020 production levels it is assumed this remains to 2030 and the energy intensity is assumed to remain the same as well.

9.6 Municipality

The energy consumption associated with the municipality is assumed to grow at the same rate as the population growth rate in this model.

9.7 Transport

9.7.1 Passenger

Simulation transport models have generally employed a simple tracking of GDP per capita to estimate future passenger-km demand, as this follows the general wealth of citizens which would lead to higher mobility demand. However, a simple GDP over population formulation would mean that a scenario where population growth outstrips economic growth would result in a decrease in transport demand. Therefore we derived an alternative formulation of the GDP per capita driver for passenger transport demand – one which keeps the GDP per capita (or general wealth of the populace) as the key component to transport demand but does not allow for a net drop in transport demand with increased population (something which would not be observed in reality). This is outlined below.

Private passenger demand is directly proportional to motorisation (vehicles per thousand people), and motorisation is proportional to GDP per capita[8] and can be written as some linear function of GDP per capita[9]:

---

[8] This relationship is typically represented using a Weibull or Gompertz relation which is a logisitic 'S-shaped curve'; however, without reliable registration data on vehicles, this Weibull relation cannot be tested or the parameters for a distribution empirically derived. With this in consideration, a linear relation is deemed sufficient until better information is available.

[9] In the methodology used in this work, GDP was set to unity as there was no data on economic activity for Kasese.

$$M \approx k\left(\frac{GDP}{Pop}\right)$$

where k is a constant to calibrate the base year values.

The number of privately owned vehicles is then:

$$prv\ vehs = M \times population \times 1000$$

Again this is calibrated to the base year value for Kasese. Then the population that is motorised (privately) is:

$$mpop = Occupancy \times prv\ vehs$$

where *occupancy* is the weighed average occupancy of the private vehicles.

And thus:

$$Private\ pass.km\ demand = Occupancy \times Avg\ Mileage \times cars$$

where *Avg Mileage* is the weighted average of private vehicles.

The population of non-private car motorisation is then:

$$NCAP = Kasese\ Population - mpop$$

Then the passenger-km demand for public transport is assumed to be linearly linked to the non-private car populace:

$$pass.km\ public\ = x \times NCAP$$

where *x* is used to calibrate to the base year values in the transport model.

With this formulation, therefore, the demand for private transport is driven by population and income growth while the demand for public transport is driven by the growth in the population without access to a private vehicle.

Using the data from the transport section, these passenger transport model numbers are presented below:

Table 39 Passenger transport model constants

Population		101 679	People
GDP		1	
Cars + motorbike		2 677	Number of vehicles
Motorisation		26.33	cars/1000 people
GDP/pop		0.00000983	
Base year pass-km		27 378 102	Veh-km for all Private vehicles
Vehicle-km		24 361 719	total for cars + bikes
Avg. Mileage:		11 695	km/year per vehicle
Avg. occupancy		1.12	People per vehicle
Public Pass-km		121 502 084	From Data
Thus:	**k =**	**2 677 016**	A derived constant
such that:	M = k*GDP/pop	26.33	Motorisation linked to GDP/POP
such that:	Prvt. vehicles = M*pop/1000	2 677	
Then NCAP	Population – (Cars X occupancy)	98 671	People without private cars – ie. Using public transport
Then:	**x =**	**1 231**	A derived constant

9.7.2 Freight

We assume that freight transportation in Kasese is proportional to the economic activity of Kasese with an elasticity of 0.8.

No changes to the energy characteristics of freight are assumed.

9.7.3 Other transport

This is the unaccounted fuel consumption for Kasese. Presumably this is mainly in corridor transportation – ie transportation coming and going through Kasese.

It is assumed that the trend of activity for this component of transport follows the economic activity of Kasese.

10. LEAP Results

This section presents the results from the LEAP model BAU scenario, and the description and results for the other scenarios in this work.

10.1 BAU Scenario

Below is the fuel consumption for Kasese going to 2030 in the BAU scenario:

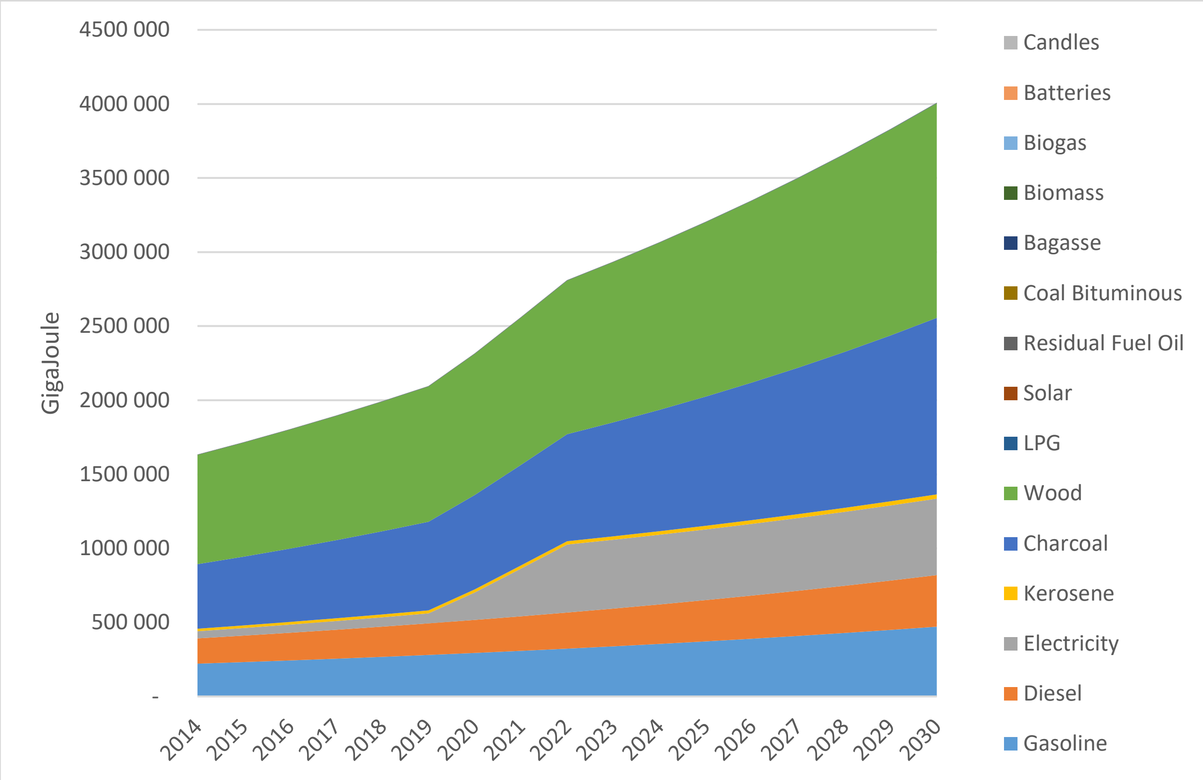
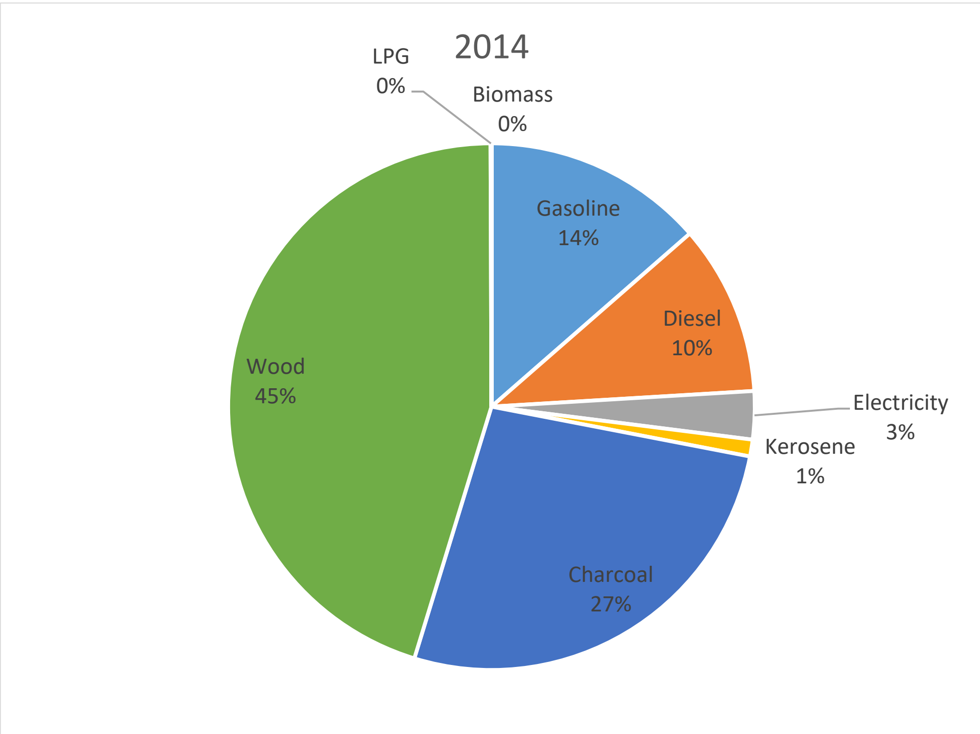
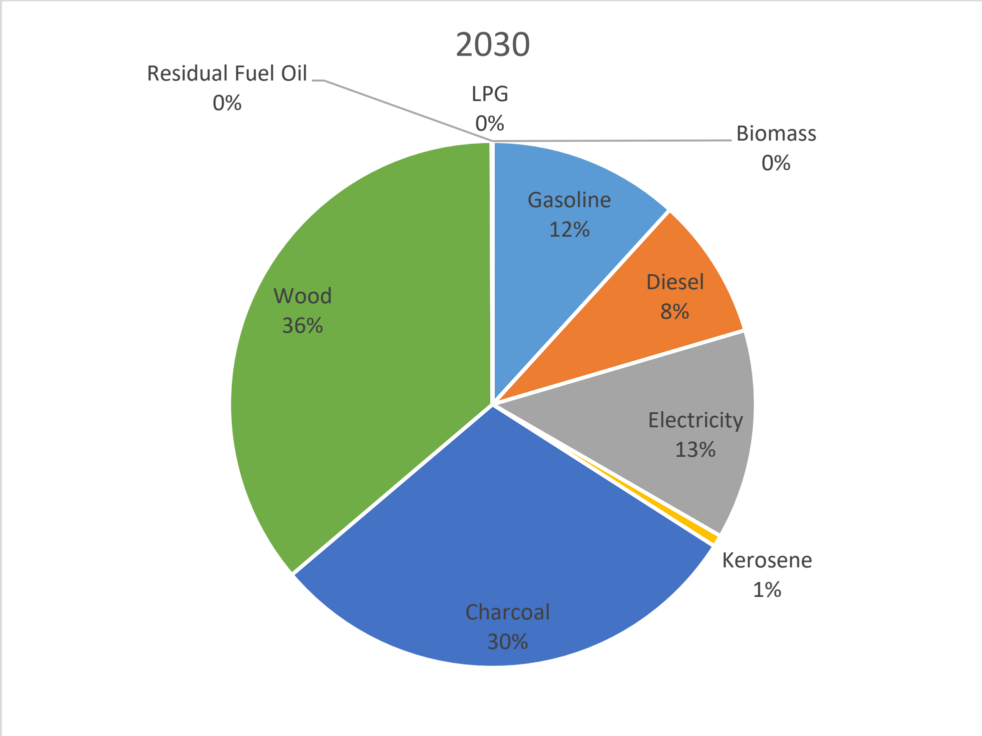


Figure 9 Energy consumption by fuel for Kasese in the BAU scenario

The majority of fuel consumed is in wood, charcoal and gasoline in 2014:



Wood consumption drops, while the electricity consumption goes up due to the mines opening up:



Most of the energy consumption in Households is in Households and transport:

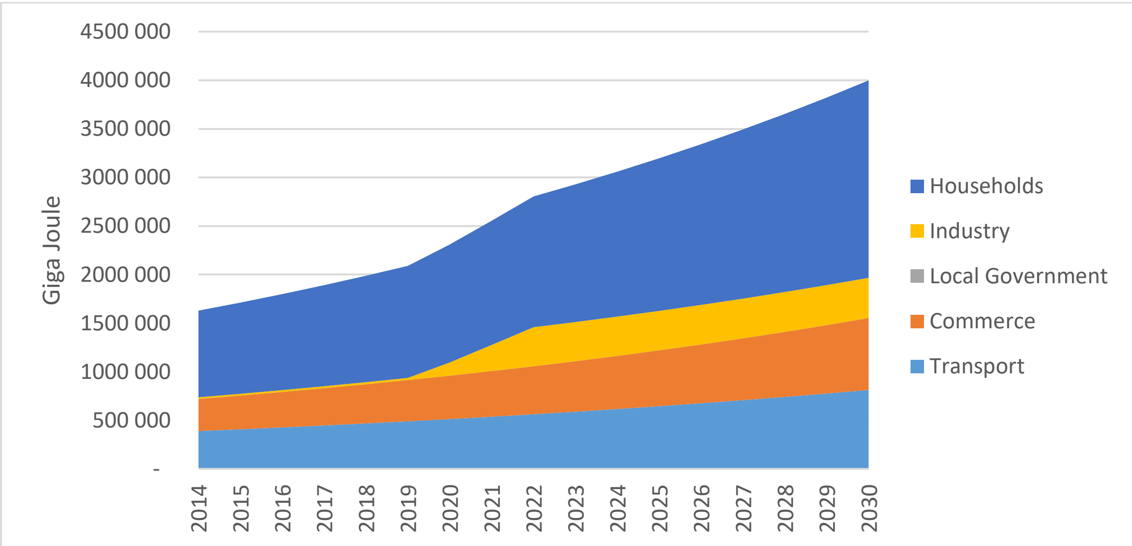


Figure 10 Energy consumption by sector for Kasese in the BAU scenario

In the base year, industry is a very small component to the overall picture, while households account for 55% of energy consumption:

