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Jinja LEAP modelling technical report

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Key points

- Jinja municipal council LEAP model data and methodology applied
- Jinja municipal council energy characteristics for energy consuming sectors
- Potential energy savings impact in Jinja from assumed changes within the demand sectors.

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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 Jinja, 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 Jinja Municipal 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 Kasese Town (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

2. General model data and methodology

Data for the model (and for the project) was collected from numerous sources over the last two years. The majority of data comes from a survey conducted on Households (HHs) and businesses in Jinja. Industry data comes mainly from interviews with industrial businesses and Jinja municipal officials working on the SAMSET project.

The energy systems model for Jinja has been developed on the Stockholm Environment Institute's (SEI) Long range Energy Alternatives Planning System (LEAP) 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).

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

From the various data points collected in this project, the year with the most intersecting data[1] is 2014. Thus, the year 2014 is the base year of the model, and 2030 is the model time horizon.

The population of Jinja Municipal Council (Saad Yahya Associates, 2008) was 72 931 people, living in 18 936 households (UBOS, 2014).

[1] More notably is that the data for liquid fuel sales and for electricity sold in Jinja overlap only in the year 2014.

3. Jinja Energy Sales

Presented in this section is the data obtained for energy supplied to Jinja municipality which is used to calibrate the Jinja model.

3.1 Liquid fuels

The municipality provided fuel sales volumes for 12 of what is thought to be 24 retail stations in Jinja. The average diesel sold per station does not vary as much as the petrol, this may be due to the locations of some fuel stations on busier routes:

Table 1: Liquid fuel sales data for Jinja municipal council for 2014

Station number	Sales per month			
	Diesel	**Petrol**	**Kerosene**	**LPG**
	L	**L**	**L**	**kg**
5	130000	801110	0	2310
6	90000	21000	0	0
4	86388	26417	7907	2025
3	75000	52500	2250	139
9	66000	36000	0	0
2	60000	45000	3000	364
7	50000	50000	0	375
12	50000	70000		1200
8	24000	21000	600	30
11	21000	24000	1500	1620
1	12000	15000	0	4800
10	4000	8000	2000	0
Average	**55699**	**97502**	**1569**	**1072**
Median	**55000**	**31209**	**600**	**370**

In this analysis, the average fuel sold per month is used and scaled to the total number of filling stations in Jinja – 24:

Table 2 Estimated liquid fuel sales total for Jinja in 2014

	Diesel	Petrol	Kerosene	LPG
	L	L	L	kg
Total Annual Sales	**16 041 312**	**28 080 648**	**432 994**	**308 706**

Converting this to mega joules, the majority of liquid fuel energy consumption in Jinja is in petrol:

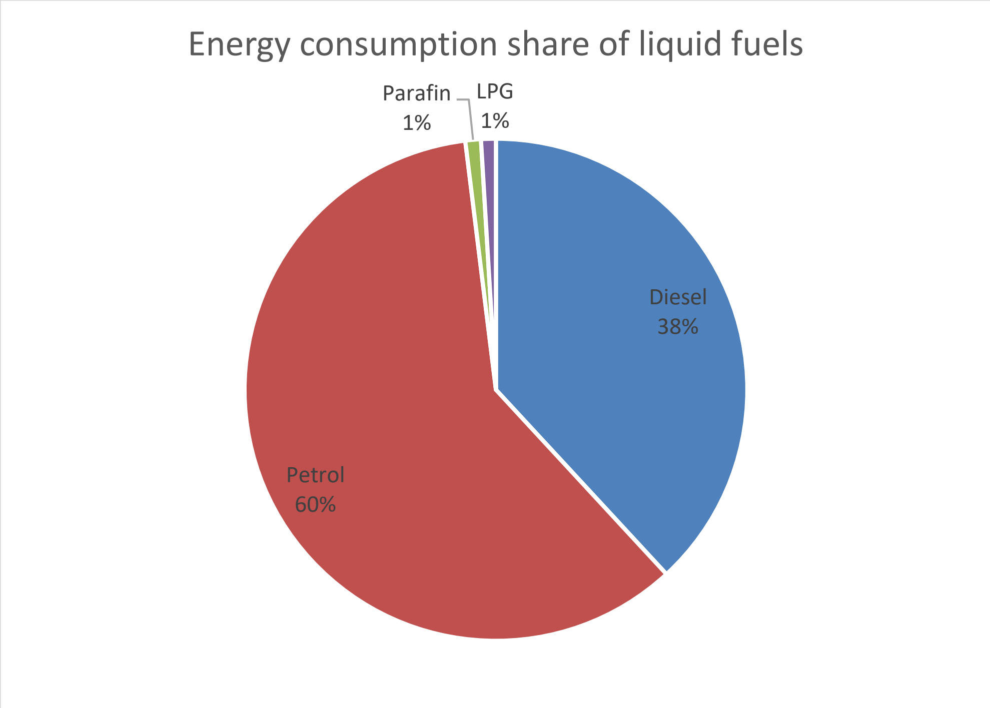

Figure 1 Jinja energy consumption shares by liquid fuels sold in 2014

3.2 Electricity

Data for electricity sales was obtained from the municipal partners, and are presented in the table below:

Table 3: Electricity (kWh) sold to within Jinja municipal council

	2010	2011	2012	2013	2014
Jinja metered electricity:	158 460 548	180 068 804	204 623 641	232 526 865	261 917 161
Industry 3 phase*	126 768 438	144 055 043	163 698 913	186 021 492	209 533 729
Single phase non domestic*	10 569 319	12 010 589	13 648 397	15 509 542	17 469 875
Domestic*	5 276 736	5 996 291	6 813 967	7 743 145	8 721 841
Losses**	15 846 055	18 006 880	20 462 364	23 252 687	26 191 716

*The municipal partners estimated industry to be 80% of the total sales, and 10% for domestic users.

**Losses were estimated by the municipality to be 10%

Converting the electricity to mega joules and combining with liquid fuels, the total fuel consumption shares show that electricity accounts for roughly the same as petrol for Jinja as given below:

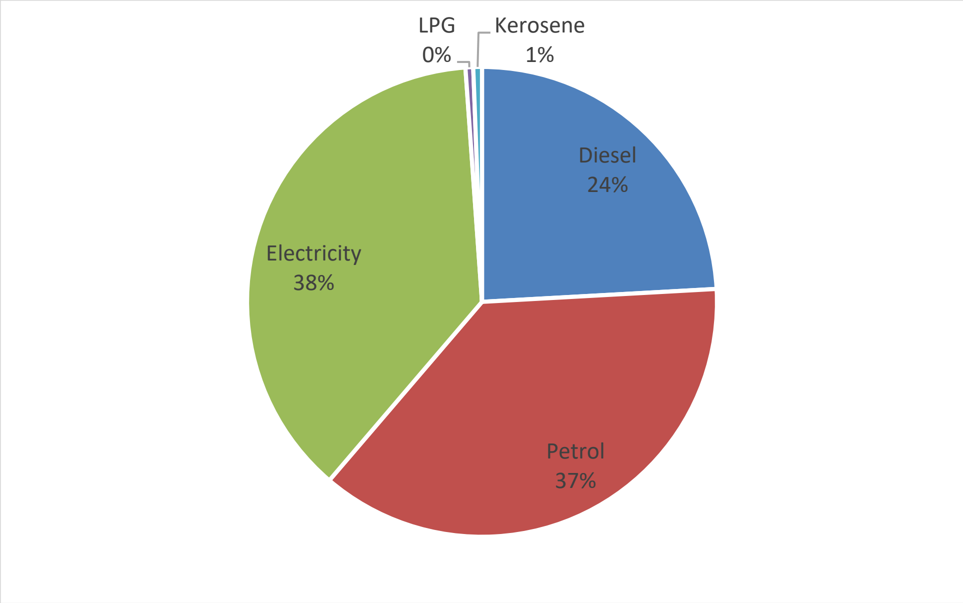

Figure 2 Jinja municipality fuel consumption shares (from sales) for 2014

4. Households

This section details the data and methodology used for the Household sector representation of Jinja.

4.1 Data

A large Household (HH) survey for Jinja was conducted by the SAMSET team – a total of 206 Households were surveyed in early 2016, 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.

The survey included numerous questions relating to quantities of fuel bought each month and how many appliances of each type the HH had. Questions about how often the appliances a HH had and used were also part of the survey.

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 Jinja in 2016

Income group	Electrification*	Survey count	Share
High income	Electrified	16	7.7%
High income	Non-Electrified	2	1.0%
Low income	Electrified	40	19.3%
Low income	Non-Electrified	63	30.4%
Middle income	Electrified	81	39.1%
Middle income	Non-Electrified	5	2.4%

* In this methodology it is assumed any HH that uses any electrical device which is not battery operated is electrified. See methodology section.

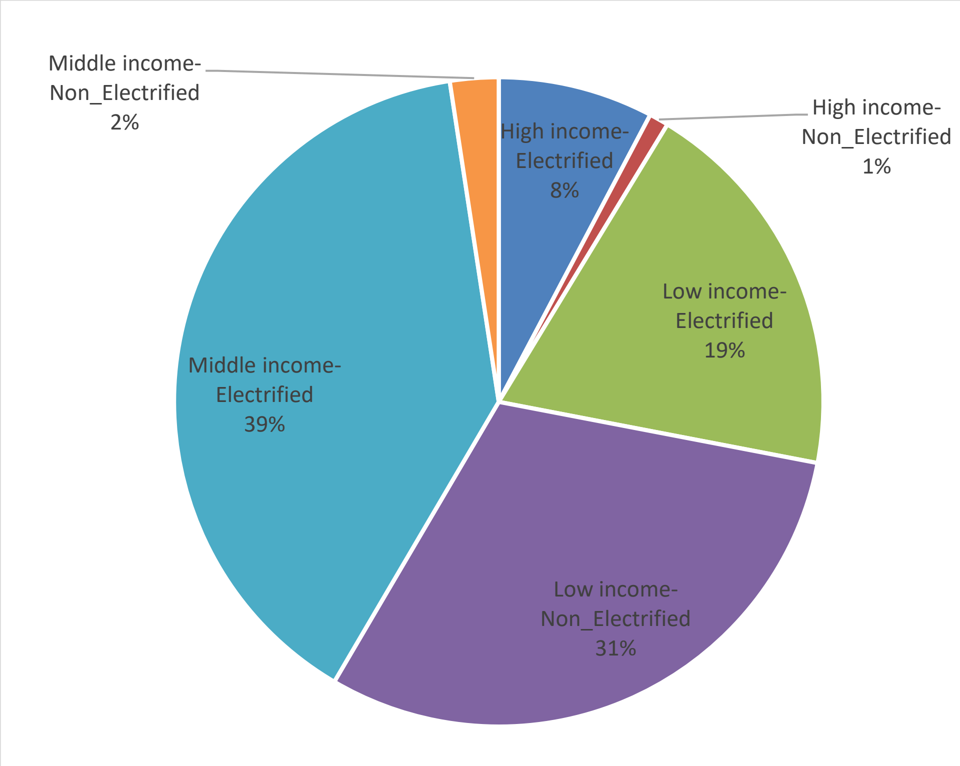

Figure 3 Households of Jinja split by income group and electrification, from HH survey

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 stereos 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:

[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.

Table 5 HH survey count of HHs using each enduse for Jinja

	Electrification	Appliances	Cooking	Cooling	Lighting	Refrigeration	Water Heating
High income	Electrified	16	49	4	21	11	2
	Non-Electrified	1	5	0	2	0	0
Low income	Electrified	37	90	6	54	11	2
	Non-Electrified	54	134	0	64	1	0
Middle income	Electrified	85	192	11	111	31	4
	Non-Electrified	5	12	0	4	0	0

These are presented as shares in the table below (using the total number of HH):

Table 6 HH enduse percentage shares from survey data for Jinja 2016

Income group	Electrification	Appliances	Cooking	Cooling	Lighting	Refrigeration	Water Heating
High	Electrified	100	100	25	100	69	13
	Non-Electrified	50	100		100		
Middle	Electrified	100	100	14	100	38	5
	Non-Electrified	100	100		80		
Low	Electrified	93	100	15	100	28	5
	Non-Electrified	86	100		100	2	

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). Using the number of Households in Jinja, the total fuel consumed can be calculated and thus checked against sales for calibration. This is presented next. For specifics about this process see the R script details in the Households section in the Appendix.

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 6) and using the energy intensities calculated for each enduse for Jinja gives a consumption of electricity that is 28% 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 three quarters of all weeks in the year instead of every week of the year.

With these assumptions the electricity consumption for households in Jinja is within 7% of the sales.

The resultant intensities by technology and their associated shares for the HH sector is given in Table 69 in the Appendix.

Observation on 'efficient' charcoal 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 use more (often substantially more) fuel than the regular stove counter parts. These results are presented in the table below and figure as well.