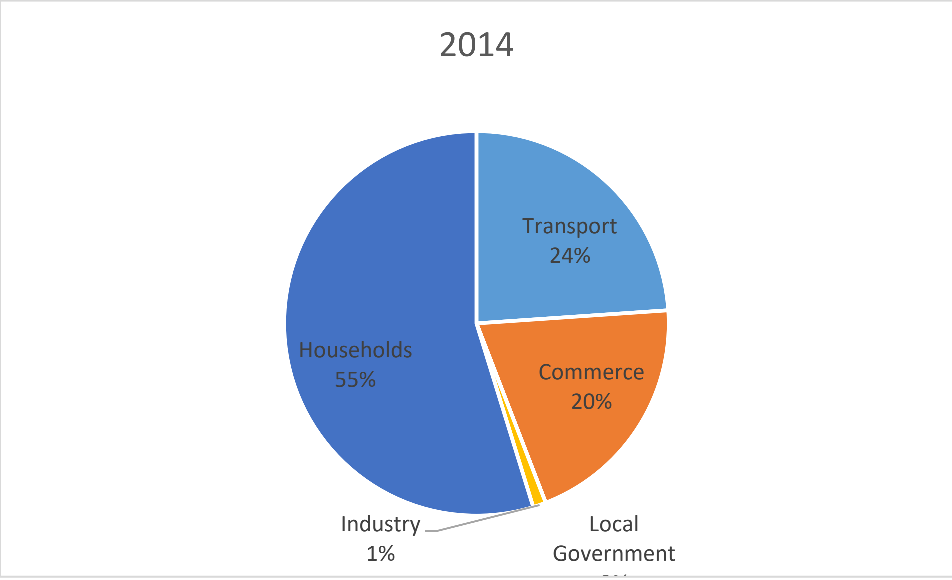


Figure 11: Share of energy consumption by sector for Kasese in 2014 for the BAU scenario

The assumed energy consumption from mining means that the mines account for about 10% overall in 2030, up from about 1% in 2014:

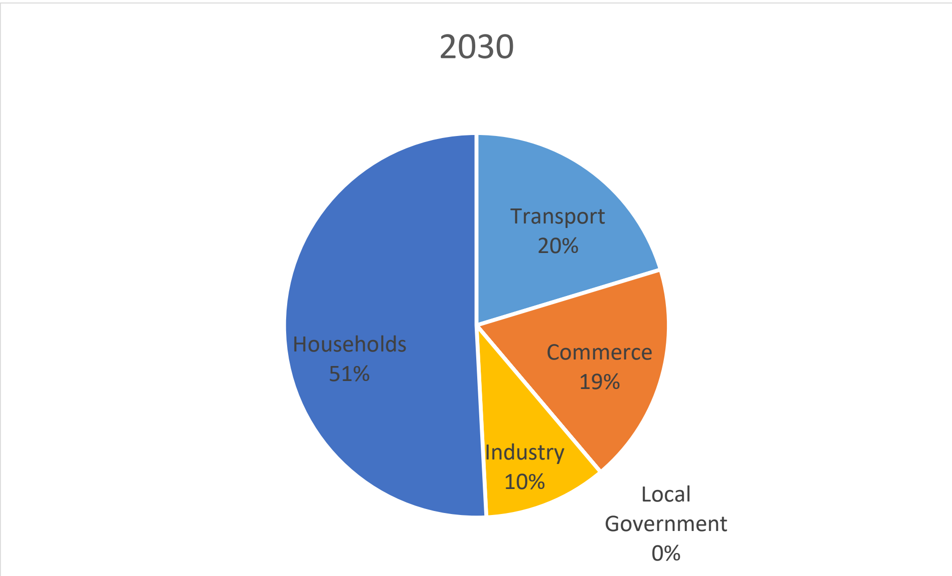


Figure 12 Energy consumption share by sector for Kasese in the BAU scenario for 2030

Industry energy consumption to 2030 is presented in the figure below, showing the sudden jump in energy consumption when the mines are assumed to begin operating, from the data available and the assumptions made, the mines completely dwarf the other industries in energy consumption (although this would come from the mini hydro plants owned and operated by the mining companies):

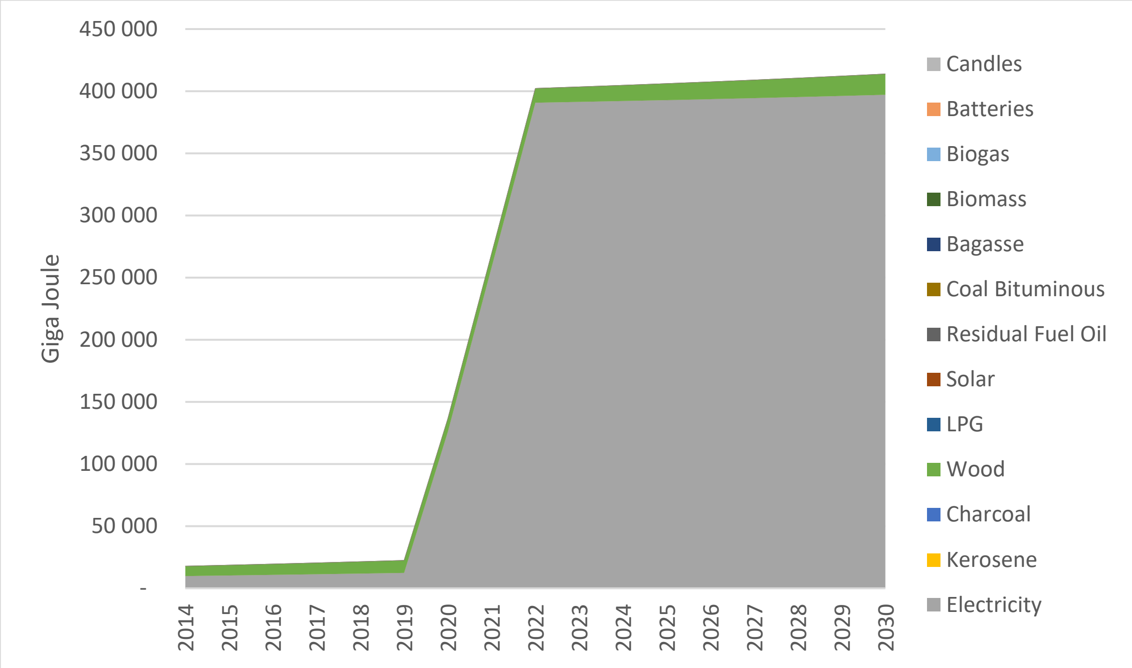


Figure 13: Industry energy consumption by fuel for Kasese in the BAU scenario

The industry sector excluding the mines shows electricity as the main energy source and wood as well (mainly from food production and ‘other industry’):

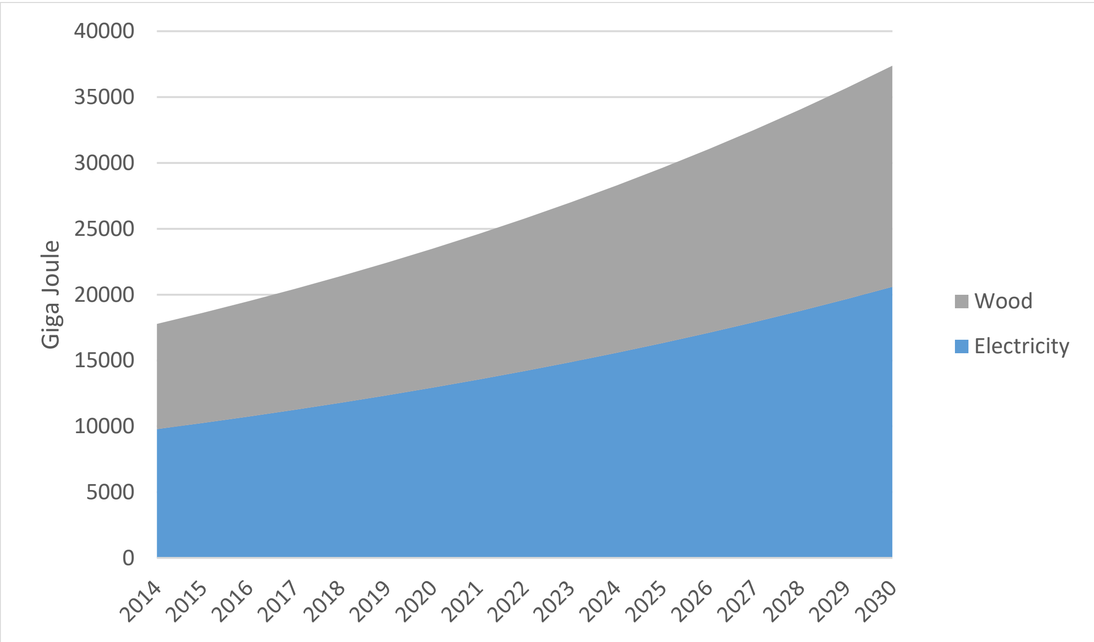


Figure 14 Energy consumption for industry without mines by fuel for Kasese

For households, the vast majority of fuel consumption is in charcoal and wood for cooking:

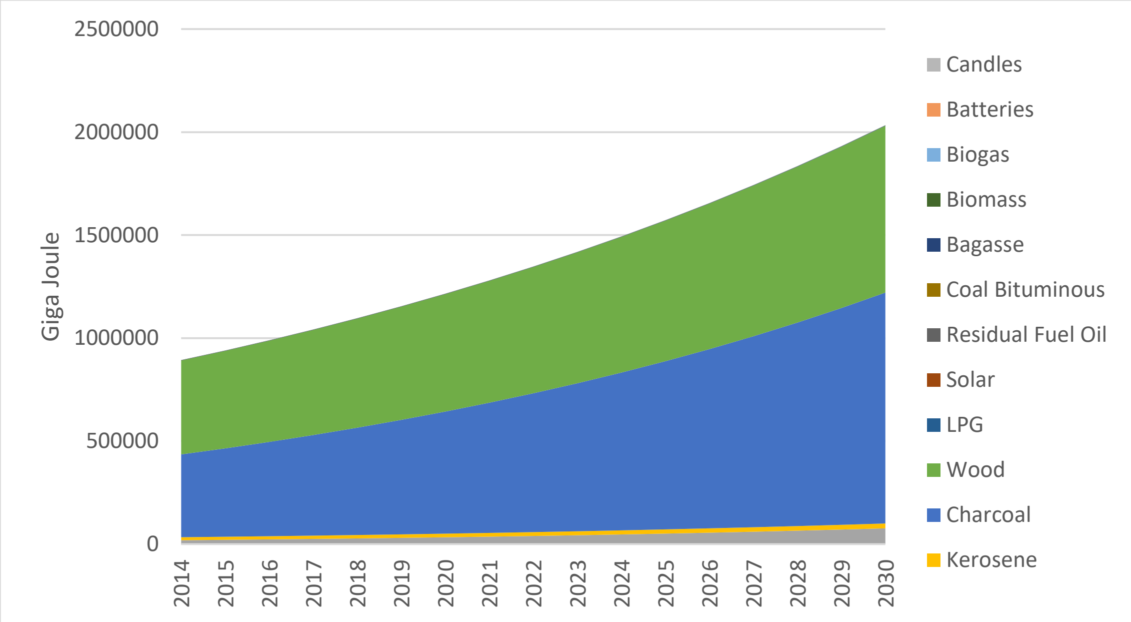
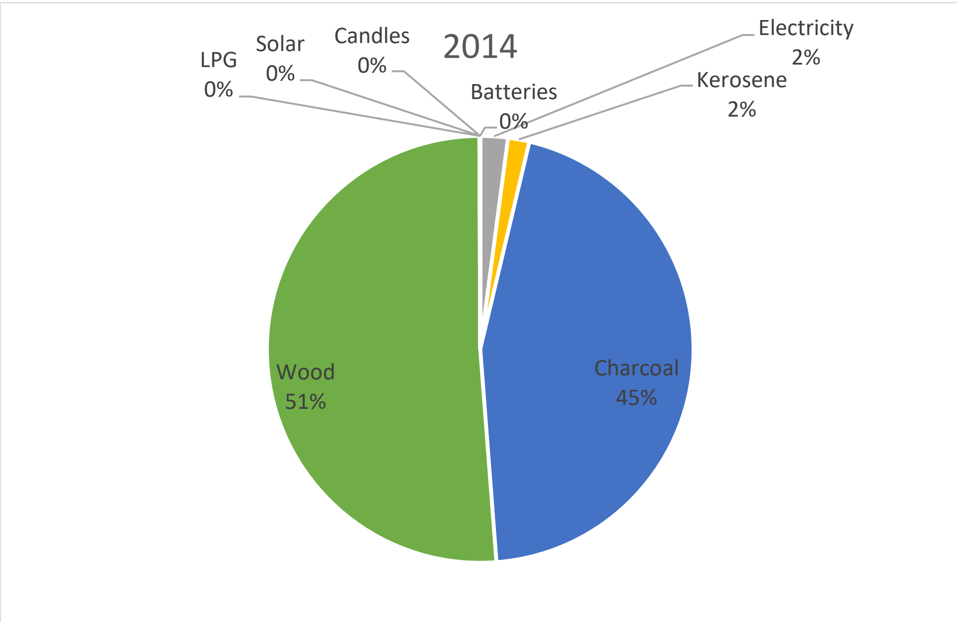