Table 7 HH survey charcoal consumption per person by stove type

Household Income Group	Charcoal Stove Type	Charcoal kg per person per month average	Count Of Survey
H-Electrified	Efficient	18.49	8
H-Electrified	Regular	11.71	8
H-Non-Electrified	Efficient	20	2
L-Electrified	Efficient	19.42	24
L-Electrified	Regular	14.41	11
L-Non-Electrified	Efficient	13.29	33
L-Non-Electrified	Regular	12.2	22
M-Electrified	Efficient	15.77	58
M-Electrified	Regular	21.27	18
M-Non-Electrified	Efficient	20	2
M-Non-Electrified	Regular	7.5	3

A histogram plot of these results below shows the overlap of 'efficient' stoves with regular ones (ie the efficient ones use as much as the regular stoves if not more):

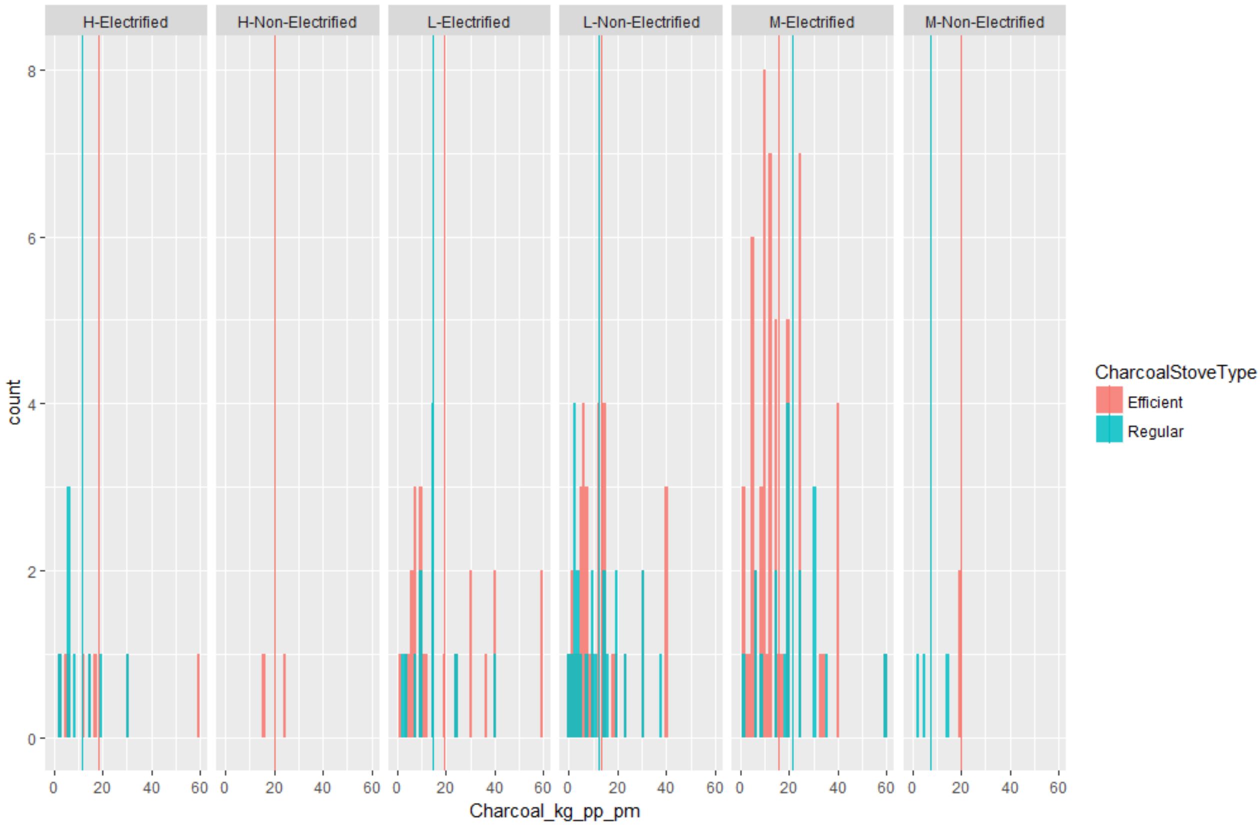

Figure 4 Charcoal usage per month per person by HH group and by cook stove type from HH survey

For firewood, being an urban area - there were less observations to draw comparisons between efficient and regular stove types[4], and thus, derivations from survey are skewed or biased based on the few observations from the survey:

Table 8 HH survey firewood consumption per person by stove type

Income Group	WoodStove Type	Firewood kg per person pm average	Count form Survey
H-Electrified	Regular	11.24	3
L-Electrified	Regular	36.04	7
L-Non-Electrified	Efficient	53.57	1
L-Non-Electrified	Regular	15.84	10
M-Electrified	Regular	17.76	14
M-Non-Electrified	Regular	62.5	1

[4] However, from the same survey carried out in Kasese as part of the SAMSET project, it was observed firewood efficient stoves suffered the same ineffectiveness issues as charcoal efficient stoves.

5. Industry

Historically Jinja has been the industrial hub of Uganda since it was in close proximity to the hydro power plant built at the Nile river mouth, where access to cheap electricity made it desirable for Industries to set up here.

The main industries in Jinja are:

- Steel manufacturing
- Leather manufacturing
- Vegetable oils and food products
- Grain Milling

This section outlines the data collected and methodology used to create a LEAP model representation of the industry in Jinja.

5.1 Data

Data for the industry sector was obtained from various interviews of large key industries by the municipality in partnership with the SAMSET team. This occurred over two years between 2014 and 2016. Other sources of data include web news articles and various literature available publically.

Data collected from these industries were accounts of how much per month (or yearly) the industry bought/consumed for the various fuels they utilised and did not indicate what the fuels were being used for – i.e. there is no data on energy consumption by enduse (Heating, machining, lighting etc.).

A total of 7 industries were surveyed:

- 2 X vegetable oil production facilities,
- 2 X tanneries,
- 1 X Steel works,
- 1 X Grain milling plant, and
- 1 X Lime production facility

However, according to various online articles as well as communication with municipal partners, it is believed there are:

- 6 more Grain millers,
- 1 other steel production facility,
- 3 more tanneries, and
- 3 more vegetable oil and food production facilities

According to the Jinja Municipal Structures report (Saad Yahya Associates, 2008), there were **52 operational industries in 2009**.

It should be noted that smaller industries or industrial businesses have not been surveyed but would undoubtable contribute significantly towards energy consumption in industry.

Data collected for these surveyed industrial entities are given below, and represent the year of 2014:

Table 9 Industry fuel consumption data for surveyed industries in Jinja 2014

	Bagasse	Biomass other	Charcoal	Coal	Diesel	Electricity	Wood	HFO	Petrol
Industry	t	t	t	t	L	kWh	t	L	L
Lime						432000	3240	540000	
Milling						408000			
Steel			6770	1030	12000	18000000		1140000	
Tanneries					162000	969504	409		1000
Vegetable oils	31407	31746			1125000	16500000	16531		165000
Total	**31407**	**31746**	**6770**	**1030**	**1299000**	**36309504**	**20180**	**1680000**	**166000**

NOTE: Much of the data collected for these industries was in another unit or scale, or occasionally only a monthly figure (in which this was scaled to represent the year). The table above represents the data after some processing and cleaning was done.

The total industrial production estimates for Jinja for the industry types in the survey are presented in the table below:

Table 10 Total Industry production data for Jinja 2014

Industry	Produces	Tonnes	Comment
Tanneries	Leather	19800	Stakeholder indicated this is the total for Jinja.
Steel	Steel	15744	Combination of data and public information.
Lime	Lime	10800	
Milling	Maize	6300	Scaled from 1 to 7 grain mills

5.2 Methodology

The approach taken here to calibrate the industrial sector was to calibrate to total electricity sold to the industrial sector as given in section 3.2.

<u>Methodology overview of industry setup and calibration:</u>

- Surveyed entities are only a sample of those industries in Jinja – scale up the surveyed entities' consumption to represent those industries in Jinja
- Using electricity sales to industries, calculate remaining electricity – this to be assigned to 'other industry'.
- Calculate other fuels (excl. electricity) consumption for 'other industry'

These methodological steps are elaborated below:

Of the 5 industry types surveyed, for steel and tanneries we have an estimate for the total production from these industries in Jinja – see Table 10. Thus the total energy consumption for these industry types are scaled up using these figures (this would inherently assume that the other industries would be fairly similar in energy characteristics). For grain milling, and vegetable oils industries we scale these up by the number of industries thought to be in Jinja. This scaling up is applied to electricity consumption and to other fuels (also assuming similar consumption characteristic for these industries). See the 'Quantity from scaling up' column in Table 12.

When summing the electricity consumption for these industries, they consume 69 822 044kWh or 33% of the total electricity sold to industries in Jinja. The remaining 67% of electricity is assigned to 'Other industry'. For other fuels in the 'other industry', they are estimated using a ratio of electricity to other fuels (LPG, Charcoal etc.) consumed and scaled using the electricity assigned to this industry multiplied by an elasticity assumption – the other industries would presumably not be similar in characteristics to those that were surveyed. These calculations and assumptions are given in the table below:

Table 11 Other industry fuel consumption – Industry calibration

Other fuels:	Survey intensities	Assumed elasticity	Total consumption	Units
Electricity*			139711685	kWh
Diesel	0.0358	0.5	2499146	L
Charcoal	0.0002	0.4	10420	Tonnes
Firewood	0.0006	0.5	38824	Tonnes
Petrol	0.0046	0.5	319367	L

* From the outstanding electricity sales.

Table 12 below gives the breakdown of the survey data and their scaled up estimates as well as the 'other industry' calibration results (from above):

Table 12 Industry fuel consumption and production estimates for Jinja 2014

Industry	Fuel	Units	Quantity from survey data	Quantity from scaling up	Total Quantity	Industry Production /output - tonnes	Energy intensity per unit output
Vegetable oils	Electricity	kWh	16500000	24750000	41250000		41250000
	Firewood	Tonnes	16531	24797	41328		41328
	Bagasse	Tonnes	31407	0	31407		31407
	Petrol	L	165000	247500	412500		412500
	Diesel	L	1125000	1687500	2812500		2812500
	Biomass other	Tonnes	31746	0	31746		31746
Tanneries	Electricity	kWh	969504	183750	1153254	19800	58
	Firewood	Tonnes	409	1023	1432		0.072
	Petrol	L	1000	2500	3500		0.177
	Diesel	L	162000	405000	567000		29
Steel	Electricity	kWh	18000000	6130790	24130790	15744	1533
	Diesel	L	12000	4087	16087		1
	Coal	Tonnes	1030	0	1030		0.065
	Charcoal	Tonnes	6770	2306	9076		1
	HFO	L	1140000	0	1140000		72
Lime	Electricity	kWh	432000	0	432000	10800	40
	Firewood	Tonnes	3240	0	3240		0.300
	HFO	L	540000	0	540000		50
Milling	Electricity	kWh	408000	2448000	2856000	15700	182

Other Industry (Calibration)	Diesel	L		2499146	2499146		2499146
	Charcoal	Tonnes		10420	10420		10420
	Firewood	Tonnes		38824	38824		38824
	Petrol	L		319367	319367		319367
	Electricity	kWh		139711685	139711685		139711685

Into the LEAP model

The production estimates (for those industries we have numbers for) are used as drivers for those industries in Jinja in the LEAP model. Thus we use the energy intensity numbers from the table above as input into the model for those industries. For industries where we do not have production numbers (including the ‘other industries’ calibration) we use absolute numbers for energy consumption in the model.

NOTE ON DIESEL AND PETROL: in this methodology we do not use do not include diesel or petrol consumption in industry in the LEAP model as it was unclear as to how much was being used for onsite purposes (generation or other) as opposed to vehicle transport which would be covered in the transport section. Thus they are excluded to avoid double counting in transport.

NOTE ON CHARCOAL: The one steel works is reportedly producing iron from a Direct Reduction process. In this case, the charcoal would be used as a reducing agent – essentially a chemical, rather than to combust as a fuel. In this work however, we include the charcoal here as part of energy consumption.

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.

In this study, we model the energy demand from transportation of passengers in Jinja and to some extent local freight activity using survey data, estimates elicited from stakeholders and assumptions. A significant corridor component is included in order to balance local fuel sales but detail on corridor activity was lacking and this part of the representation relies heavily on assumption.

The public transport situation has been summed up qualitatively in the Jinja Municipal Council (JMC) Proposed Structure Plan Report 2009 – 2019 (Saad Yahya Associates, 2008) as follows:

> *"Public Transport – Short, medium and long distance travel to and from the Municipality is mainly by minibus, while commuting within is by bicycle and motorcycle (privately owned or as a fare paying passenger) and walking.*
>
> *The major public transport means is the 14-seater minibus (matatu), followed by 28-seater minibus. There are also a few big buses of capacity ranging from 40 – 60 seats. The public transport is organized in four categories i.e. taxis (Matatus), buses, special hire taxis and boda-bodas (bicycle and motorcycle)"*

The report noted that all the minibuses travel beyond the JMC boundary each day. Most (90%) were the 14 seater type vehicles, and that the minibuses have 6 dropping and pick up areas in the municipality. Most of these travel to Kampala, Kamuli, Buwenge and Kayunga.

For buses: these operate for medium distance destinations. Roughly 10 large buses and 26 medium buses service about 5 key routes. There are also 3 drop and pick up areas for buses in JMC.

Special hire taxi's operate from 5 drop-off and collection zones and are typically 5 seater vehicles with a few 7 seater vans as well. These are typical for tourists going to nearby national parks or to Kampala or the airport in Entebbe.

"Boda Bodas" are the colloquial name for motorcycle taxi's. These operate within and just outside of the CBD of Jinja. There are about 30 collection sites around JMC for bodas.

The report summarised the status of the rail service to Jinja as follows:

- The railway line is only cargo services currently. The Jinja railway station handles about 250 wagons of 40 tonnes each, monthly. The cargo is destined for Jinja and neighbouring districts.
- There is also a large amount of cargo coming through Jinja from Mombasa to Kampala.
- The railway cannot handle (in 2009) containers as there is no crane.
- There is lots of room for capacity growth, with the shunting yard having a capacity of 400 parked wagons.

6.1 Data

Data on transportation was gathered by two methods: stakeholder engagement and from responses to a transport section of the household survey undertaken by the University of Uganda Martyrs (UMU, 2016). The stakeholders, which included the municipal partners of the project, estimated the count of operating vehicles of different types and the local retail sales of petroleum fuels from 12 of the 24 outlets (see Section 3.1) which were scaled up. The household survey captured the following data from individual householders:

- 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

Stakeholder engagement data

The municipality provided the following vehicle count data for JMC:

Table 13: Vehicle count data for JMC for 2014 obtained from SAMSET municipal partners

Type or source	Vehicle count	Engine Size
Private individual vehicles	2100	1000-3000cc
Taxi's	690	3000-5000
Institutions	151	3000-6000
Lorries and pickups	290	5000-1000
Special hire taxi	290	1000-2500
Motorcycles	1500	100-300
Lorries and trucks	290	

NOTE: This vehicle count equates to a motorisation of 48.3 vehicles per 1000 people.

From section 3.1 the fuel sales assigned to transport are:

Table 14: Liquid fuel sales for JMC in 2014

	Litres
Petrol	28 080 648
Diesel	16 041 312

HH survey transportation data

For the 206 households surveyed, a total of 1161 household members were indicated. Data fields were initiated for 828 and 413 of these were completed. A further 20 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 432 householders or 37% 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 (4%) and missing trip time data (22%) 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 15 below.

Table 15: Passenger transport Trip Based mode data from HH survey for Jinja 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	194	2173	44%	110	53%
Bicycle	5	66	1%	4	2%
Motorbike (personal/work)	12	129	3%	6	3%
Boda Boda	138	1534	31%	89	43%
Taxi (Special hire)	2	16	0.32%	2	1%
Minibus taxi	31	370	7%	27	13%
Bus	0	0	0%	0	0%
Company minibus/bus/truck	15	151	3%	8	4%
Own Car	36	498	10%	29	14%

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 16 and Figure 5.

Table 16: Passenger transport trip frequency, trip time and estimated passenger.km based mode data from HH survey for Jinja 2016

Mode	Average Trips/Week	Average Trip Time (min)	Assumed Mode Speed	pkm per week	pkm Mode Share
Walk	11	29	4	4177	17.4%
Bicycle	13	24	10	263	1.1%
Motorbike (personal/work)	11	8	35	575	2.4%
Boda Boda (Motorcycle taxi)	11	13	35	11916	49.6%
Taxi (Special hire)	8	20	30	160	0.7%
Minibus taxi	12	15	30	2736	11.4%
Bus	-	-	25	0	0.0%
Company minibus/bus/truck	10	19	30	1374	5.7%
Own Car	14	11	30	2805	11.7%

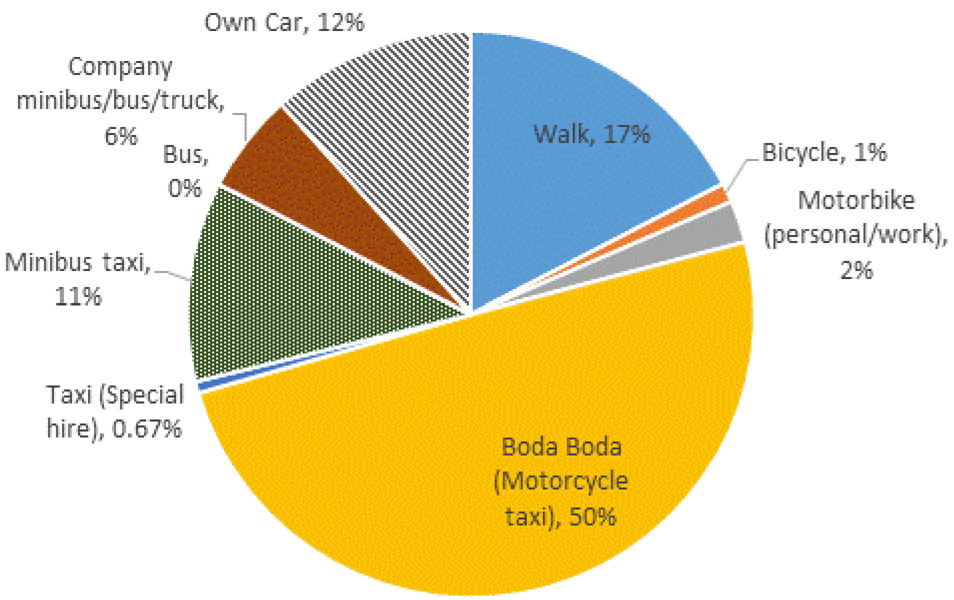

Figure 5: Surveyed passenger km based Mode Share for Jinja

As expected, walking dominates trip mode share 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 half of all passenger km demand. Trip times are short on average suggesting low levels of congestion.

As shown below in Table 17, 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 17: 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	7%	16%	9%	33%	34%	64%
Bicycle	0%	0%	0%	0%	3%	3%
Motorbike (personal/work)	0%	1%	5%	6%	0%	0%
Boda Boda (Motorcycle taxi)	46%	26%	52%	39%	49%	25%
Taxi (Special hire)	0%	0%	1%	1%	0%	0%
Minibus taxi	17%	15%	12%	8%	8%	5%
Bus	0%	0%	0%	0%	0%	0%
Company minibus/bus/truck	0%	0%	9%	6%	4%	1%
Own Car	30%	42%	12%	8%	2%	2%
Summary Data	**km**	**trips**	**km**	**trips**	**km**	**trips**
TOTAL/week (sample)	4167.2	724.2	11346.4	2021.2	8491.4	2192.4
TOTAL/person/day	12.9	2.2	10.6	1.9	7.1	1.8
Average Trip Length (km)	5.8		5.6		3.9	

Respondents	54	179	199

Interestingly, the preference for the boda-boda mode was consistently high across income groups. The high income group undertake more and longer trips (arises because we assumed motorised trips are faster) but in general, assuming 6 travel days a week, the respondents travelled around 10 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 bottom up survey data can be reconciled with the top down vehicle count data in Table 13 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 (413 for Jinja)
P_D = Population of District (72,931 for Jinja)
$T_{S,M}$ = 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 13 where relevant and possible as presented below:

Table 18 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]	0.5	3%	1011	3818	1.3	3.0	1011
Boda Boda (Motorcycle taxi)[1,2]	5.5	43%	1500	45270	2.2	13.7	1500

Taxi (Special hire)	3.1	1%	59	472	2.0	4.0	59
Minibus taxi[2]	3.6	13%	690	10922	5.0	3.2	690
Company minibus/bus/truck[3]	2.6	4%	281	4455	6.3	2.5	281
Own Car[2]	1.27	14%	2100	14687	2.3	3.0	2100

1: Occupancy includes driver because drivers appear to be captured in survey data
2: Assumptions have been used to calibrate vehicle count to Table 13 (motorcycles assumed to be all bodas)
3: Used survey data to estimate vehicle counts for these modes

The survey data supported the top down estimates of boda-bodas and private cars given reasonable but quite high assumptions for occupancy and vehicle usage rates. If the car preference of the survey sample is extended to the entire district for example, a fleet of only 2100 private cars implies that over 20% of households who have members who prefer the private car mode are sharing a car with another household. 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 survey mode preferences and trip rates didn't however strongly support the numbers of taxis (special hire) and minibus taxis captured in the stakeholder consultation process. The numbers of vehicles indicated by the stakeholder consultation may however be active if these vehicles are used for longer inter-city trips not captured by the survey or if they are used for part time employment. The special hire taxis may also be used by commercial clients that were not part of the survey. The survey data was also used to estimate probable numbers of company transport vehicles (minibus/bus truck) and private motorcycles which were not estimated by stakeholder consultation.

Other sources of data

To construct the transportation model, detail about the energy efficiencies and fuel types of the vehicles in Uganda are used based on national numbers from Mutenyo et. al. (2015):

Table 19: 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%

Table 20 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

Construct Passenger transport

Using the vehicle count data from stakeholders' data and from the HH survey, the vehicle count for the passenger transport model is given below:

Table 21 Passenger vehicle count for Passenger transport model in Jinja

Vehicle type/mode	Vehicle count	Comment
Motorbike (personal/work)	1011	From HH survey estimate
Boda Boda (Motorcycle taxi)	1500	
Taxi (Special hire)	290	
Minibus taxi	690	
Company minibus/bus/truck	281	Added to vehicles based on HH survey results
Own Car	2100	

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

Table 22 Fuel split by transport mode for Jinja

Vehicle type	Diesel	Petrol
Motorbike (personal/work)	0%	100%
Boda Boda (Motorcycle taxi)	0%	100%
Taxi (Special hire)	2%	98%
Minibus taxi	77%	23%
Bus	100%	0%
Company minibus/bus/truck	77%	23%
Own Car	1%	99%

The fuel economy for vehicles is adapted from Mutenyo et. al. (2015):

Table 23 Fuel economy (L/100km) of passenger vehicles

Vehicle type	Diesel	Petrol
Motorbike (personal/work)		1.9
Boda Boda (Motorcycle taxi)		1.9
Taxi (Special hire)	13.4	11.8

Minibus taxi	11.4	13.5
Bus	31.2	
Company minibus/bus/truck	11.4	13.5
Own Car	13.4	11.8

Passenger occupancy of the vehicles is an assumption:

Table 24 Assumed Vehicle occupancy for passenger transport

Vehicle type	People/vehicle
Motorbike (personal/work)	1
Boda Boda (Motorcycle taxi)	2.2*
Taxi (Special hire)	5
Minibus taxi	10
Bus	
Company minibus/bus/truck	5
Own Car	1.5

**this is used to bring down the total mileage (km/year) per boda boda and also includes the driver. This is not unreasonable as boda boda's frequently have more than one passenger.*

Using the passenger-km data from the survey scaled up to district level, the passenger-km demand by each vehicle mode is given in the table below:

Table 25 Passenger-km by mode for Jinja

Vehicle type	pkm
Motorbike (personal/work)	5 288 973
Boda Boda (Motorcycle taxi)	94 012 960
Taxi (Special hire)	1 472 781
Minibus taxi	25 188 745
Company minibus/bus/truck	12 649 044
Own Car	25 820 803

From the passenger transport analysis (using the HH survey combined with stakeholder data) the total demand for transportation by public or private mode was calculated:

Table 26 Passenger-km total for Public and Private transportation in Jinja

	Pass-km
Public	119 201 705
Private	45 231 600
Total	**164 433 306**

Below is the figure for pass-km for Jinja showing boda boda's making up the majority of passenger transport activity for Jinja:

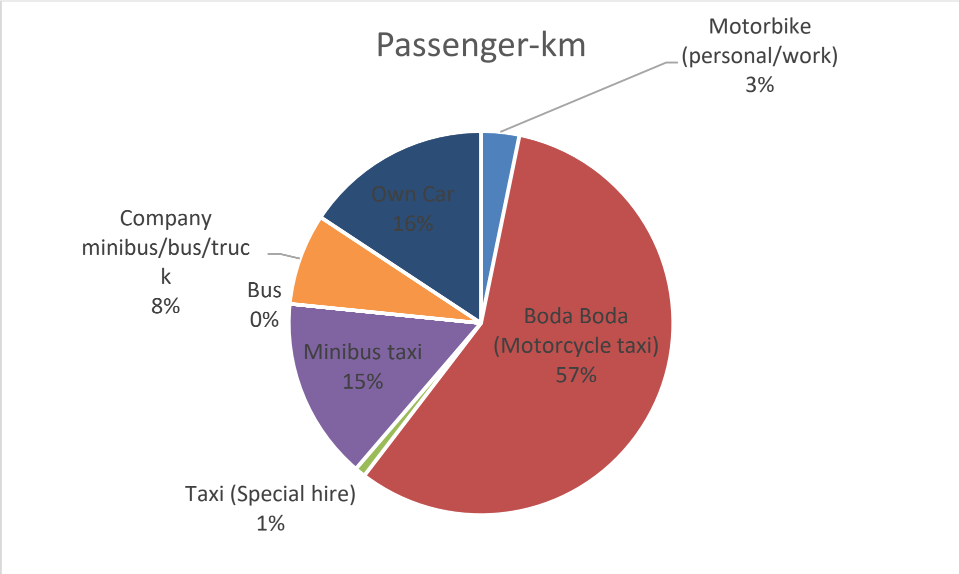

Figure 6 Passenger-km share by motorised transport mode for Jinja

Using the assumed occupancies of each vehicle, the total mileages (km/year) for each mode is calculated:

Vehicle type	Pass-km	veh-km
Motorbike (personal/work)	5288973	5288973
Boda Boda (Motorcycle taxi)	94012960	42733164
Taxi (Special hire)	1472781	294556
Minibus taxi	25188745	2518875
Company minibus/bus/truck	12649044	2529809
Own Car	25820803	17213869

Using the fuel splits and fuel efficiencies (Table 22 and Table 23) with the total vehicle-km from above, the total fuel consumption for these vehicles is given below:

Table 27 Fuel consumption (L/year) by mode for passenger transport in Jinja

Vehicle type	Diesel	Petrol
Motorbike (personal/work)		100490
Boda Boda (Motorcycle taxi)		811930
Taxi (Special hire)	744	34102
Minibus taxi	220302	79164
Company minibus/bus/truck	221258	79508
Own Car	21081	2012673
Total	**463,385**	**3,117,867**

Using vehicle count and vehicle occupancy with the total passenger-km serviced for each mode, an indicator of vehicle mileages for this transport model are given below:

Table 28 Vehicle mielages by vehicle type in this passenger transport model for Jinja

Vehicle type	Occupancy	km/year per vehicle
Motorbike (personal/work)	1	5 231
Boda Boda (Motorcycle taxi)	2.2	28 489
Taxi (Special hire)	5	1 016
Minibus taxi	10	3 651
Company minibus/bus/truck	5	8 989
Own Car	1.5	8 197

6.2.2 Freight

From Yahya (2008) it is thought that there were at least 33 heavy vehicles (up to 21.4 tonnes capacity) operating with the industries in Jinja, and about 60 trucks with 7.5 tonne capacities.

In this work, we assume the 33 heavy vehicles (HCV – heavy commercial vehicles) and the 33 7.5 tonne capacity or MCV (medium commercial vehicles) are accounted for within the 290 'lorries and trucks' data given by stakeholders in this work. Thus there would be 197 other vehicles, which we assume 75% of which would be pickup trucks and 25% would be MCV's.

Thus the freight vehicle count for Jinja is given in the table below:

Table 29 Freight vehicle count for Jinja transport

Vehicle	Count
Heavy	33
MCV	109
Pick ups	148

The fuel type split used is given in the table below and were taken from Table 19:

Table 30 Freight transport fuel split by vehicle type for Jinja

Vehicle type	Diesel	Petrol	Comment
HCV	100%	0%	Based on >5000cc
MCV	92%	20%	'Heavy duty 3500 – 4000cc'
Pick ups	65%	50%	An average of light duty 2000 to 3500cc

To obtain freight demand (and activity) we assume vehicle mileages for these vehicle types and assume that 50% of the mileages are serviced outside of Jinja – ie. 50% of the vehicle's travels are fuelled from fuel picked up from outside of Jinja. We also assume an average load for these vehicles:

Table 31 Freight vehicle annual activity assumptions

Vehicle	Assumed Vehicle km/year	Assumed share of mileage serviced outside Jinja	Vehicle load capacities
HCV	40000	50%	21
MCV	30000	50%	8
Pick ups	20000	50%	1

The fuel economies of the freight vehicles are given below, and come from SATIM methodology (Energy Research Centre, 2013):

Table 32 Freight vehicle fuel efficiencies (L/100km)

Vehicle	Diesel	Petrol
HCV	37	
MCV	29	22.9
Pick ups	18	20

NOTE: more local numbers for fuel efficiencies should have been used rather than those from Mutenyo et. al. (2015) in Table 20, as 'light' and 'heavy' vehicles is not descriptive enough to adequately adapt for this work. Also, diesel consumption should be less (in Litres/100km) than the petrol counterpart generally (depending on relative vehicle mass).

Using the assumed vehicle mileages, the vehicle counts, vehicle load factors, and the assumption that Jinja only accounts for a portion of all the vehicles travels, then the fuel total fuel consumption for these freight vehicles is calculated:

Table 33 Freight transportation fuel consumption and ton-km for Jinja

Vehicle	Fuel consumption – Litres per year		Tonne km per year	
	Diesel	Petrol	Diesel	Petrol
Heavy	244200		14140000	
MCV	442313	75055	11322005	2458125
Pick ups	111010	96038	965307	738750
Total	**797,523**	**171,092**	**26,427,312**	**3,196,875**

6.3 Transport sector in the LEAP model

Passenger-km was used as the driver for passenger transport, and tonne-km as the driver for freight in the model. Thus, we use the energy intensities for each vehicle type for passengers and their share of passenger-km to represent the transport sector as given below:

Table 34 Passenger transport energy intensities and shares for Jinja

Public or private transport	Technology	%share of Public/private passenger-km	MJ/pkm
Public	Boda Boda	79%	0.29
Public	Minibus P	5%	0.45
Public	Minibus D	16%	0.41

Private	Individual Car P	57%	2.61
Private	Individual Car D	1%	3.20
Private	Omnibus D	0%	0.96
Private	Omnibus P	3%	0.78
Private	Minibus prvt P	7%	0.90
Private	Minibus prvt D	21%	0.82
Private	Motorbike	12%	0.63

The freight detail input into the LEAP model:

Table 35 Freight transport shares and energy intensities for Jinja LEAP model

Vehicle	Share of freight	MJ/ton-km
Pickups Diesel	3%	4.34
Pickups Petrol	2%	4.31
Heavy trucks	48%	0.65
MCV Diesel	38%	1.47
MCV Petrol	8%	1.01

7. Local government

This section describes the fuel consumption relating to the operations of the Jinja municipality.

7.1 Data

The data obtained from the municipality indicated the following consumption patterns for municipal operations:

Table 36 Municipal operations energy consumption for Jinja

Fuel	Units	2010	2011	2012	2013	2014
Diesel	Litres	49 194	48 643	28 221	47 499	45 842
Petrol	Litres	9 663	9 299	6 652	10 518	9 474
Electricity	kWh	147 785	198 288	268 701	53 244	33 741

The use of the energy within the municipal buildings and operations is unclear at this point. It is assumed the fuel consumption is for the municipal vehicles.

The electricity consumption drops rapidly between 2012 and 2013 due to non-payment to the electricity supplier by the municipality.

Converting to Mega Joules, in 2014 most of the municipality's energy consumption was in diesel:

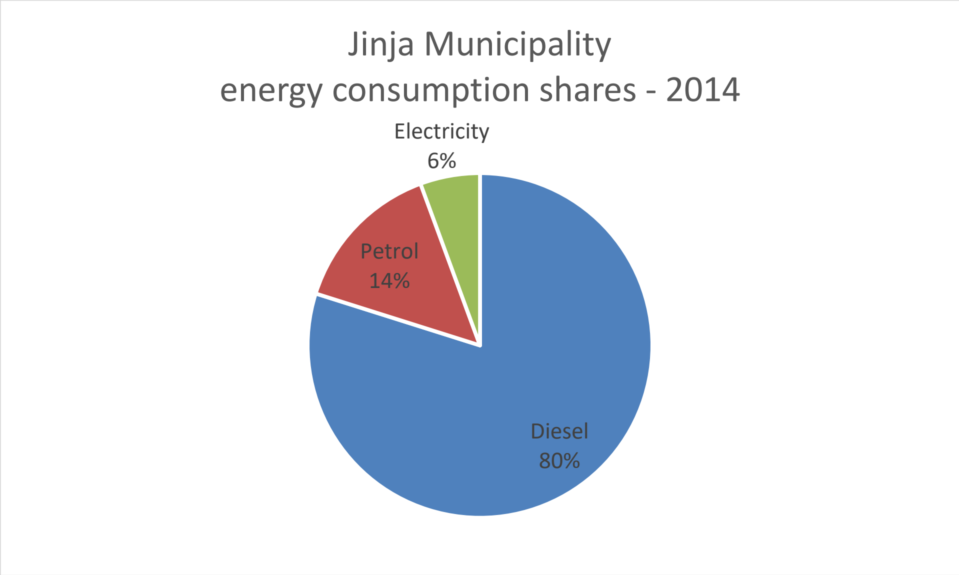

Figure 7 Jinja Municipality operations energy consumption share by fuel for 2014

Into the LEAP model

The absolute consumption numbers as given in the table above are used as input into the model.

8. Commercial sector

This section describes the commercial sector representation of Jinja from data collected to the input into the LEAP model.

8.1 Data

A survey was conducted in Jinja of several commercial activities in 2016 as part of the SAMSET project. The survey was conducted at:

10 Primary Schools

6 Secondary schools

2 Tertiary institutes

6 Hotels

10 Guesthouses

3 Bar/Guesthouses

8 Restaurants

2 Banks

This survey did not cover shops, informal commercial activities or offices which would also constitute part of the commercial sector of Jinja. This is an area for improvement in understanding Jinja's 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, instead another approach to calculating their total consumption is used. This is described in the next section. See Table 67 in the appendix 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 surveyed entity.
- Make an assumption of number of hours a working/active day each surveyed entity 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.

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

The commercial entities were assigned to subsectors, these are:

Table 37 Commercial sector surveyed entities assignment to sector type

Surveyed entity	Commercial subsector
Schools	School
Tertiary	School
Banks	Offices
Hotels	Hospitality
Guesthouses	Hospitality
Restaurants	Hospitality

Yearly activity for each surveyed entity:

Table 38 Assumptions on yearly activity for each commercial entities

	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	0.42	142
Guesthouses*	7	4	12	0.42	142
Restaurants	7	4	12		336
Hospitals/clinic	7	4	12		336
Offices	7	4	12		336

* These are adjusted based on data given for the % occupancy average for a year.

For energy ratings of each appliance used in this methodology see Table 67 in the Appendix.

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 39 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
	GuestHouses	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

Multiplying the ratings for each appliance type and for each commercial sector, gives the total fuel consumed for each enduse by appliance and fuel, this is presented in Table 68 in the appendix. A summary of fuel consumption for each commercial entity is given below:

Table 40 Commercial sector survey calculated fuel consumption by fuel type for Jinja

	Electricity	**Charcoal**	**Wood**	**LPG**	**Paraffin**
	kWh	tonnes	tonnes	kg	L
Schools	183715	7	1382		158
Tertiary	135383	1	72		
Banks	137756			90	
Hotels	289375	24	76	18540	
Guesthouses	41028	5		342	
Restaurants	80089	80	91	6527	
Total	**867346**	**117**	**1621**	**25499**	**158**

This energy consumption is then scaled up to represent the whole of Jinja commerce using assumptions on the sample size of the survey (there was no indication of how much of the population the survey covered). The assumption on survey size is presented below:

Table 41 Assumed sample size of the commerce survey for Jinja

Surveyed entity	**Sector group**	**Assumed sample size coverage**
Schools	School	20%
Tertiary	School	20%
Banks	Offices	5%
Hotels	Hospitality	20%
Guesthouses	Hospitality	20%
Restaurants	Hospitality	5%

Scaling based on this assumption, the total fuel consumption for these subsectors for commerce in Jinja is given below:

Table 42 Fuel consumption of commercial surveyed subsectors scaled to Jinja

	Charcoal	Firewood	LPG	Kerosene	Electricity
	tonnes	tonnes	kg	L	kWh
Schools	41	7270	0	788	1595490
Offices	0	0	1800	0	2755123
Hospitality	144	381	94410	0	1652015
Restaurants	1597	1824	130536	0	1601786
Total	1781	9475	226746	788	7604414

From this bottom up scaled up calculation, this representation of the commercial sector consumes 7 604 414 kWh of the total 17 469 875 kWh sold to commercial entities in Jinja, or about 43%.

Calibration

To calibrate the commercial sector, the remaining electricity sales is assigned to 'Other commerce' and an estimate of the other fuels used is calculated by using a ratio of other fuel consumption to electricity consumption from the table above. This assumption is given in the table below:

Table 43: Commerce 'other' sector – calibration details

Fuel	Units	Ratio of fuel to electricity (kWh) from survey	Assumed elasticity*	Total 'Other Commerce' consumption
Charcoal	tonnes	0.000117	0.5	1 155
Firewood	tonnes	0.000623	0.5	6 146
LPG	kg	0.014909	0.5	147 083
Paraffin	L	5.18E-05	0.5	511
Electricity	kWh	1		9 865 461

* This is an assumption on how 'different' the 'other commerce' sector might be compared to the surveyed entities – ie. Other sectors might use less charcoal (<1) than those in the survey. Here we assumed they are all less for each fuel type.

Combining this with the survey data the total commercial sector fuel consumption is given in the table below for each fuel:

Table 44 Total fuel consumption for commercial sector of Jinja by fuel type

Fuel	Units	Quantity
Charcoal	tonnes	2 937
Firewood	tonnes	15 621
LPG	kg	373 829
Kerosene	L	1 298
Electricity	kWh	17 469 875

Input to the LEAP model

The commercial sector is split into those groups as given in Table 41 with the added 'Other Commerce' sector group. The final inputs into the LEAP model for these are presented below.