Figure 15: Energy consumption trajectory for households in Kasese in the BAU scenario

With the increasing electrification in Households, more charcoal is consumed than wood by 2030, and electricity shares double from 2% to 4%, also kerosene halves its share of energy consumption:



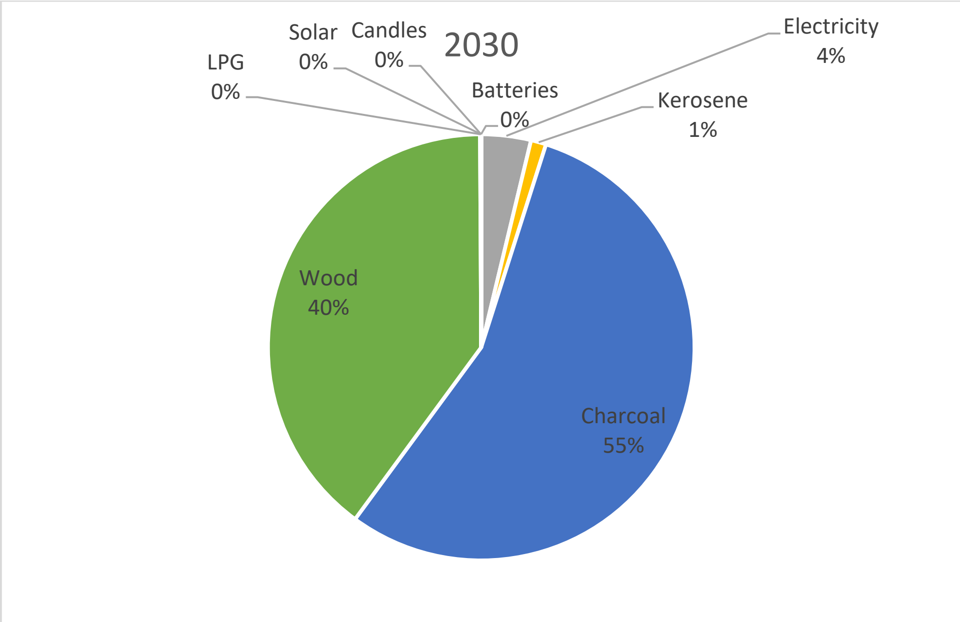


Figure 16 Household energy consumption shares for 2014 and 2030 in the BAU scenario

10.2 Sustainable Biomass Usage scenario (SBU)

Kasese is located near to national parks which are under threat by wood cutting for use as fuel wood. This will only be exacerbated by continued growth in Kasese.

This scenario looks at better usage of wood and charcoal in Kasese in order to save on wood and charcoal usage. This scenario is constructed in line with the SE4ALL goals on reducing reliance on biomass by efficient use of the fuel, and falls within the same scope as the Biomass Energy Strategy (BEST) for Uganda (Ministry of Energy and Minerals, 2015)

The tree resource in Uganda is estimated to sustainably supply only 26 million tonnes pa which is little more than half of what was being consumed annually – about 44 million tonnes pa (Ministry of Energy and Minerals, 2015).

Households

This scenario looks at a program to replace all wood or charcoal stoves with efficient ones, starting in 2020 and finalising by 2030.

These efficient stoves will have assumed efficiency gains – results from survey show the ‘efficient’ stoves were using more fuel than the ‘regular’ stoves, see section 4.2. In this scenario it is assumed new stoves are rolled out and people using them are trained or educated on how to most effectively use them.

Efficient charcoal cookstoves in this scenario for households are assumed to use 36% less[10] charcoal, and efficient wood stoves use 58% less wood.

For costs, it is assumed that efficient stoves cost 25 000 UGX (Ministry of Energy and Minerals, 2015). The same cost is assumed for wood burning stoves.

Commerce and Industry

From the SE4ALL report (Ministry of Energy and Minerals, 2015) between 70% and 100% of commercial entities used inefficient wood and/or charcoal stoves or burners.

In this scenario, both commercial and industrial entities begin to phase out their older stoves or burners for efficient new ones. This begins in 2020 and is complete by 2030.

These new cook stoves for commercial entities are assumed to use 45% less[10] fuel than inefficient (current) stoves, while for industry it is assumed that the savings[11] for both wood and charcoal consumption is 30%.

Table 40 Cost details for SBU scenario

Sector	Technology	Fuel	% fuel saved	Cost – UGX per unit	Life – years*	Subsectors applied to
HH	Improved charcoal stove	Charcoal	36%	25000	5	All
HH	Improved firewood stove	Wood	59%	25000	5	All
COM	Improved charcoal stove	Charcoal	45%	25000	5	All
COM	Improved firewood stove	Wood	45%	25000	5	All
IND	Overall Better wood burners	Wood	30%			All, except Mining

*Assumed. http://catalog.cleancookstoves.org/

[10] http://www.climatefriendly.com/projects/ugandan-cookstoves

[11] SE4ALL (Ministry of Energy and Minerals, 2015), page 58 – this is mainly in switching to wood chips and better burner technologies.

This scenario results in an energy savings of about 30% by the year 2030, a rather significant reduction:

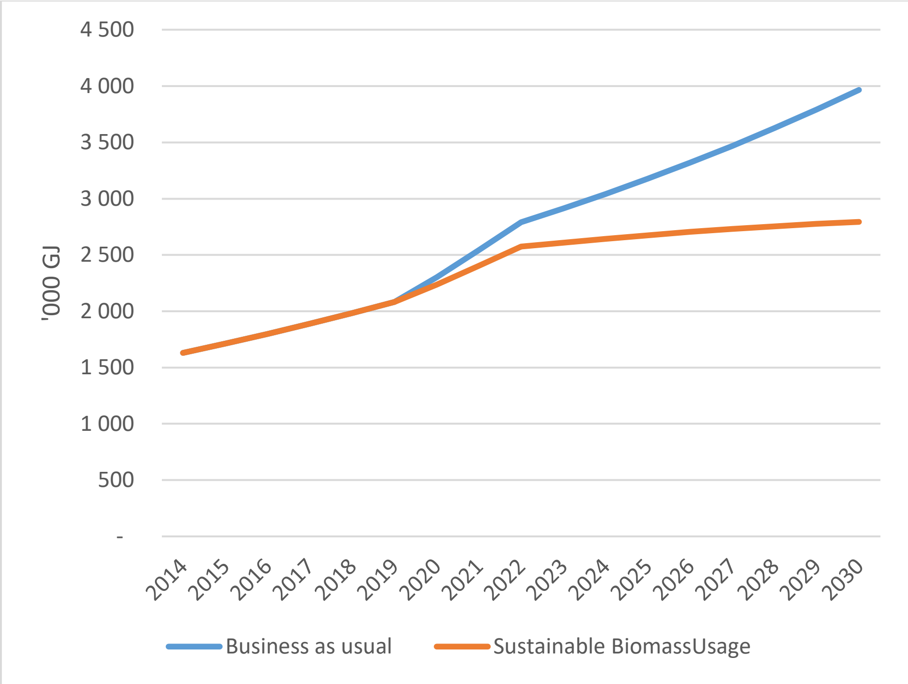


Figure 17 Kasese final energy demand for SBU and BAU scenarios

The majority of this fuel savings comes from Households:

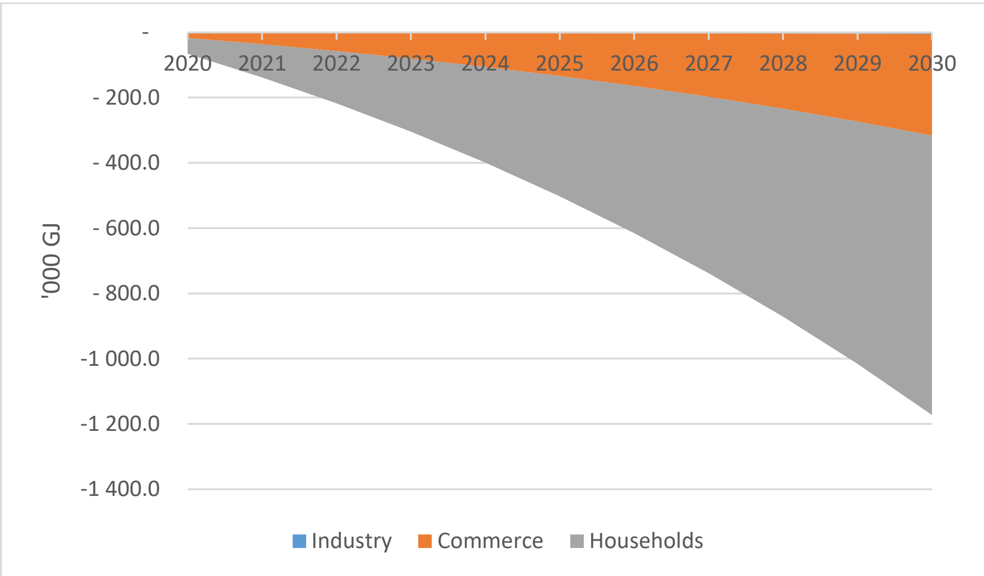


Figure 18 Wood and Charcoal energy savings in SBU scenario compared to BAU

In this scenario, by 2030 about 60 kt of wood and charcoal per year would have been averted by the replacement of all stoves with more efficient ones. Cumulatively this is about 330kt saved between 2020 and 2030.

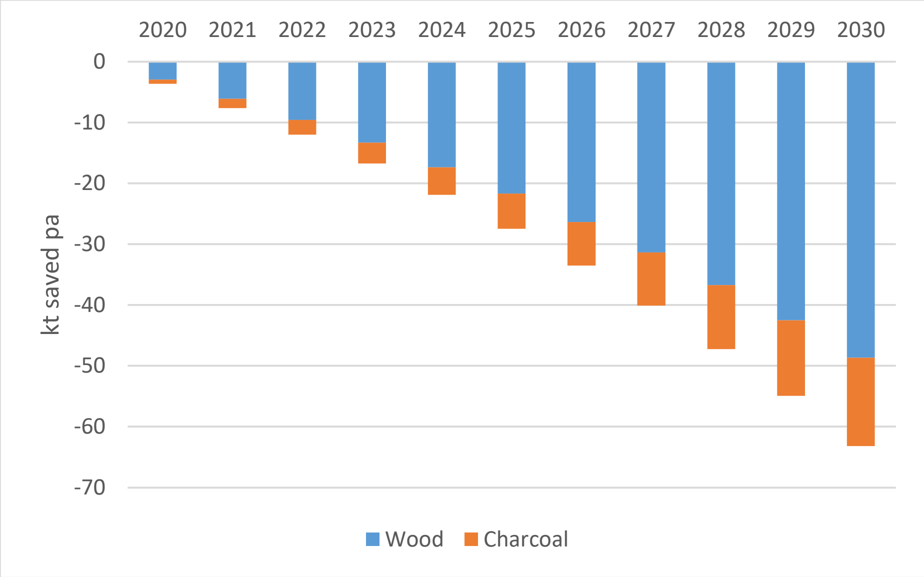


Figure 19: Tonnes of wood and charcoal saved per annum in SBU scenario

Assuming wood costs 189UGX per kg, and charcoal 583UGX per kg, then the total monetary savings is about 90 000 Million UGX cumulatively between 2020 and 2030:

Table 41 Savings in Million UGX from wood and charcoal for Kasese in the SBU scenario

	2020	2025	2030	Total 2020 - 2030
Wood	556	4 098	9 198	48 499
Charcoal	410	3 376	8 471	41 799

It requires three to four times as much wood for the same mass of charcoal once it is converted. Thus the total wood savings for Kasese is more than 60 kt per year as indicated in Figure 19, but closer to 150kt per year:

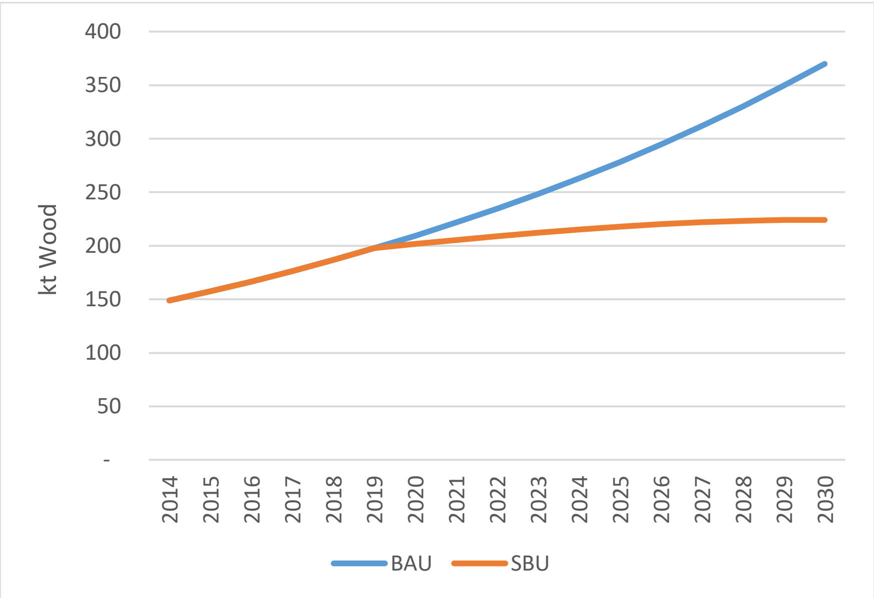


Figure 20 Wood consumption of Kasese for BAU and SBU scenario including wood for charcoal

In this scenario the wood consumption flat lines from 2020 through to 2030 – increasing only very slightly. This is a significant impact, but would not be enough to reduce the consumption of wood to less than half – the requirement to bring wood consumption to sustainable levels (ie. Wood consumption without deforestation).