Note that in this methodology, without sufficient data on the activity of the commercial sector (usually this is tracked using floorspace data), the fuel consumption total is entered as absolute.

Table 45 Commerce subsectors fuel consumption per annum by enduse for Jinja

Enduse	Technology	Units	Schools	Offices	Hospitality	Restaurants
Lighting	Incandescent	kWh	21600		46571	
	CFT	kWh	214162	547430	244939	284498
	Kerosene Lamps	L	720			
	Solar	unit			8519	
Appliances	Electricity	kWh	1255835	476410	611958	817925
Refrigerator	Electricity	kWh	61599		203392	403200
Cooling	Fan	kWh	34194	10886	121077	96163
	AC Split	kWh				
	AC ducted	kWh		1720397	424078	
	AC wall	kWh	8100			
Cooking	Electricity	kWh				
	LPG	kg		1800	94410	130536
	Kerosene	L	68			
	Charcoal	tonnes	41		144	1597
	Firewood	tonnes	7270		381	1824

The total fuel consumption into the LEAP model for the 'other commerce' subsector is given below:

Table 46 'Other Commerce' subsector fuel consumption for Jinja

Fuel	Units	Total
Electricity	kWh	9 865 461
Charcoal	Tonnes	1 155
Firewood	Tonnes	6 146
LPG	kg	147 083
Kerosene	L	511

9. BAU Scenario

The Business as Usual (BAU) scenario is the assumed projection of Jinja's energy system to the year 2030. It is generally the expected average trend (if any) of the energy system components – such as transport and Households, without much institutional change or policy changes. This is done so as to serve as a baseline in which to measure possible impacts of various changes in the energy system which may be useful to energy planners and decision makers.

9.1 General model drivers

Population growth rate

According to the statistical abstract by UBOS (2012) the population was 71 213 people in 2002, while the 2014 census gave the population for Jijna in 2014 as 72 931 (UBOS, 2014b). This gives an annual growth rate of just 0.2%. Most of the growth in activity in Jinja is due to surrounding areas of Jinja increasing in population but working in Jinja. It is thought that the daytime varies between 200 000 and 300 000 people (UBOS, 2012)

In this work, we use only the population of JMC area and its growth rate of 0.2% pa. However, future work should include further analysis and representation of the surrounding areas.

Economic activity

The economic activity is assumed to be proportional to the country's economic activity and thus equal to the growth rate of the country's economy. This is done since there is no data currently on the economic activity of Jinja itself. The country's economy grew on average 5.98% between 2009 and 2013 (WorldBank,nd)

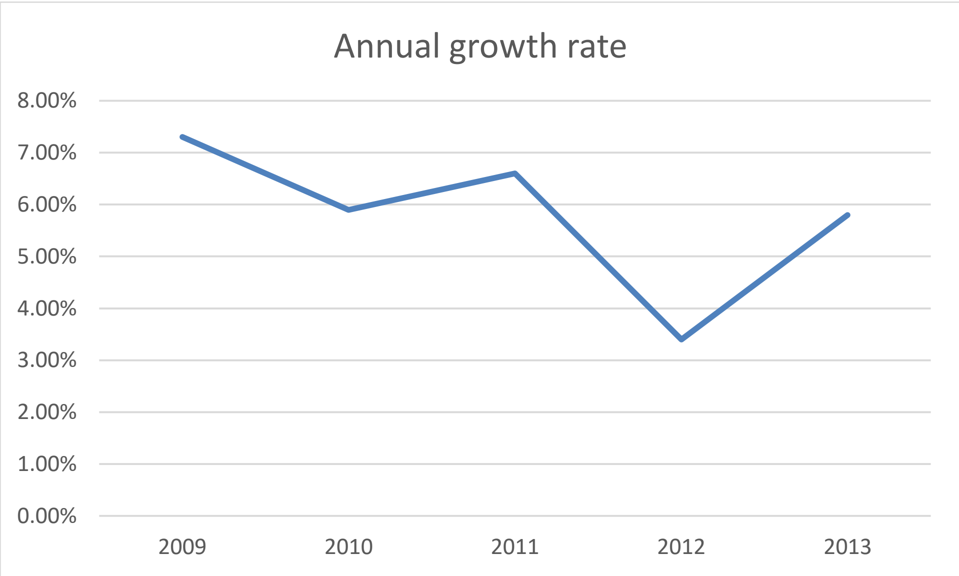

Figure 8 Annual average GDP growth rate for Uganda – source Worldbank

In this model, we use unity as the reference base year value with a growth rate of 5.98% - the average between 2009 and 2013. It is assumed this high economic growth is maintained through to 2030.

Inflation in Uganda has varied over the last 10 years, from 2.5% to 25%, but over the last 3 years has been around the 5% mark:

Figure 9 Uganda Inflation rate per annum. Source: Tradingeconomics.com

In this work, we assume an average of 5.6% (Dec 2016) annual inflation rate for Uganda.

9.2 Fuel costs

These costs are in 2016 Uganda Shillings (UGX).

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 47 Fuel costs from the HH survey data for Jinja in 2016

	LPG	Kerosene	Charcoal	Firewood	Electricity
UGX per	*kg*	*L*	*kg*	*kg*	*kWh*
Min	4615	1200	250	80	400
Mean	9672	2767	1078	671	638
Median	9117	2500	583	189	640
Max	25581	9067	30000	4800	640

The mean and median as well as the maximum values are presented to show the variation that HHs were reporting their costs for fuels. Some HHs may not have correctly given their monthly figures while others might have been mistaken, thus skewing the results. In which case the median value is used to avoid this skewing of the true value.

Fuel retail prices were obtained from the Ugandan SAMSET team from various petrol stations 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 2500 in BAU.

The summary of fuel costs for this work are given in the table below:

Table 48: Fuel costs for Jinja in UGX 2016

Fuel	Sectors	Units	UGX per unit	Source
Electricity	Residential	kWh	640	HH survey
	Commercial	kWh	574	Umeme*
	Industrial M	kWh	577	Umeme*
	Industrial Large	kWh	376	Umeme*
	Industrial V. Large	kWh	372	Umeme*
LPG	All	kg	9 117	HH survey
Charcoal	All	kg	583	HH survey
Firewood	All	kg	189	HH survey
Petrol	All	L	3100	SAMSET team
Diesel	All	L	2375	SAMSET team
Kerosene	All	L	2 500	HH survey

*Adjusted prices using UMEME tariffs for 2017 and HH survey for 2016 value of residential

9.3 Households

The 2014 census (UBOS, 2014b) indicated there were a total of 18 936 households in Jinja, combined with the population this would give a total of 3.85 people per HH. In this work, it is assumed that the number of households grows with population in this model, and the number of people per households is assumed not to change between 2014 and 2030.

9.3.1 Electrification and income groups

From stakeholder engagement by the municipal partners, the UMEME engineers indicated that on average new electricity connections were growing at 10% pa. In the BAU scenario this 10% change per year is applied – moving non-electrified HHs into the electrified grouping.

The proportion of HH income groups is assumed not to change.

In this analysis it is assumed that 10% electrification of non-electrified households is uniform across the income groups, and that a Low income non electrified household then moves into the low income electrified category and so on. With this methodology, the different income groups which are electrified will grow at different paces. This is given in the table below:

Table 49 HH income group changes with electrification rate change

Non electrified	2014	2030
H	2.9%	2.9%
M	7.1%	7.1%
L	90.0%	90.0%
Electrified		
H	11.7%	9.2%
M	59.1%	44.3%
L	29.2%	46.6%

At 10% per annum electrification, by 2030, the electrified population of households would be 92%.

9.4 Commerce

Detail about commercial activity and trends are limited, thus in this work we do not assume any change in the characteristics of the commercial subsectors. The commercial sector energy consumption is assumed to change proportionally with the GDP growth rate assumed for Jinja.

9.5 Local Government

In this scenario, it is assumed that the energy consumption of the municipal vehicle operations tracks population growth – presumably service vehicles would need to service more people and thus require more fuel, while the electricity consumption also tracks population – requiring more street lighting, and more activity within the municipal offices to handle a growing population.

9.6 Industry

9.6.1 Steel industry

It was indicated in the interviews done by the municipality at the steel works, that the steel works were planning to expand their production by 50% as early as 2016. However, with the downturn in commodity prices worldwide, it was indicated by SAMSET partners that this has not happened yet as of writing.

In this work, it is assumed that the expansion takes place in 2020 and the average operating factor for these plants increases to 80% by 2020 for the smaller steel plant and 50% for the larger plant. The assumed plant outputs are given below:

Table 50 Analysis of Steel output (tonnes) for BAU scenario

		2014	2015	2016	2017	2018	2019	2020	2030
Operating factors	Plant 1	48.93%	58.25 %	58.25 %	58.25 %	66%	70%	80%	80%
	Plant 2	8.00%	9.52%	9.52%	9.52%	23%	32%	50%	80%
Total Output		**15 744**	**18 742**	**18 742**	**18 742**	**27 228**	**32 885**	**53 802**	**68 804**

<u>**Fuel Switching**</u>

From stakeholder discussions with the SAMSET partners, the steel plant has switched from using imported coal to using charcoal between 2014 and 2015.

From the data obtained from the stakeholders, the charcoal intensity (per unit of steel produced) increased in 2015 (when coal was phased out) from 0.58 tonnes to 0.67 tonnes. In the BAU scenario, the 2015 value is used through to 2030.

Table 51 Steel industry energy intensity for BAU scenario

	Per tonne of steel	2014	2015 to 2030
Electricity	kWh	1 533	1 533
Coal	Tonnes	0.07	0
Charcoal	Tonnes	0.58	0.67
HFO	L	72.41	72.41

9.6.2 Lime

From the SAMSET survey, it was indicated the lime production facility in Jinja was set to double in 2016 as the company relocated to a newer and larger factory. They also indicated a switching of fuel source from wood to HFO. After this expansion in 2016 it is assumed that the industry does not expand beyond that capacity. This is given in the table below:

Table 52 Lime works energy intensity and production per annum for BAU scenario

	2014	2016 to 2030
Electricity	40	40
Firewood	0.300	0
HFO	50	50
Output tonnes pa	**10 800**	**21 600**

9.6.3 Milling

The milling production of grains is assumed to track GDP growth rates in this model.

9.6.4 Tanneries

For the leather industry in Jinja, it is assumed that the production capacity does not change from 19800 tonnes/year.

9.6.5 Vegetable oils and food products

In the BAU scenario, it is assumed that the output from these industries follows the GDP growth rate. In this model, the fuel consumption is in absolute terms (ie. Not an energy intensity), however, this energy consumption will then track GDP growth rates.

9.6.6 Other industries

This subsector represents all other industries in Jinja that were not covered by the surveys. In this methodology, it is assumed that ‘other industries’ follows the GDP growth rates. The energy intensities for ‘other industries’ is assumed to remain as is in the base year.

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[5] and can be written as some linear function of GDP per capita[6]:

$$M \approx k\left(\frac{GDP}{Pop}\right)$$ ...equation 1

where *k* is a constant to calibrate the base year values (in the year 2011 of the model).

The number of cars (private 4 wheel cars) is then:

$$cars = M \times population \times 1000$$ ...equation 2

Again this is calibrated to the base year value for Awutu Senya (this is 29 418 vehicles of the active four-wheel private vehicles).

Then the population that is motorised (privately) is:

$$mpop = Occupancy \times cars$$ ...equation 3

where *occupancy* is the assumed base year value of 1.5 people per vehicle.

And thus:

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

...equation 4

where *Avg Mileage* is the weighted average of 4 wheel private vehicles (private cars and the LCV's assumptions) from the analysis in the transport section of this report.

The population of non-private car motorisation is then:

$$NCAP = Population - mpop$$ ...equation 5

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

$$pass.km\ public\ = x \times NCAP$$ ...equation 6

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 model numbers are presented below:

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5 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.

6 In the methodology used in this work, GDP was set to unity as there was no data on economic activity for Jinja.

Table 53 Passenger transport model constants

Population		72 931	
GDP		1	In absence of data
Private vehicle count		3 682	Cars, motorbikes, special hire, company Minibus
Motorisation		50.49	Prvt veh/1000 people
GDP/pop		0.00001371	
Base year pass-km		45 231 601	Private pass-km
Vehicle-km		25 327 206	Cars, motorbikes, special hire, company Minibus
Avg. vehicle-km per private vehicle.		6 878	Weighted average for Cars, motorbikes, special hire, company Minibus
Avg. occupancy		1.79	
PUBLIC Pass-km		119 201 706	From transport section
	k =	**3 682 438**	Equation 1
Check:	**M = k*GDP/pop**	**50.49**	Motorisation linked to GDP/POP
So then:	Cars = M*pop/1000	3 682	
Pop – cars X occupancy	NCAP	**66 355**	**People without prvt. Veh.**
PubPass-km = x(NCAP)	**x =**	**1 796**	Equation 6
Using variables results in:			
Pub. Pass-km		119 201 706	
Prvt. Passkm		45 231 601	
Total Pass-km		164 433 307	

With this transport model set up, the drivers for private passenger-km is driven by GDP per capita, while public transport is driven by population as well.

In this methodology it is assumed that the shares of transport by mode for both private and public vehicles do not change relative to the base year – ie. The number of people using Bodas does not change.

9.7.2 Freight

In this scenario it is assumed that all freight demand is driven by GDP growth rate. It is assumed that freight characteristics (demand shares by vehicle type) do not change relative to the base year.

9.7.3 Other transport

Other transport in this model is all unaccounted-for fuel sold in Jinja after calculating passenger and freight fuel consumption. Although this sector acts to balance the books of fuel consumption, it could be argued that this represents the corridor component of transport running through Jinja. Typically the activity of the corridor component of transport in a small city connected to major travelling routes would be heavily influenced by regional economic activities and population growth. Thus it is assumed here that this component of transport grows with GDP assumed in the model.

9.8 BAU scenario results

This section presents the LEAP model results of the Business as Usual scenario.

The total fuel consumption for Jinja doubles by the year 2025 in the BAU scenario:

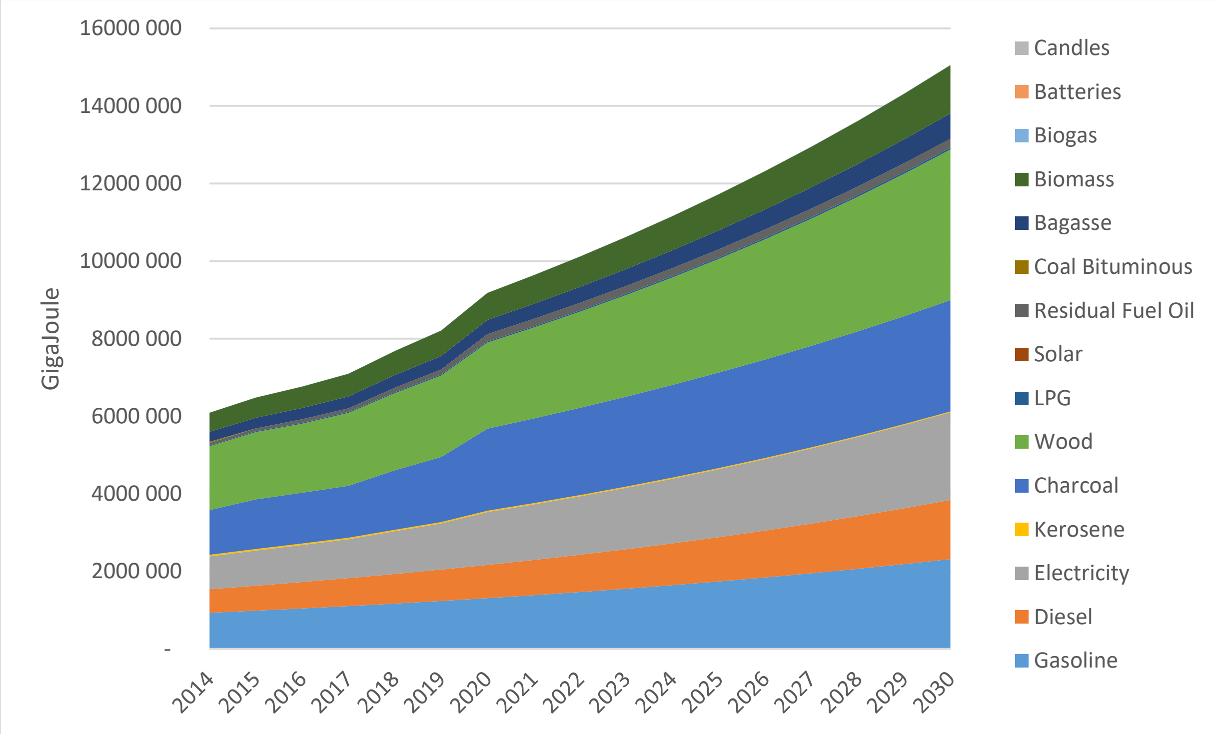


Figure 10 Energy consumption by fuel for Jinja in the BAU scenario

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

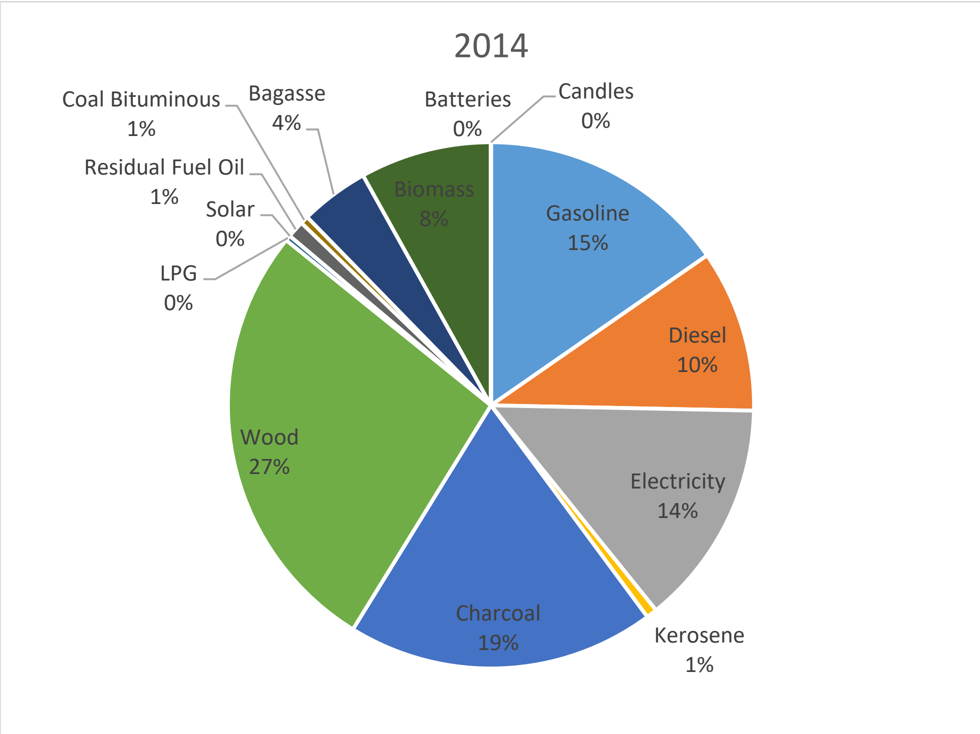


Figure 11 Energy consumption shares by fuel for Jinja in 2014

This energy consumption characteristic does not change significantly by 2030:

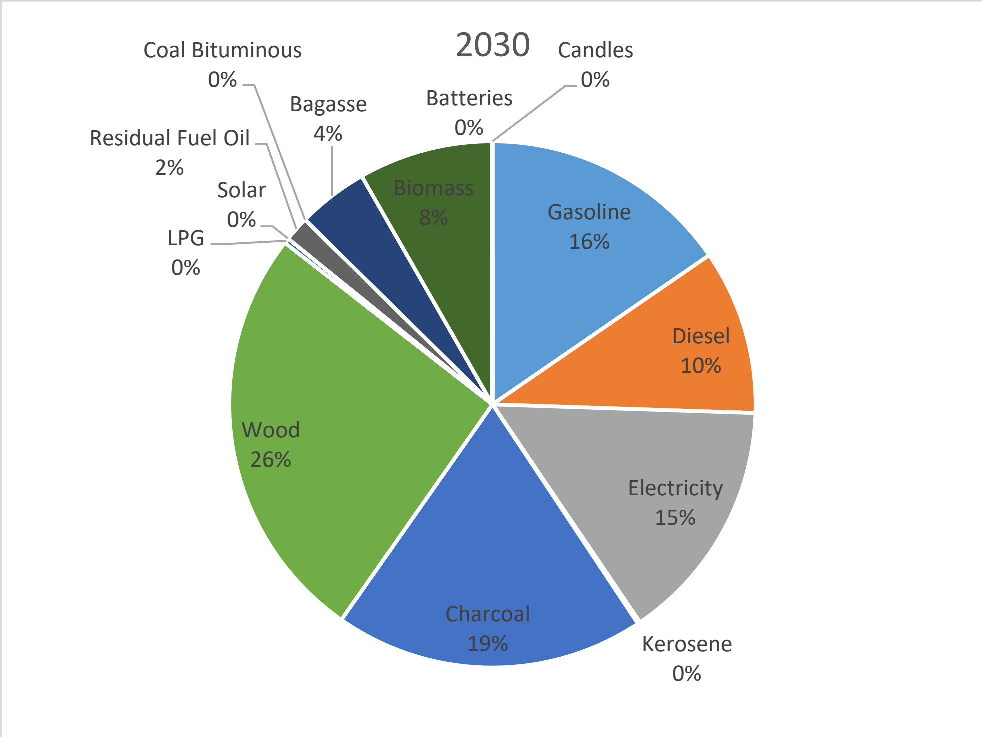


Figure 12 Energy consumption shares by fuel for Jinja in 2030 in BAU

Jinja has significant local industry and as shown in Figure 16 below, the fuel mix for these mirror the high share of biomass based fuels seen for all sectors above. The breakdown of energy consumption by sector for Jinja reflects its industrialised history projecting this forward, with the greater share of energy demand from Industry, with transport as next largest consumer:

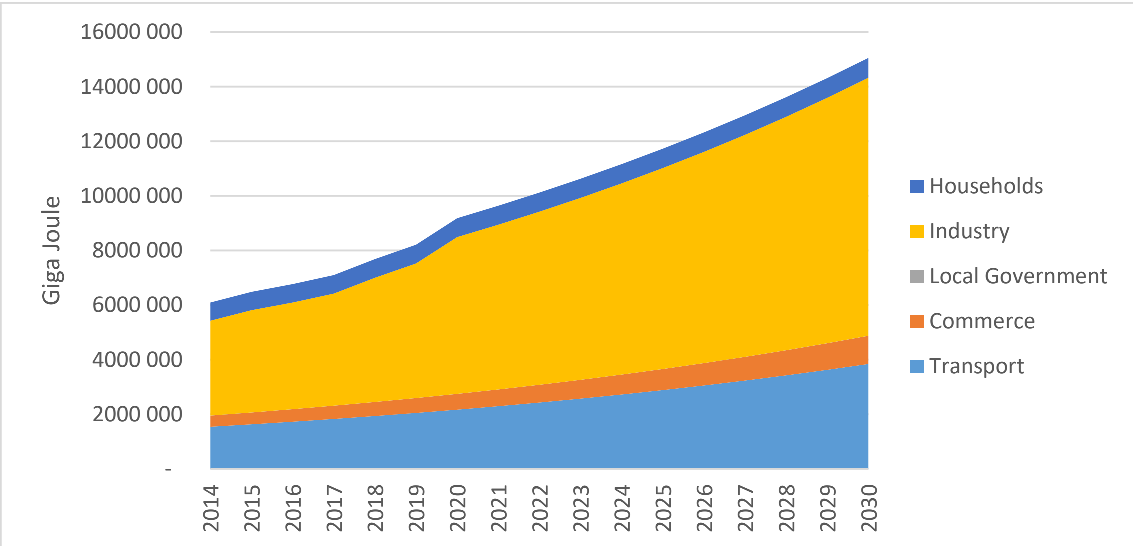


Figure 13 Energy consumption by sector for Jinja in the BAU scenario

Industry makes up almost 60% of the energy consumed in 2014:

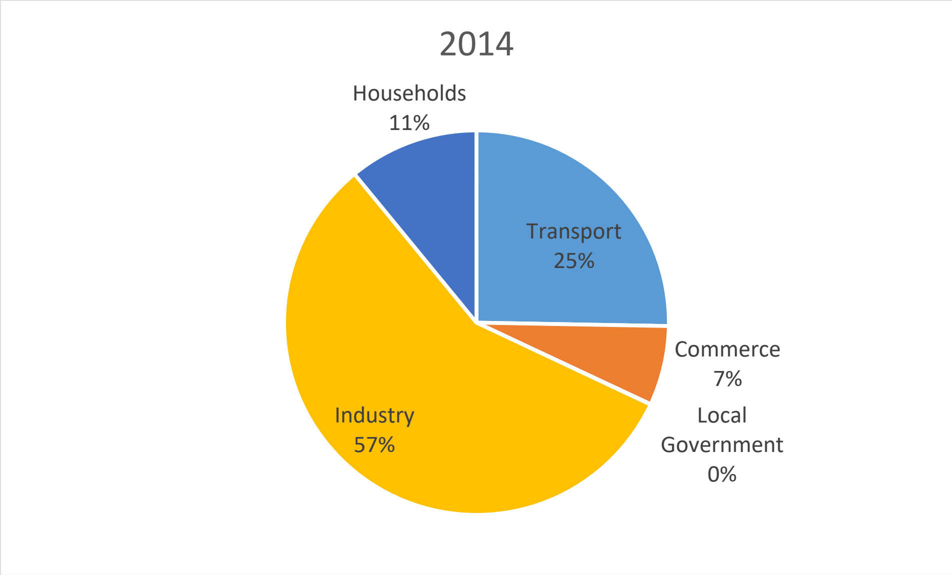


Figure 14: Share of energy consumption by sector for Jinja in 2014 for the BAU scenario