10.3 LPG access scenario (LPGA)

A refinery is planned to be built by 2020 in Uganda to refine the soon to be developed oil fields discovered in West Uganda (Burite, and Ojambo, 2016).

This will make petroleum products more accessible and likely to be cheaper as well. LPG is considered clean in terms of emissions and could be used for cooking and heating purposes. The SE4ALL report (Ministry of Energy and Minerals, 2015) notes that LPG is considered a clean fuel, but Households consider it dangerous. The report also highlights the fact that the LPG industry in Uganda is targeting 20% HH share of cooking on LPG by 2020.

This scenario looks at the possible gradual improved access to LPG as a fuel for cooking and heating, with some firewood use in Industry replaced by LPG.

<u>In this scenario:</u>

More HHs use LPG, replacing wood and charcoal stoves (not necessarily all of them) with LPG burning stoves, and all of commercial cooking is done on LPG rather than wood or charcoal.

HHs start phasing in LPG usage from 2020, then by 2030:

- Low income – replace 50% of wood and charcoal useage with LPG
- Low income nonelec – replace 60% of wood and charcoal usage with LPG
- Mid income – replace 75% of wood and charcoal with LPG
- Mid income nonelec – replace 85% of wood and charcoal with LPG
- High income – replace 100% of wood and charcoal with LPG
- High income nonelec – replace 100% of wood and charcoal with LPG
- Commercial sector[12] – all non-electric cooking done on LPG.
- Industrial sector – all firewood[13] consumption is replaced with LPG

This scenario assumes a gradual phasing in of LPG starting when the refinery is expected to start in 2020. It may be that the phasing in of LPG could happen faster (than 10years).

Also it is not known what the LPG would cost after the refinery begins operating. It is assumed that LPG is 20% cheaper than current prices.

For the stove/burners for LPG the following costs are used:

Table 42 LPG stove costs used[14]

	UGX
Grill	26 000
Burner	28 000
Regulator	35 000
Pipe	15 000
Total	**104 000**
Life - years	10

[12] LPG replacing wood in this scenario is often done on an energy enduse basis (ie replace 10GJ of wood with LPG), however, LPG burning technology is assumed to be more efficient than firewood burning technology. In HH and Commerce this is assumed to be about 60% compared to firewood stoves of roughly 20 to 30% efficiency. For industry, it is assumed biomass burners are more efficient than HH stoves generally, and LPG here is assumed to be only a quarter more efficient.

[13] In Kasese, from the survey data it was found that the various industrial subsectors were using firewood for cooking for employees or specifically for producing food. In this work we assume that all this firewood is replaced with LPG. We do not assume replacement of other fuels with LPG with the level of data available.

[14] Source: http://www.dignited.com/12873/cooking-gas-in-uganda-brands-prices-refilling-and-where-to-buy/

With these assumptions in the model, the total energy consumption of Kasese drops by 30.5% by 2030. These are similar energy reduction numbers to the SBU scenario – where all firewood and charcoal burning technologies were replaced with more efficient ones. In this scenario, LPG usage reduces the overall energy consumption of Kasese by a similar amount because of a similar efficiency improvement when moving from firewood to LPG stove – we assume that an LPG stove is about 60% efficient at combusting fuel and heating food, while a wood and charcoal stove are only 20 and 25% efficient. Thus less LPG energy compared to wood and charcoal is needed to heat the same food that was cooked on a charcoal or wood stove.

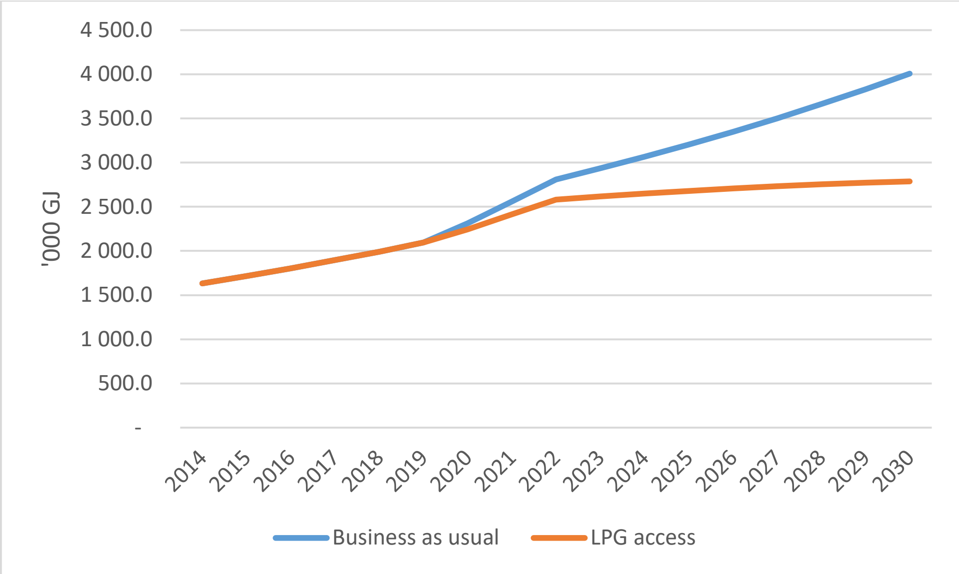


Figure 21 Total energy consumption for Kasese in LPGA and BAU scenario

There is a large reduction in energy consumption in both the household and commerce (the two largest changes in this scenario), while the commercial sector reduces the energy consumption relative to the base year, the household trajectory is somewhat flat to 2030:

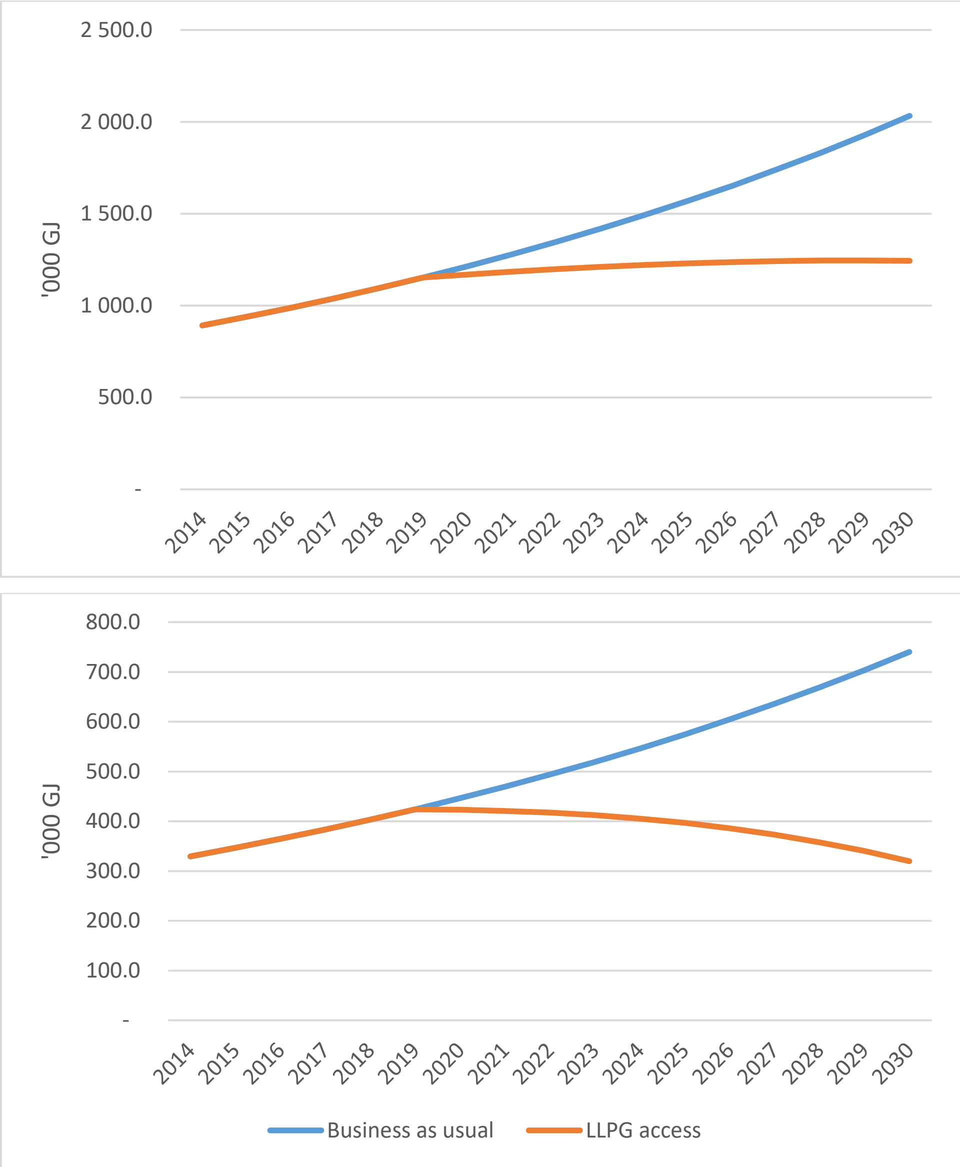


Figure 22 Household (above) and commercial (below) energy consumption of LPGA scenario compared to BAU scenario

With charcoal and wood costing 583 and 189 UGX per kg, and assuming a 20% reduction in LPG costs (thus 7293 per kg), then the costs (in nominal terms) of this scenario greatly increase relative to the BAU:

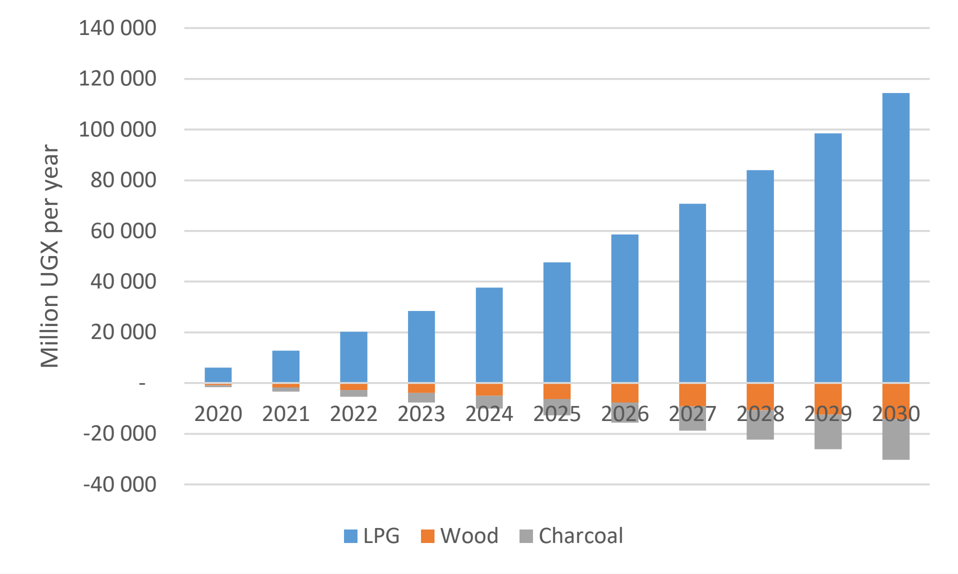


Figure 23: Cost impact (in Million UGX per annum) of the LPGA scenario relative to BAU

This cost impact is very sensitive to the price of LPG which was an assumption in this scenario. A basic sensitivity analysis reveals that LPG fuel prices would have to drop by 78% to break even with the savings from wood and charcoal consumption:

Table 43 Sensitivity analysis of LPG cost assumption for LPGA scenario

Assumption on LPG cost:	**20%**	**50%**	**70%**	**79%**	**80%**
LPG cost	579 175	361 985	217 191	153 621	144 794
Wood and Charcoal	-153 621	-153 621	-153 621	-153 621	-153 621
Total	**425 554**	**208 364**	**63 570**	**0**	**-8 827**

NOTE: Investment cost for LPG, wood and charcoal stoves are not included in this sensitivity analysis.

10.4 Electrification of Households scenario

In this scenario, we would like to investigate what a city energy consumption and particularly HH consumption would look like when all HH are electrified and use electricity.

From the survey, however, electrified HH's are not using a lot of electricity, mainly it might be used for one or two light bulbs or charging mobile phones. Thus, for each enduse, in this scenario HHs switch to using electricity from other fuels starting in 2020, and by 2030 there is 100% electrification of HHs and a higher utilisation of the fuel.

Below, for each enduse, is the scenario specific detail for HHs by 2030.

Cooking

HHs that use LPG or electricity will continue to do so, but if they were using wood or charcoal as well then they use more of either LPG or electricity.

If HHs use only wood and/or charcoal and/or kerosene, then they switch to using electricity only.

If a household uses firewood or charcoal in a wood/charcoal stove, then switching to electricity (or LPG) would make the conversion of fuel to cooking heat more efficient because of the poor efficiencies overall in wood or charcoal stoves compared to electric (or LPG) stoves. Thus, to get final energy intensity numbers for these HHs, the data from the HH survey is used to obtain LPG or electricity consumption by converting the charcoal, firewood or kerosene fuels to LPG or electricity using the equation below, and Table 44 gives the stove efficiencies and fuel densities used for these calculations.

Enduse energy consumption conversions for other fuels to electricity or LPG usage:

$$E_i \times \eta_i = E_j \times \eta_j$$

Where E_i is the final energy consumption for fuel ***i*** of the set of fuels excluding electricity or LPG (such as charcoal or kerosene) in use by HHs, and

n_i is the efficiency of the stove or device for using the fuel ***i*** to cook with,

E_j is the energy consumption of the new technology ***j*** of the set of either electricity or LPG, and n_j is the efficiency of the stove or device for using the fuel ***j*** (of the set of either electricity or LPG),

Table 44 Cooking stove technologies used for HH electrification scenario

Technology	Stove efficiency	Fuel density	Units
Charcoal Reg. stove	20%	28.8	MJ/kg
Charcoal Imp. Stove	27%	28.8	MJ/kg
Firewood Reg. Stove	15%	15.5	MJ/kg
Firewood Imp. stove	24%	15.5	MJ/kg
Kerosene stove	40%	44.7	MJ/L
Electricity stove*	80%	3.6	MJ/kWh
LPG stove/burner*	60%	44.7	MJ/L

* Stoves that the HHs will switch to in this scenario

Using these equations and the HH survey data, the HHs energy intensity for cooking with electricity or LPG if they all switched from charcoal and wood (and kerosene) is given in Table 45.

Table 45 Electricity and LPG energy intensities from converted wood, charcoal and kerosene fuel consumption for electrification scenario

Income Group	kWh electricity per HH per year	kg of LPG per HH per year
H-Electrified	3 002	256
H-Non-Electrified	4 264*	
L-Electrified	2 380	62
L-Non-Electrified	2 426	
M-Electrified	2 188	227
M-Non-Electrified	2 690	27

* Often in the HH survey data, a household will be cooking as part of a business and thus use a lot of fuel. Also, some households are large – with 10 or more people and would require more fuel in general. These factors affect the average overall intensity that is seen here, and it was opted to not remove these from the calculations.

The proportion of HHs that would use LPG or electricity was computed from the HH survey and from this result, the majority of HHs would switch to electricity rather than LPG. This is given in Table 46.

Table 46 Share of HHs that would use electricity or LPG from the HH survey for the electrification scenario

Income Group	% share Electricity	% share LPG

H-Electrified	94%	6%
H-Non-Electrified	100%	0%
L-Electrified	99%	1%
L-Non-Electrified	100%	0%
M-Electrified	98%	2%
M-Non-Electrified	98%	2%

Lighting

All HHs, in all income groups use electric CFT lights. All households using candle, or kerosene lamps switch to using a CFT bulb. However a bulb will replace two of either non-electric devices. Computing this from the survey gives the following increases in HH average intensity for electric lights in Table 47.

Table 47 Increase in electricity energy intensity for lighting in electrification scenario

Income Group	Lighting Electric intensity increase
H-Electrified	12%
L-Electrified	14%
M-Electrified	12%

Refrigeration

All high income groups have a fridge, 75% of middle income groups, and 50% of low income groups.

Appliances

All HHs have and use appliances by 2030. However, more appliances per HH are used – this increases the average energy intensity of HHs. This increase is given

Table 48 Appliance energy intensity increase by HH group in the electrification scenario

Income group	% increase in appliance energy intensity
High	100%
Middle	50%
Low	25%

Cooling

The number of HHs using fans as a means for space cooling increases in this scenario.

High income – 50% (up from 6%)

Middle income – 25% (up from 11%)

Low income – 15% (up from 4%)

Scenario results

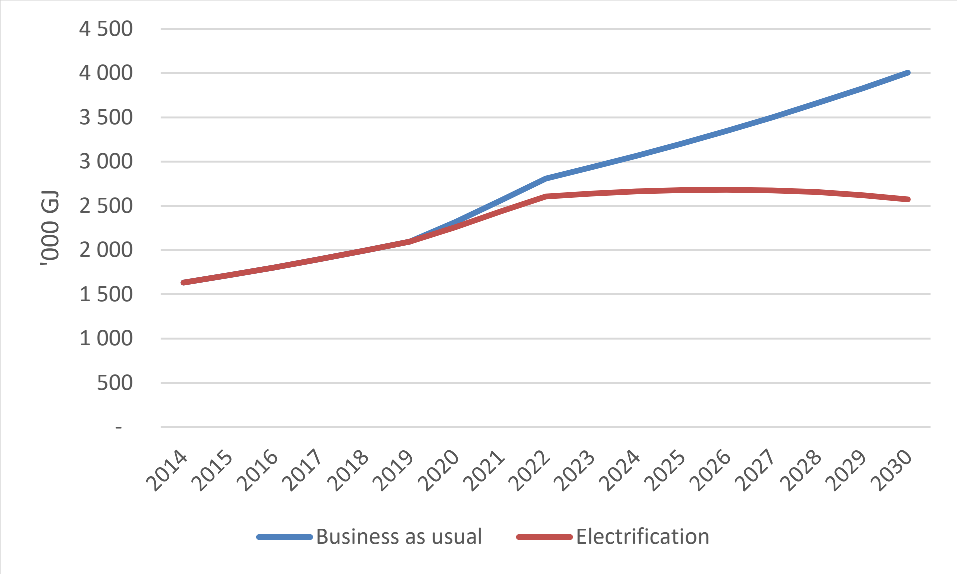


Figure 24 Final energy consumption for Kasese in the electrification scenario

Overall, the final energy consumption for Kasese by 2030 is only about 35% less than the BAU scenario. This is mainly due to the savings in wood and charcoal consumption in cooking in the households. As for electricity there is almost an eight fold increase in consumption in the household sector – mainly in cooking in low and middle income groups. Figure 25 shows the difference in the HH sector in fuel consumption to the BAU scenario.

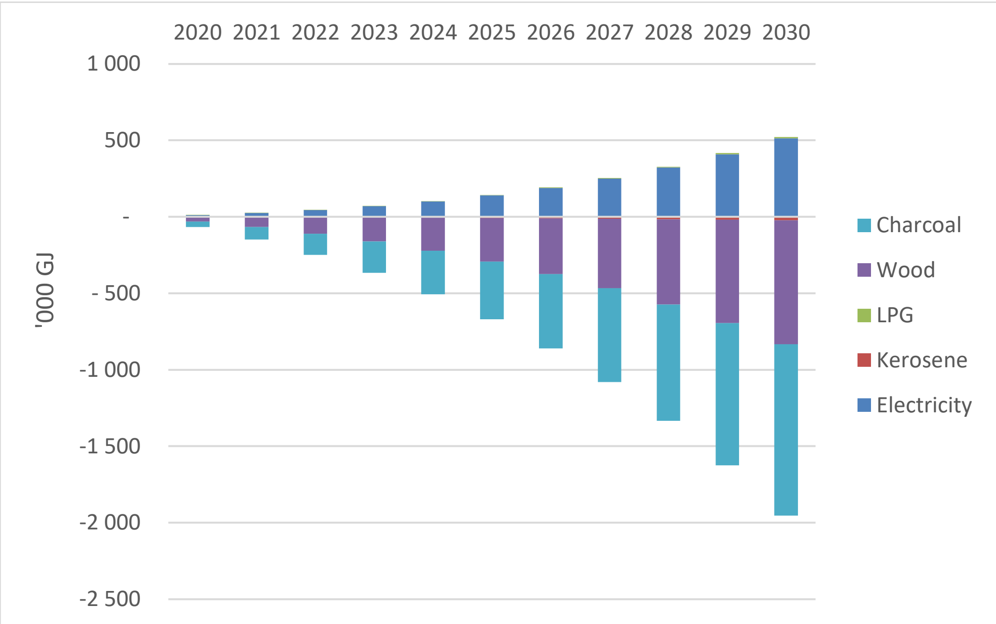


Figure 25 Final energy consumption difference of fuels in HH sector comparing BAU to electrification scenario

In this scenario, this equates to a total of 576 000MWh more electricity used by HHs between 2020 and 2030, but a reduction of 174 800 tonnes of charcoal and 240 000tonnes of wood (see Table 49).

Table 49 Cumulative difference in energy consumption in HHs in the electrification scenario

Fuel	Units	2020	2025	2030
Electricity	MWh	2 932	108 518	576 044
Kerosene	kL	-20	-567	-2 433

LPG	Tonnes	5	156	774
Wood	Tonnes	-1 894	-55 415	-239 903
Charcoal	Tonnes	-1 270	-38 978	-174 805

With the increase in purchases of electricity, HHs will be spending 222 Billion Shillings more over the 2020 to 2030 period overall as given in Table 50.

Table 50 Cumulative cost impact (million UGX) on HH sector for fuels in the electrification

Fuel	2020	2025	2030
Electricity	1 877	69 452	368 668
Kerosene	-49	-1 417	-6 083
LPG	42	1 426	7 059
Wood	-358	-10 473	-45 342
Charcoal	-741	-22 724	-101 911
Nett cost	**771**	**36 264**	**222 391**

10.5 Increased usage of private transport (HTRA)

The HH survey data collected in this work has enough detail to allow for a scenario to be developed where people buy and use transport the way High income households do – more private vehicle transport etc and further distances in general. This scenario explores this potential future where more and more people use transport the way the high income HH users do.

This is done by simulating a transition from the average mode share for the whole of Kasese to just the High income group mode share (first column) given by the HH survey data as shown below:

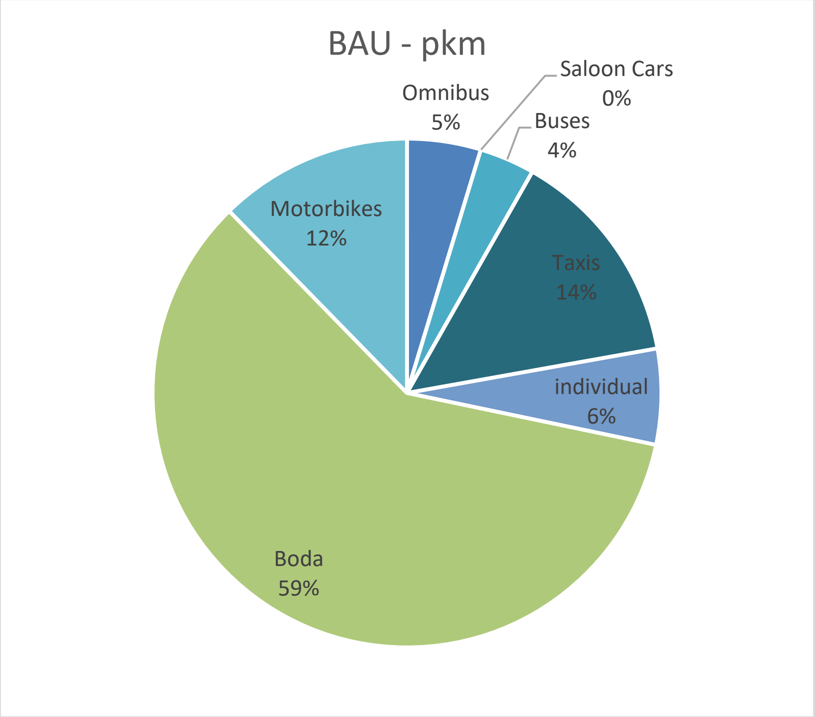
Table 51: HH transport mode shares from HH survey for each income group

Income Group	High		Medium		Low	
Mode	Mode Share (pkm)	Mode Share (trips)	Mode Share (pkm)	Mode Share (trips)	Mode Share (pkm)	Mode Share (trips)
Walk	7%	21%	24%	50%	38%	67%
Bicycle	0%	0%	2%	1%	3%	2%
Motorbike (personal/work)	5%	2%	12%	6%	6%	3%
Boda Boda (Motorcycle taxi)	30%	32%	44%	34%	39%	21%
Taxi (Special hire)	0%	0%	0%	0%	0%	0%
Minibus taxi	9%	7%	11%	5%	9%	3%
Bus	0%	0%	2%	0%	1%	0%
Company minibus/bus/truck	23%	12%	4%	2%	2%	1%
Own Car	25%	27%	2%	2%	3%	2%
Other (specify)	0%	0%	0%	0%	0%	0%

What is noticeable from the HH survey transport mode data is that there is a higher share of 'company minibus/bus/truck' usage in high income HHs than the other income groups. It may be that the HHs run businesses involving transport or work for one. However, in this scenario, we use this result, as this mode is similar to minibus taxi's which would have very similar efficiencies.

NOTE: 'Company minibus/bus/truck' is renamed to 'Omnibus' here (as well as the BAU scenario).

It should also be noted, that as HH begin to move about in a similar fashion to the high income groups, they would move about more – increases the distances travelled.



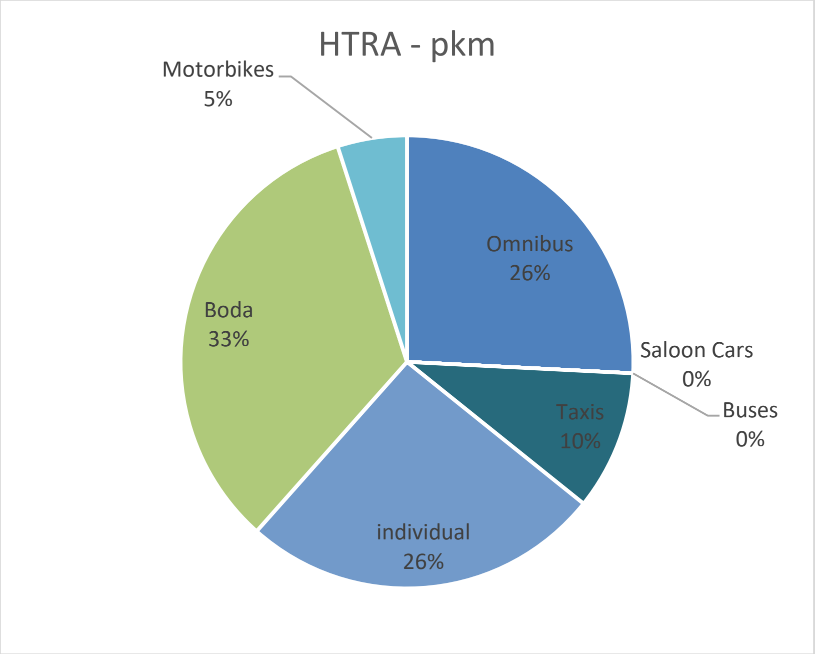


Figure 26: HH transport mode shares for HTRA scenario compared to the BAU scenario.

Using these mode shares and the methodology developed in section 6.2 the increase in passenger transport for private and public transport is shown below:

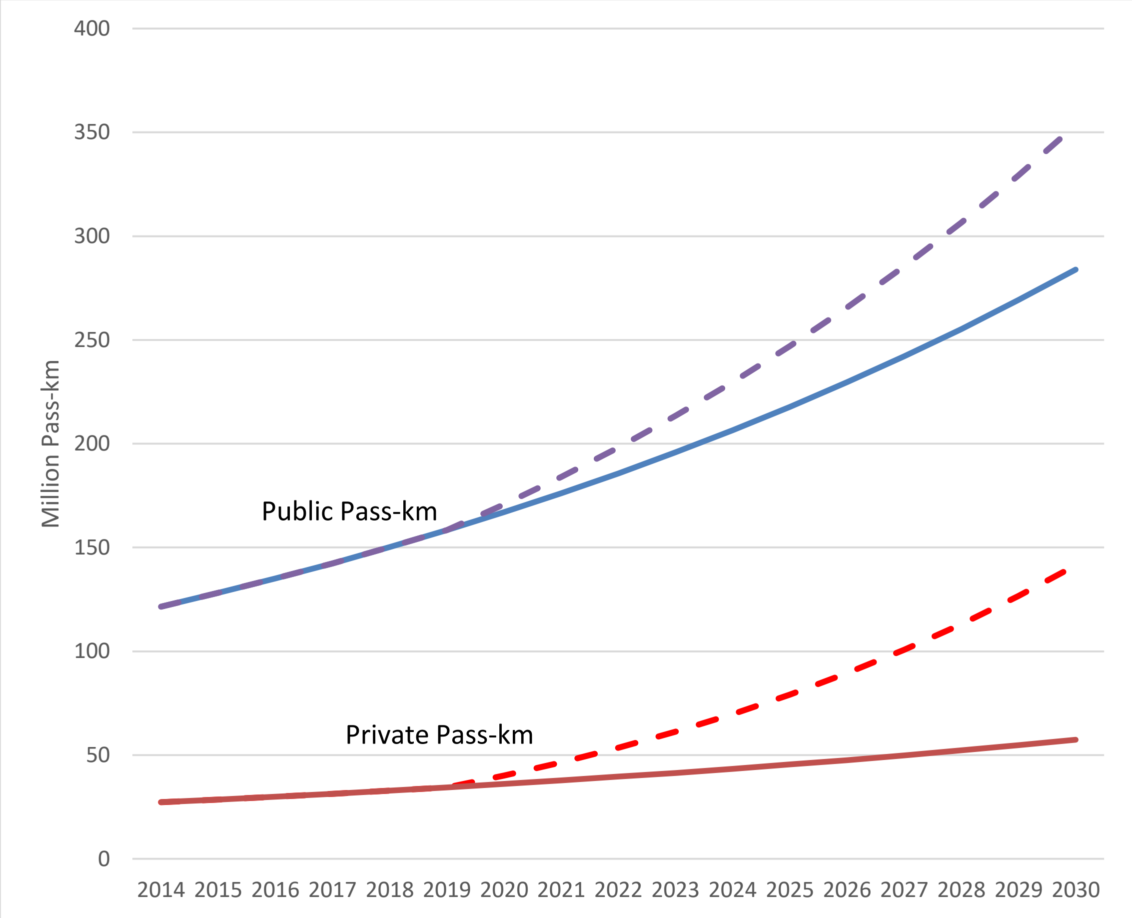


Figure 27 Passenger-km demand increase in the HTRA scenario (dashed) relative to the BAU scenario

The pass-km increase in the HTRA scenario results in 146% increase in private transport, and 25% increase in public transport. This will have implications for congestion in the town especially since much of the usage of the Boda's is removed and replaced by cars and omnibuses/minibuses.

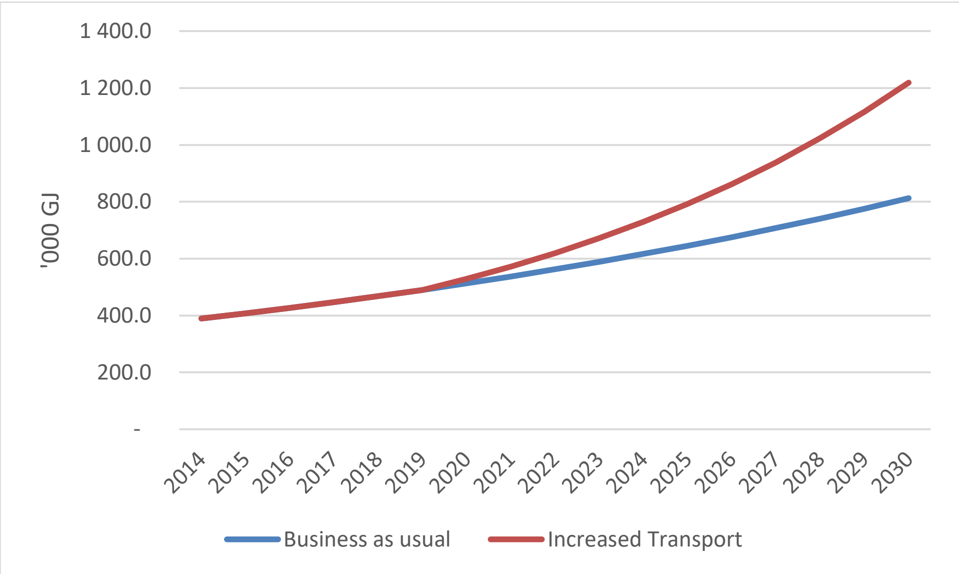


Figure 28 Energy consumption for transport in Kasese for the HTRA scenario

This fuel consumption increase corresponds to about 12 Million extra litres of petrol and diesel – largely in the former, by 2030:

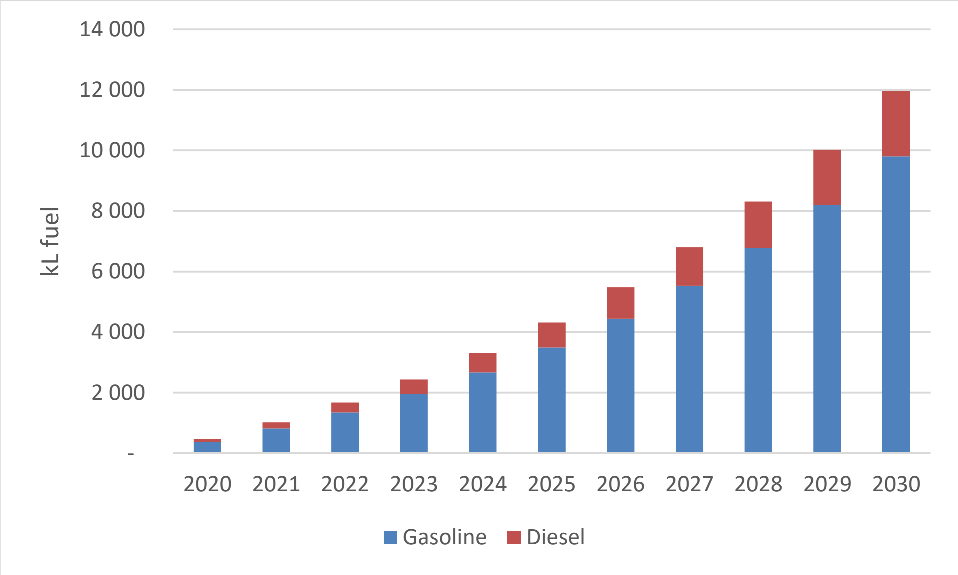


Figure 29 the increase in fuel consumption for petrol and diesel in the HTRA scenario

This is a 70% increase in Petrol, and 25% increase in diesel, which will have an impact on the air quality of the municipality.

11. Discussion

This report details the methodology and data used to create an energy systems simulation model for the municipality of Kasese, Uganda. Data on energy consumption was collected by the local members of the SAMSET project team, Uganda Martyrs University. From the data and the analysis of the data, it was found that the majority of fuel consumed in Kasese is in the form of wood and charcoal. The majority of this fuel consumption is attributed to households, and these fuels remain the major fuel sources in 2030 even with an electrification rate of 85% assumed in the Business as Usual scenario developed for the model.

The share of electricity consumed in Kasese rises from 3% of total energy consumption to 13% by 2030 under the assumption that by 2030 there would be 85% electrification rate in Kasese, and that the mines in Kilembe begin to operate in 2020. Despite the mines becoming operational using all the hydro power output from the upgraded 19MW hydro plant, the dominant energy consumers in Kasese will remain households, followed by transport.

An electrification scenario was developed whereby HH's become electrified, or use more LPG if already doing so, and would utilise electricity for more of their energy needs, including cooking, and not simply for lighting and mobile phone charging. This scenario leads to about 240 000 tonnes of charcoal and 170 000 tonnes of wood saved by 2030. However, due to the low cost of biomass fuels, this scenario leads to an increase in cost to the Kasese household sector of about 220 billion Shillings cumulatively by 2030.

Efficient cook stoves utilisation in HHs, businesses and industries was also studied. This 'Sustainable Biomass Usage' scenario showed a reduction in wood consumption to 2030 – reducing the overall wood consumption in Kasese by about 40% in 2030 relative to the BAU scenario. These savings are largely from Households but also a significant portion from the commerce sector – mainly restaurants and schools. Despite this savings, this would not be enough to reduce Kasese's consumption of wood and charcoal use to below half of the base year consumption – a national strategic goal in Uganda as part of the BEST strategy (Ministry of Energy and Minerals, 2015).

A refinery is planned to be built in western Uganda which is thought it will improve access to petroleum fuels. In a scenario looking at greater uptake in LPG, it was found that by replacing all wood and charcoal consumption in households and commerce with LPG stoves, there is a significant reduction in energy consumption – similar to the efficient cookstoves scenario. This reduction is mainly from an improved efficiency that comes with using an LPG burner. However, this comes with an increase in costs as LPG is currently about 10 times more expensive than charcoal per unit of energy. Despite assuming a 20% reduction in price for LPG in this scenario, there is still a significant increase in costs to Kasese in converting to LPG. A sensitivity test on the reduction in price for LPG shows that the cost would have to come down by about 80% in order to break even on fuel costs in this scenario.

On the transport side a scenario was investigated that modelled the impact of more of the population using private vehicles for transport. This assumed that with rising incomes, that a greater share of households would assume the mode share of private transport observed for high income respondents. The result was an increase overall for private passenger-km's of 146% and public transport by 25%. A scenario like this would impact the congestion of the roads, and the mortality rates by road accident but also from air pollution.

Kasese is mainly biomass dependant, and this will remain so if HH energy consumption characteristics do not change. Access to cleaner fuels like electricity and LPG is important in development, but these results show that there will be a high cost to Kasese in using these fuels.

11.1 Limitations of this work

There was a substantial amount of data collected in this work by the Ugandan SAMSET team. However, there are still some areas which still require data collection. The commercial sector survey did not cover shops, informal commercial activities or general business offices which would also constitute a significant part of the commercial sector of Kasese. Data on transportation in and out of Kasese would also be required to better model the

A trend in HH energy consumption behaviour can only be determined using a follow up survey. This model assumes the behaviour does not change significantly between now and 2030 (in the BAU).

A transport modelling methodology was developed from the surveys and locally relevant literature but some assumptions around vehicle activity data and vehicle fuel consumptions were still required. This methodology could only account for about 40% of liquid fuel sales in the area with the observed commuter and freight activity of the population within the municipality itself. Thus while the transport sector is a significant component of energy demand, most of this was attributed to a poorly understood ‘corridor’ component. A future survey of vehicles travelling into Kasese from outside and passing through would greatly increase the detail of this transport component.

The mines will become energy intensive. In this work however, from the information gathered, the mines would be using all the hydro power from the hydro plant located near the mines, but it may also be the case that the mines would still require grid electricity, which in this work we do not have data or information about how much this might be.

12. References

Bhattacharyya, S., & Timilsina, G. (2010). A review of energy system models. International Journal of Energy Sector Management, 4(4), pp. 494-518. Retrieved from http://www.ewp.rpi.edu/hartford/~ernesto/S2013/MMEES/Papers/ENERGY/1EnergySystemsModeling/Bhattacharyya2010-ReviewEnergySystemModels.pdf

Energy Research Centre, University of Cape Town, South African TIMES model methodology, 2013, available at http://www.erc.uct.ac.za/groups/esap/satim

Estimates of Electricity Requirements for the Recovery of Mineral Commodities, with Examples Applied to Sub-Saharan Africa

http://www.theeastafrican.co.ke/business/Copper-production-to-resume-at-Kilembe-/-/2560/2585030/-/tgtux1/-/index.html

Gwilliam K. (2011) Africa's Transport Infrastructure Mainstreaming Maintenance and Management, The World Bank

Mutenyo, J., Banga, M., Matovu, F., Kimera, D., and Lawerence, K. Baseline survey on Uganda's national average automotive fuel economy, Global Fuel Economy Initiative, 2015. Available at: http://www.unep.org/Transport/new/PCFV/pdf/Uganda_baseline.pdf

National Population and housing census 2014 Provisional results revised edition, UBOS, Nov 2014

Newvision Kilembe Mines rehabilitation starts, June 2014, available at: http://www.newvision.co.ug/new_vision/news/1341497/kilembe-mines-rehabilitation-starts

Supee Teravaninthorn and Gaël Raballand, Transport Prices and Costs in Africa: A Review of the Main International Corridors", AICD, July 2008

The East African, "Copper Production to resume at Kilembe", Jan 2015, available at:

The Observer, Kilembe mines to produce 12 MW, Feb 2014, available at: http://observer.ug/index.php?option=com_content&view=article&id=30221:-kilembe-mines-to-produce-12-megawatts&catid=38:business&Itemid=68

Uganda Bureau of Statistics (UBOS), National population and housing census 2014 provisional results revised edition, Nov 2014

Uganda Safari Portal, "Kilembe mines rehabilitation starts", June 2014, Available at: https://ugandasafariportal.wordpress.com/2014/06/07/kilembe-mines-rehabilitation-starts/comment-page-1/

UMU (2014), "State of Energy report for Uganda with a focus on Jinja and Kasese Municipalities", Draft project Report – SAMSET Project, Faculty of the Built Environment, Uganda Martyrs University

UMU (2016), Results of Household, Commercial and Industry Energy Use Survey for Kasese Muncipality, Database of survey responses collected for the SAMSET Project, Faculty of the Built Environment, Uganda Martyrs University

Worldbank country indicators, available at: http://data.worldbank.org/

13. Appendix

13.1 Households

Table 52 HH enduse technology shares and energy intensities for Kasese

Share of these HHs with this technology	Intensity Units per HH	Technology	End Use	Income group	Electrification	Unit
5.9	78.0	Charcoal	Appliances	High	Electrified	kg
82.7	784.2	Charcoal	Cooking	Middle	Electrified	kg
94.1	1068.8	Charcoal	Cooking	High	Electrified	kg
64.7	1030.9	CharcoalImp Stove	Cooking	High	Electrified	kg
29.4	1152.0	CharcoalReg Stove	Cooking	High	Electrified	kg
38.7	2165.1	FirewoodReg Stove	Cooking	Low	Non_Electrified	kg
23.5	1537.5	Firewood	Cooking	High	Electrified	kg
23.5	1537.5	FirewoodReg Stove	Cooking	High	Electrified	kg
5.9	65.5	LPGBurner	Cooking	High	Electrified	kg
5.9	21.9	LPGStove	Cooking	High	Electrified	kg
26.4	1963.4	FirewoodImp Stove	Cooking	Low	Non_Electrified	kg
34.0	2338.9	Firewood	Cooking	Low	Electrified	kg
57.1	273.0	Charcoal	Appliances	High	Non_Electrified	kg
42.0	813.0	CharcoalReg Stove	Cooking	Low	Electrified	kg
82.0	762.5	Charcoal	Cooking	Low	Electrified	kg
60.0	3000.1	Firewood	Cooking	Middle	Non_Electrified	kg
9.0	600.6	Charcoal	Appliances	Low	Electrified	kg
29.0	2155.1	FirewoodReg Stove	Cooking	Low	Electrified	kg
33.7	788.2	CharcoalImp Stove	Cooking	Middle	Electrified	kg
1.0	2.2	LPGStove	Cooking	Low	Electrified	kg
42.9	760.0	Charcoal	Cooking	High	Non_Electrified	kg
10.8	3164.1	FirewoodImp Stove	Cooking	Middle	Non_Electrified	kg
1.0	21.9	LPGStove	Cooking	Middle	Electrified	kg
40.0	709.4	CharcoalImp Stove	Cooking	Low	Electrified	kg
42.9	760.0	CharcoalImp Stove	Cooking	High	Non_Electrified	kg

30.7	131.6	Charcoal	Appliances	Low	Non_Electrified	kg
5.0	3405.0	FirewoodImp Stove	Cooking	Low	Electrified	kg
1.5	12.5	Biogas	Cooking	Middle	Non_Electrified	Cubic Meter
56.9	554.6	Charcoal	Cooking	Middle	Non_Electrified	kg
57.1	3375.0	FirewoodReg Stove	Cooking	High	Non_Electrified	kg
23.5	2785.7	FirewoodReg Stove	Cooking	Middle	Electrified	kg
40.5	504.3	CharcoalReg Stove	Cooking	Low	Non_Electrified	kg
55.8	693.5	Charcoal	Cooking	Low	Non_Electrified	kg
0.6	27.4	LPG	Refridgeration	Low	Non_Electrified	kg
15.3	1192.9	CharcoalImp Stove	Cooking	Low	Non_Electrified	kg
30.8	513.0	CharcoalReg Stove	Cooking	Middle	Non_Electrified	kg
7.1	2262.0	FirewoodImp Stove	Cooking	Middle	Electrified	kg
2.0	14.5	LPGBurner	Cooking	Middle	Electrified	kg
49.2	2964.2	FirewoodReg Stove	Cooking	Middle	Non_Electrified	kg
57.1	3375.0	Firewood	Cooking	High	Non_Electrified	kg
49.0	781.5	CharcoalReg Stove	Cooking	Middle	Electrified	kg
30.6	2663.5	Firewood	Cooking	Middle	Electrified	kg
1.0	27.4	LPG	Refridgeration	Middle	Electrified	kg
35.4	230.7	Charcoal	Appliances	Middle	Non_Electrified	kg
1.5	1.6	LPGBurner	Cooking	Middle	Non_Electrified	kg
26.2	603.5	CharcoalImp Stove	Cooking	Middle	Non_Electrified	kg
7.1	151.3	Charcoal	Appliances	Middle	Electrified	kg
65.0	2083.3	Firewood	Cooking	Low	Non_Electrified	kg
88.2	196.3	CFT	Lighting	High	Electrified	Kilowatt-Hour
5.9	109.2	Electricity	Cooling	High	Electrified	Kilowatt-Hour
100.0	148.0	Electricity	Appliances	High	Electrified	Kilowatt-Hour

12.9	0.1	TorchBattery	Lighting	Low	Non_Electrified	Kilowatt-Hour
1.0	728.0	Electricity	Cooking	Low	Electrified	Kilowatt-Hour
42.9	39.7	Electricity	Appliances	High	Non_Electrified	Kilowatt-Hour
44.2	19.6	Electricity	Appliances	Low	Non_Electrified	Kilowatt-Hour
91.8	88.6	CFT	Lighting	Middle	Electrified	Kilowatt-Hour
4.0	107.6	Halogen	Lighting	Low	Electrified	Kilowatt-Hour
5.9	13.7	LED	Lighting	High	Electrified	Kilowatt-Hour
100.0	273.8	Electricity	Refridgeration	Low	Electrified	Kilowatt-Hour
73.0	102.3	Electricity	Appliances	Low	Electrified	Kilowatt-Hour
100.0	273.8	Electricity	Refridgeration	Middle	Electrified	Kilowatt-Hour
6.7	20.8	SolarLamp	Lighting	Low	Non_Electrified	Kilowatt-Hour
12.0	1061.7	ElectricCoil	Cooking	Low	Electrified	Kilowatt-Hour
5.1	6.2	SolarLamp	Lighting	Middle	Electrified	Kilowatt-Hour
38.5	28.5	Electricity	Appliances	Middle	Non_Electrified	Kilowatt-Hour
4.0	38.4	Electricity	Cooling	Low	Electrified	Kilowatt-Hour
6.0	0.1	TorchBattery	Lighting	Low	Electrified	Kilowatt-Hour
94.0	53.9	CFT	Lighting	Low	Electrified	Kilowatt-Hour
2.0	185.6	Halogen	Lighting	Middle	Electrified	Kilowatt-Hour
13.3	1274.0	ElectricCoil	Cooking	Middle	Electrified	Kilowatt-Hour
100.0	273.8	Electricity	Refridgeration	High	Electrified	Kilowatt-Hour
23.1	39.4	SolarLamp	Lighting	Middle	Non_Electrified	Kilowatt-Hour
88.8	161.2	Electricity	Appliances	Middle	Electrified	Kilowatt-Hour
4.1	113.8	Electricity	WaterHeating	Middle	Electrified	Kilowatt-Hour
1.0	0.9	SolarLamp	Lighting	Low	Electrified	Kilowatt-Hour
11.2	173.4	Electricity	Cooling	Middle	Electrified	Kilowatt-Hour

5.1	720.7	FT	Lighting	Middle	Electrified	Kilowatt-Hour
5.9	327.6	FT	Lighting	High	Electrified	Kilowatt-Hour
42.9	54.0	SolarLamp	Lighting	High	Non_Electrified	Kilowatt-Hour
11.8	212.9	ElectricCoil	Cooking	High	Electrified	Kilowatt-Hour
3.1	1274.0	Electricity	Cooking	Middle	Electrified	Kilowatt-Hour
71.4	18.3	KeroseneLamps	Lighting	High	Non_Electrified	Liter
0.6	18.2	KeroseneStove	Cooking	Low	Non_Electrified	Liter
44.6	32.7	KeroseneLamps	Lighting	Middle	Non_Electrified	Liter
68.1	40.4	KeroseneLamps	Lighting	Low	Non_Electrified	Liter
5.9	18.2	KeroseneStove	Cooking	High	Electrified	Liter
9.0	39.4	KeroseneStove	Cooking	Low	Electrified	Liter
3.1	15.2	KeroseneStove	Cooking	Middle	Non_Electrified	Liter
11.8	69.3	KeroseneLamps	Lighting	High	Electrified	Liter
27.0	23.5	KeroseneLamps	Lighting	Low	Electrified	Liter
8.2	18.2	KeroseneStove	Cooking	Middle	Electrified	Liter
21.4	29.4	KeroseneLamps	Lighting	Middle	Electrified	Liter
4.3	80.6	Candles	Lighting	Low	Non_Electrified	Megajoule
4.6	40.6	Candles	Lighting	Middle	Non_Electrified	Megajoule
11.8	12.2	Candles	Lighting	High	Electrified	Megajoule
14.3	0.9	Candles	Lighting	High	Non_Electrified	Megajoule
20.4	36.7	Candles	Lighting	Middle	Electrified	Megajoule
22.0	37.7	Candles	Lighting	Low	Electrified	Megajoule

13.2 Industry

Table 53: The estimated annual energy consumption values by enduse for industry in Kasese

Industry Survey ID	Lighting			Cooking	Cooling		Machinery		Office	Other	Generator set		Vehicles
	Fluorescent	Mercury Vapour	Kerosene	Firewood	Fan	AC	Motors (estimated)**	Other	Devices	Firewood	Diesel	Petrol	Diesel
	kWh	kWh	L	kg	kWh	kWh	kWh	kWh	kWh	kg	Litres	Litres	Litres
Large1							43392				176000		
Large2	10210						38584						
Large3													
Ginnery1	13634				562		217382		2320				
Ginnery2	28166	7020			40		397380			2000	6667*		14000
Ginnery3	11523*	2872*					86086						
Construction				55000					800				880000
Millers1	249						37296						
Millers2							22200						
Millers3							28860						
Millers4							142080						
Millers5							340992						
Millers6							24864						
Hullers1							4607				240*		
Hullers2	17						622						
Hullers3	35						2286						
Hullers4	46						119347						
Bakery1	864			240000	77			91					
Bakery2				42000				320*					
Bakery3								268*			14400		
Fabricator1								737					
Fabricator2								526					
Fabricator3								421					
Fabricator4								842					
Total	**64745**	**9892**	**0**	**337000**	**679**	**0**	**1505979**	**3204**	**3120**	**2000**	**197307**	**0**	**894000**

*These instances are where the industry indicated that this was in use but didn't provide a number. An average using the other industries or any relevant information from the industry was used to estimate these numbers.

**These motor consumption numbers come from the estimates in Table 9

13.3R script details

Appliance ratings used:

```
wickflow = 0.1#L/hr
hurrflow = 0.1#L/hr
pressflow = 0.1#L/hr
LPGflow = 0.01#kg/hr
LEDwatt = 0.005 #Watts
CFTWatt = 18
FTWatt = 30
HalWatt = 60
solarlamprating = 100 #watts
cookWatts = 1000
lpgstoveflow = 0.1#kg/hr
lpgburnerflow = 0.1#kg/hr
parffflow = 0.1#L/hr
fridgewatts = 125#watts
tvwatts = mean(hhdata[hhdata$Other_TV_Watts != 0,"Other_TV_Watts"])
tvhrs = mean(hhdata[hhdata$Other_TV_hrs_pw != 0,"Other_TV_hrs_pw"])
radiowatts = 100
pchrs = mean(hhdata[hhdata$Other_PC_hrs_pw!=0,'Other_PC_hrs_pw'])
pcwatts = 250
laptophrs = pchrs
laptopWatts = 125
IronWatts = mean(hhdata[hhdata$Other_ElectricIron_Watts != 0,'Other_ElectricIron_Watts'])
ceilfanWatts = 100
fanmobwatts = 100
candleJg = 670 #J/g
candlekg = 0.1#kg per candle
candleMJ = (candlekg*1e3*candleJg/1e6) #MJ per candle
batterykWh =1.5*2500/1e3 # 1.5V X 2500 Ah to give Wh divide by 1000 to kWh
ElectricCookWatts = cookWatts
ElectricCoilWatts = cookWatts
otherDeviceWatts = 100
otherElecRadio = 75
phonechargerwatts = 25
charcIronBoxKG = 1.5 #kg per hour
AirConWatts = 250
AirConSplitWatts = 500
AirConDuctWatts = 800
biogasStoveflow = lpgstoveflow #make it the same as LPG stoves
waterheaterWatts = 1000
fridgeLPGflow = 300/(1000*24) #kg/hr. or 300 grams per day
```

R script grouping of appliances into Enduses and technologies:

```
tmp = hhdata %>%
  mutate(Total_charcoal_kg_pa = Total_Charcoal_kg_pm*12,
      Total_Firewood_kg_pa = Total_Firewood_kg_pm*12,
      Total_LPG_kg_pa = Total_LPG_kg_pm*12,
      Total_Paraffin_L_pa = Total_Paraffin_Liters_pm*12,
      Total_ElectricityBill_kWh_pa = Total_Grid_Elec_kWh_pm*12)%>%
  #Compute Lighting
  mutate(EULighting_CFT_kWh = Lighting_CFT_number*Lighting_CFT_hrs_pw*52*(CFTWatt/1000),
      EULighting_FT_kWh = Lighting_FT_number*Lighting_FT_hrs_pw*52*(FTWatt/100),
      EULighting_Halogen_kWh = Lighting_Halogen_number*Lighting_Halogen_hrs_pw*52*(HalWatt/1000),
      EULighting_LED_kWh = Lighting_LED_number*Lighting_CFT_hrs_pw*52*LEDwatt,
      EULighting_SolarLamp_kWh = Lighting_SolarLamp_number*Lighting_SolarLamp_hrs_pw*(solarlamprating/1000)*52,
      EULighting_Candles_MJ = (Lighting_Candle1_number_pw+Lighting_Candle2_number_pw)*52*candleMJ,
      EULighting_KeroseneLamps_L = 52*(Lighting_WickLamp_number*Lighting_WickLamp_hrs_pw*wickflow+
Lighting_HurricaneLamp_number*Lighting_HurricaneLamp_hrs_pw*hurrflow),
      EULighting_TorchBattery_kWh = Lighting_TorchBattery_number*12*batterykWh)%>%
  #Compute Cooking
  mutate(EUCooking_CharcoalRegStove_kg = Cooking_CharcoalRegStove_kg_pm*12,
      EUCooking_CharcoalImpStove_kg = Cooking_CharcoalImpStove_kg_pm*12,
      EUCooking_FirewoodRegStove_kg = Cooking_FirewoodRegStove_kg_pm*12,
      EUCooking_FirewoodImpStove_kg = Cooking_FirewoodImpStove_kg_pm*12,
      EUCooking_Firewood_kg = Total_Firewood_kg_pm*12,#so we have avg. overall
      EUCooking_Charcoal_kg = Total_Charcoal_kg_pm*12, #so we have avg. overall
      EUCooking_Biogas_kg = Cooking_BiogasStove_hrs_pw*biogasStoveflow*12,
      EUCooking_Electric_kWh = (Cooking_Electric1_hrs_pw+Cooking_Electric2_hrs_pw)*ElectricCookWatts*52/1000,
      EUCooking_ElectricCoil_kWh = Cooking_ElectricCoil_hrs_pw*ElectricCoilWatts*52/1000,
      EUCooking_LPGStove_kg = Cooking_LPGStove_hrs_pd*lpgstoveflow*365,
      EUCooking_LPGBurner_kg = Cooking_LPGBurner_hrs_pw*lpgburnerflow*52,
      EUCooking_KeroseneStove_L = Cooking_KeroseneStove_hrs_pw*parffflow*52)%>%
  #Fridge
  mutate(EURefridgeration_Electricity_kWh = Has_Fridge_Electric*fridgewatts*(6*365/1000),
      EURefridgeration_LPG_kg = Has_Fridge_LPG*fridgeLPGflow*(6*365))%>%
  #Appliances
  mutate(EUAppliances_Electric_kWh = (52/1000)*(Other_TV_number*Other_TV_hrs_pw*tvwatts +
       Other_PC_number*Other_PC_hrs_pw*pcwatts+
       Other_laptop_number*Other_laptop_hrs_pw*laptopWatts +
       Other_mobilePhone_number*phonechargerwatts*6 +
       Other_Device_number*otherDeviceWatts*6+
       Other_ElectricIron_hrs_pw*IronWatts+
       Other_Radio_number*Other_Radio_hrs_pw*otherElecRadio),
      EUAppliances_Charcoal_kg = Other_CharcoalIronBox_hrs_pw*charcIronBoxKG*52)%>%
  #Cooling
  mutate(EUCooling_kWh = (52/1000)*(Cooling_FanCeiling_hrs_pw*ceilfanWatts+
                   1*Cooling_FanMobile_hrs_pw*fanmobwatts+
                   1*Cooling_AirConWall_hrs_pw*AirConWatts+
                   1*Cooling_AirConSplit_hrs_pw*AirConSplitWatts+
                   1*Cooling_AirConDuct_hrs_pw*AirConDuctWatts))%>%
```

```
mutate(EUWaterHeating_kWh = (52/1000)*(WaterHeating_WaterHeater_hrs_pw*waterheaterWatts))
```

13.4 Commerce

Table 54 Appliance types from the commercial sector survey

Survey detail		Assigned ratings*	
Enduse	**Appliance**	**Units**	**Rating**
Lighting	Incandescent lamp	kW	0.1
	Halogen lamp	kW	0.1
	Compact Flourescent 6 - 18W	kW	0.018
	Flourescent 36W	kW	0.036
	LED	kW	0.005
	Open wick	Candles	1
	Hurricane lamp	L/hr	0.1
	Pressure lamp	L/hr	0.1
	Rechargeable single solar module	unit	1
	Battery powered torches	batteries/hr	0.2
	Bio gas	kg/hr	1
Appliances	Computer-desktop	kW	0.275
	Computer-laptop	kW	0.15
	Photocopier	kW	0.25
	Printer	kW	0.12
	Cooker	kW	1
	Microwave	kW	1.5
	Refridgerator	kW	0.5
	Television	kW	0.1
	Radio	kW	0.05
	Flat Iron	kW	1
	Kettle	kW	1.5
	Instant Shower heater	kW	2
	Water heater	kW	2.5
	Mobile phone/other	kW	0.01
Cooling	Fan - ceiling mounted	kW	0.045
	Fan - wall mounted	kW	0.2
	Fan - mobile	kW	0.2
	AC-split	kW	1.06
	AC-ducted	kW	2.62
	AC-wall hung	kW	0.75
Cooking	Electricity	Units given in context of each entry	
	LPG/LNG		
	Biogas		
	Kerosene		
	Charcoal		
	Firewood		
	Solar PV		

*These ratings are adapted from online sources, as well as from the SATIM model (Energy Research Centre, 2013)

Table 55 Energy consumption by enduse and technology for the surveyed commercial entities

End use	Fuel	Technology	Units	Schools	Tertiary	Banks	Banks Small	Hotels	Guest Houses	Restaurants	Hospitals/clinics	Offices
Lighting	Electricity	Incandescent lamp	kWh	518	0	0	276	0	409	1613	0	0
	Electricity	Halogen lamp	kWh	0	0	0	0	0	0	0	0	0
	Electricity	Compact Flourescent 6 - 18W	kWh	4821	254	2986	1161	28977	16425	3000	19776	10741
	Electricity	Flourescent 36W	kWh	4095	0	19575	1825	6231	0	0	1193	387
	Electricity	LED	kWh	0	0	507	0	160	34	0	0	0
	Candle	Open wick	Candle	0	0	0	0	0	20429	0	0	0
	Kerosene	Hurricane lamp	L	2880	0	4608	0	0	0	0	0	0
	Gas	Pressure lamp	L	0	0	0	0	0	0	0	0	0
	Battery	Rechargeable single solar module	?	720	0	0	0	0	0	0	0	0
	Battery	Battery powered torches	Batteries	0	0	0	0	0	0	0	0	0
	Biogas	Bio gas	L	0	0	0	0	0	0	0	0	0
Appliances	Electricity	Computer-desktop	kWh	48263	605	38016	9979	2166	527	0	4435	11088
	Electricity	Computer-laptop	kWh	0	330	0	778	0	0	0	1512	13003
	Electricity	Photocopier	kWh	90	220	1728	432	0	0	0	0	0
	Electricity	Printer	kWh	0	106	553	276	0	0	0	323	0
	Electricity	Cooker	kWh	0	2640	0	0	2780	0	0	0	2016
	Electricity	Microwave	kWh	0	0	864	0	927	638	0	0	1008

	Electricity	Refrigerator	kWh	2700	660	1728	0	4633	8938	11088	12096	4032
	Electricity	Television	kWh	720	88	576	0	13404	4171	672	538	269
	Electricity	Radio	kWh	0	0	58	0	0	85	0	67	0
	Electricity	Flat Iron	kWh	0	0	0	0	309	2979	0	1344	0
	Electricity	Kettle	kWh	540	0	864	864	0	0	0	1008	2016
	Electricity	Instant Shower heater	kWh	0	0	0	0	0	6810	0	0	0
	Electricity	Water heater	kWh	0	0	0	0	71033	14151	0	0	0
	Electricity	Mobile phone/other	kWh	0	0	47995	950	0	0	0	0	0
Cooling	Electricity	Fan - ceiling mounted	kWh	0	0	2765	4838	14268	8938	2419	806	2419
	Electricity	Fan - wall mounted	kWh	0	0	0	346	0	0	0	806	0
	Electricity	Fan - mobile	kWh	432	528	4838	0	9451	5363	0	806	2419
	Electricity	AC-split	kWh	4579	0	0	0	34374	0	0	0	4274
	Electricity	AC-ducted	kWh	0	0	67910	0	84962	0	0	0	0
	Electricity	AC-wall hung	kWh	0	0	14256	1296	13898	12449	0	3024	7560
Cooking	Electricity	Electricity	kWh	0	0	0	0	0	0	0	0	0
	LPG	LPG/LNG	kg	0	0	24	6	3018	74	0	0	0
	Biogas	Biogas	L	0	0	0	0	0	0	0	0	0
	Kerosene	Kerosene	L	0	0	0	0	0	213	0	0	0
	Charcoal	Charcoal	tonnes	0	0	6	0	14	23	44	0	0
	Firewood	Firewood	tonnes	927	36	0	0	288	84	157	0	0
	Solar	Solar PV		0	0	0	0	0	0	0	0	0