With the increase in steel capacity and the assumed growth in the various other industries, it is expected that this share of Jinja energy consumption increases to 63% by 2030:

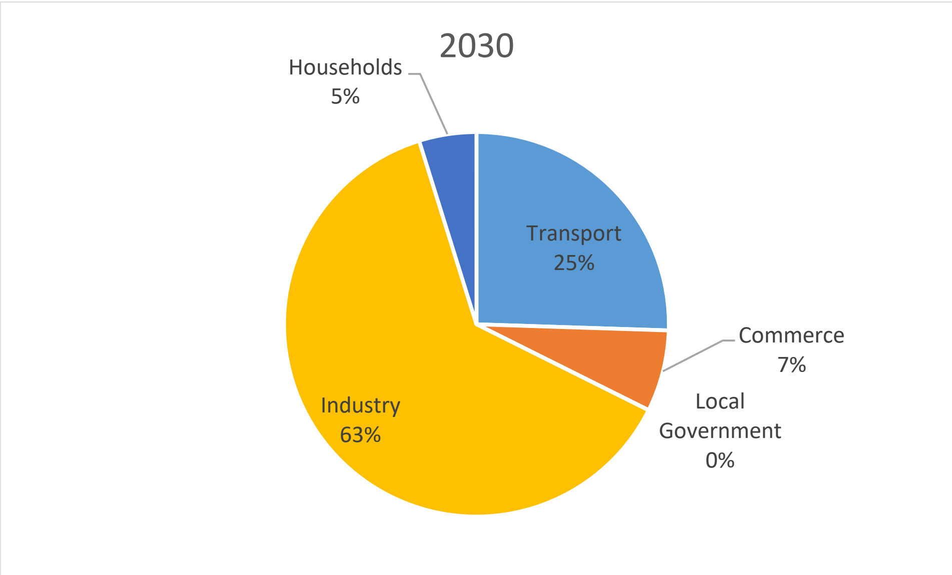


Figure 15 Energy consumption share by sector for Jinja in the BAU scenario for 2030

Most of the Industry's energy consumption is in the form of wood, charcoal[7], and electricity:

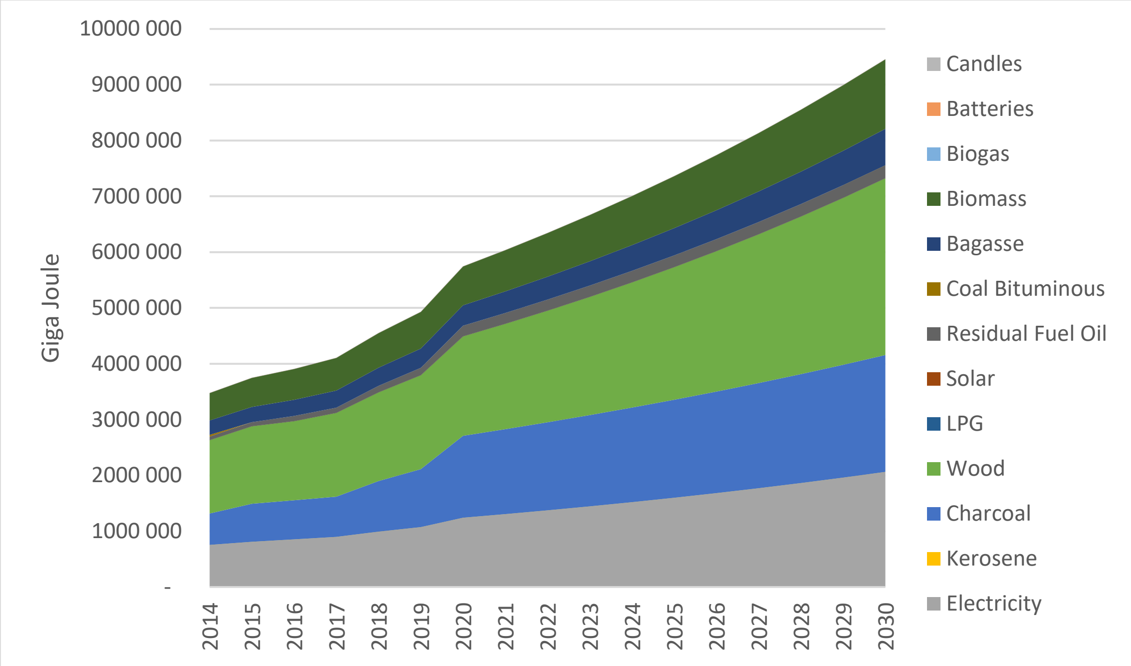
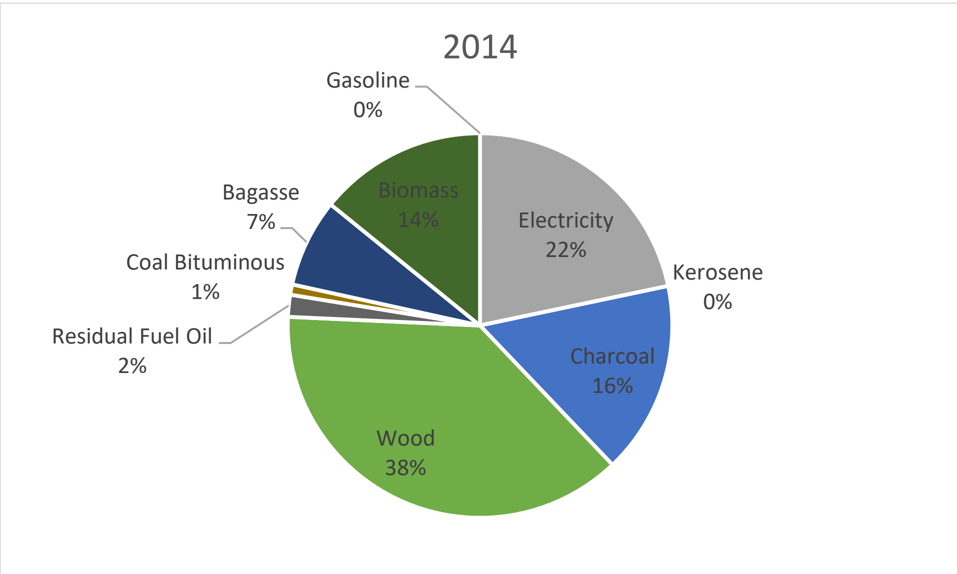


Figure 16: Industry energy consumption by fuel for Jinja in the BAU scenario

About half of the wood consumption comes from the vegetable oils and food industries, and roughly the other half is from the 'other industries' which is open to much uncertainty since this sector was a calibration mechanism to calibrate for electricity in industry.

With the assumptions used in this scenario – mainly around industry expansion and accounting for an increase in charcoal consumption in the steel works, as well as overall industry growth, the charcoal consumption in industry grows to almost a quarter of all energy by 2030:



[7] Most of the charcoal consumption is in Steel, and this is likely used as a reducing agent for iron production, which is not a fuel but more of a chemical agent in the process – in this work it is included as a fuel however.

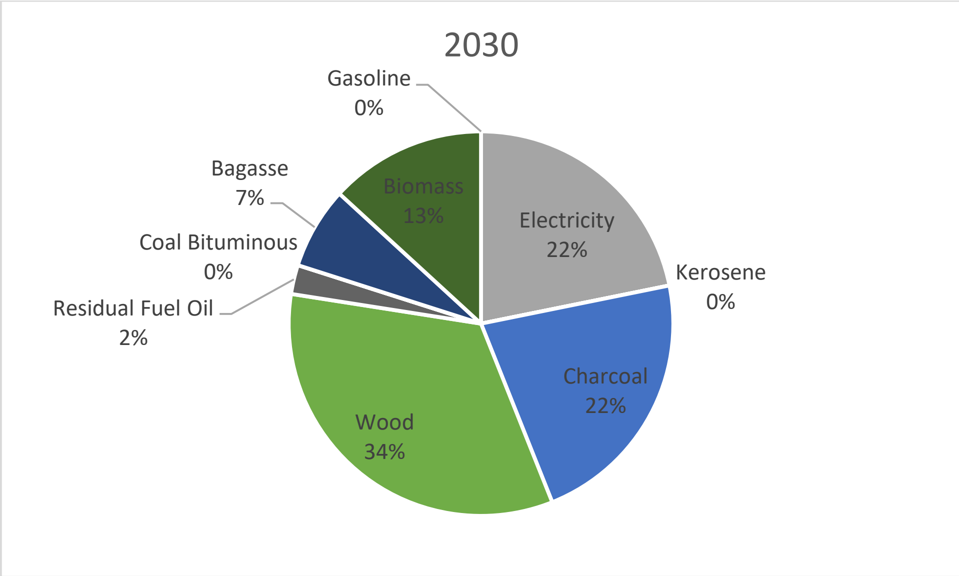


Figure 17 Energy consumption shares by fuel for industry in 2014 and in 2030 for the BAU scenario

For households, total energy consumption does not significantly increase up to 2030 due to the low growth rate for the Jinja population. Without a change in energy consumption behaviour or fuel switching the household sector will continue to use mainly charcoal and wood for its energy needs:

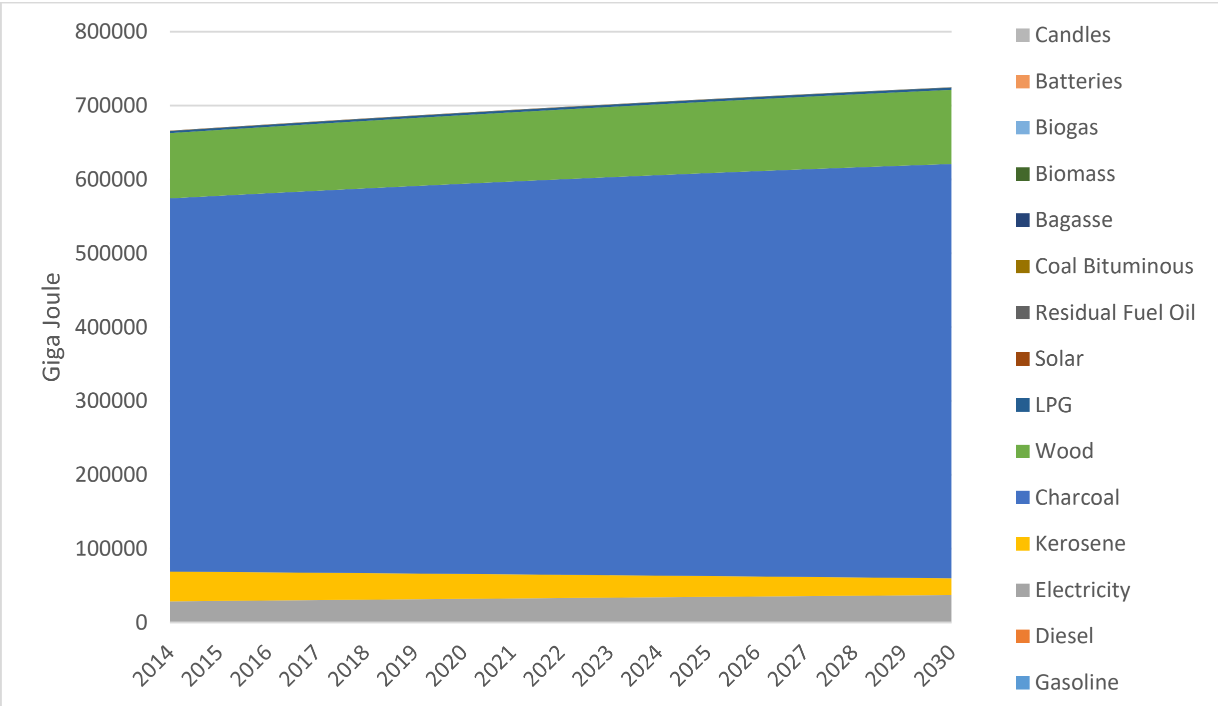


Figure 18: Energy consumption trajectory for households in Jinja in the BAU scenario

Despite the changing in electrification and more households moving into the electrified category, there is relatively little changes in the energy consumption patterns for households:

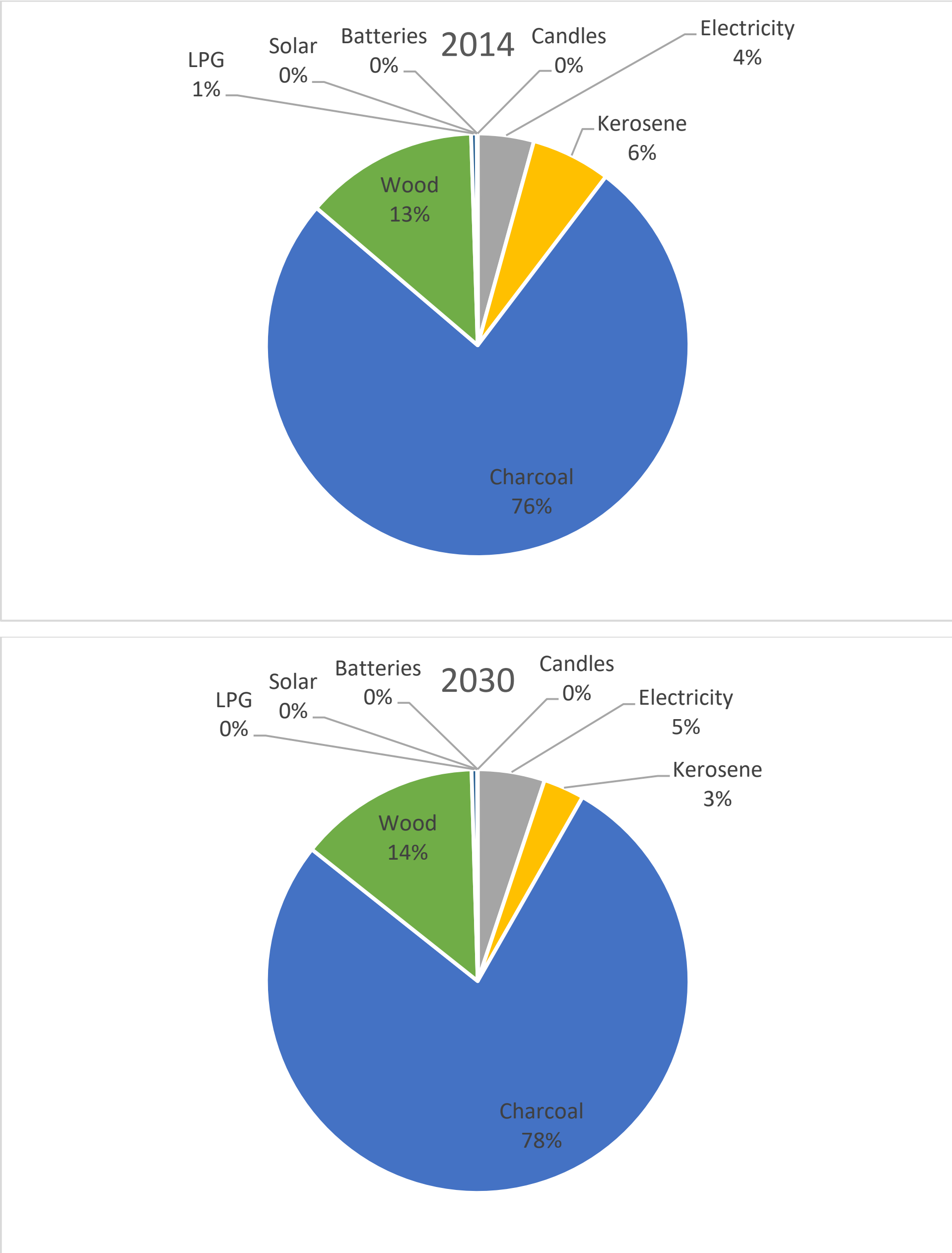


Figure 19 Household energy consumption shares for 2014 and 2030 in the BAU scenario

This lack of change in the HH sector can be attributed to the assumption that HH energy consumption behaviour does not change in the BAU. This trend may be illuminated by a future HH survey to observe appliance ownership and monthly fuel cost changes relative to this survey.

9.9 Sustainable Biomass Usage scenario (SBU)

This scenario looks at better usage of wood and charcoal in Jinja 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[8] 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[8] fuel than inefficient (current) stoves, while for industry it is assumed that the savings[9] for both wood and charcoal consumption is 30%.

Table 54 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%			Tanneries, Vegetable oils, and 'other'

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

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

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

Wood and Charcoal fuel consumption difference relative to the BAU scenario:

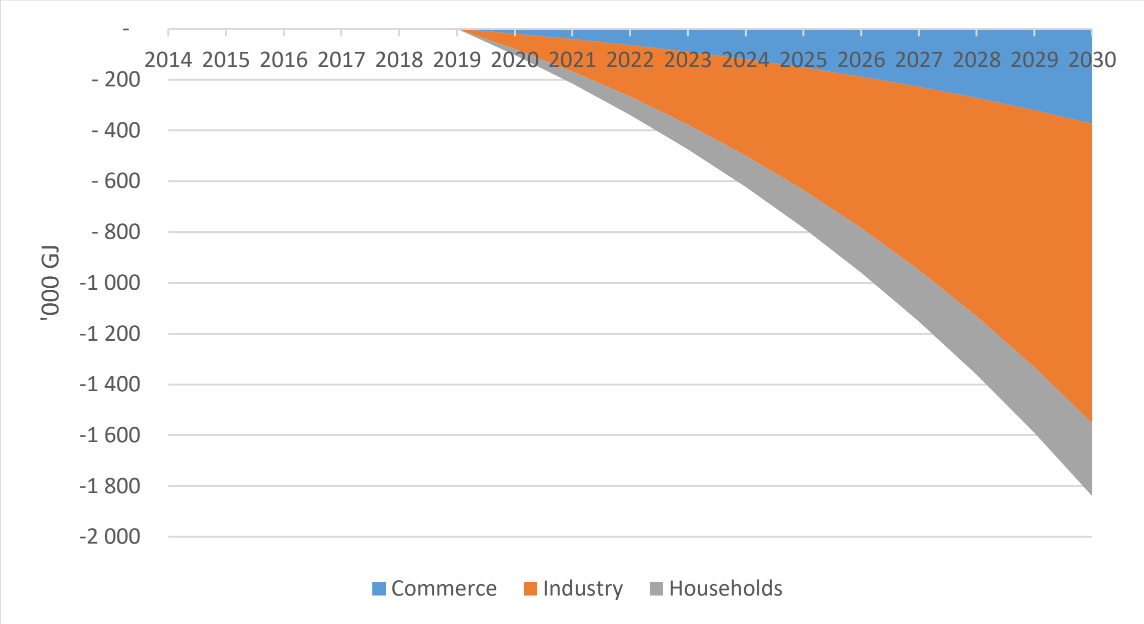


Figure 20 Reduction in Wood and Charcoal consumption per annum in each sector of Jinja for the SBU scenario

Most of the savings is in industry where a blanket 30% efficiency in Tanneries, vegetable oils and 'other' industry was applied to wood consumption. The next largest savings is in the commerce sector – mainly in schools, restaurants and 'other' sectors.

Table 55 Tonnes per annum saved in wood and charcoal in SBU scenario

	2020	2025	2030
Wood	4 340	34 249	82 831
Charcoal	1 237	8 777	19 266

The cumulative savings for Wood from 2020 to 2030 is **417 676** tonnes, and **103 019** tonnes for charcoal.

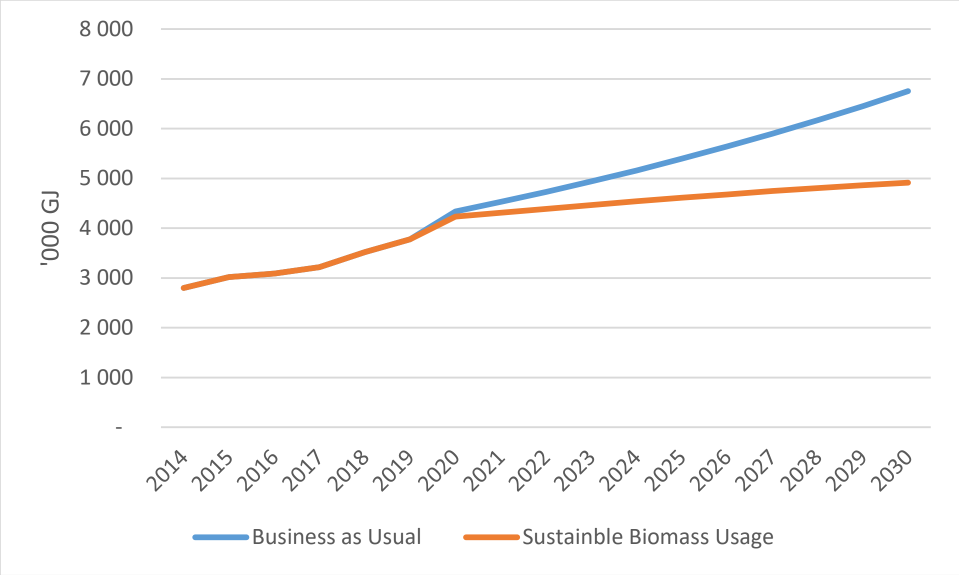


Figure 21 Total energy consumption for wood and charcoal in Jinja in BAU and SBU scenarios

The total wood consumption (including wood for charcoal production) for Jinja would equate to an almost flat lining demand of wood after 2020:

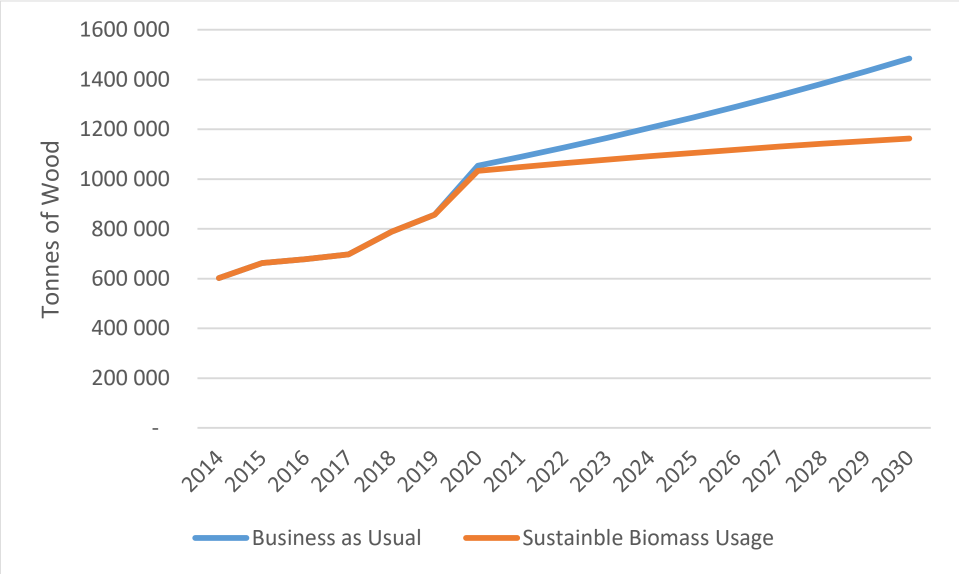


Figure 22 Wood consumption (incl. for charcoal production) for Jinja in SBU scenario

The cumulative savings of all primary wood consumption for Jinja would equate to 1.674 Million tonnes between 2020 and 2030.

However, even with this substantial savings in wood consumption, this would not meet the BEST goal of reducing consumption to sustainable levels – around half of the present day consumption.

The cost impacts of the Sustainable biomass scenario reaches about 5 Billion Uganda Shillings by 2022, and 25 Billion shillings per year by 2030 for a cumulative savings of 138 Billion shillings over the 10 year period.

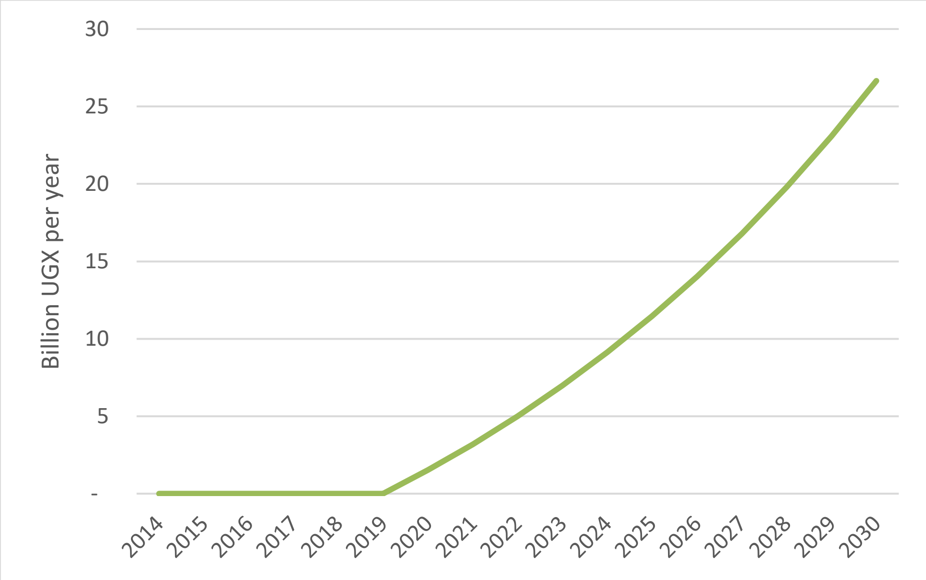


Figure 23 Annual savings in Ugandan Shillings for the SBU scenario for Jinja

9.10 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[10].

<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 – 30% of cooking is on LPG
- Low income nonelec – 60% cooking on LPG
- Mid income – 50% cooking on LPG
- Mid income nonelec – 75% cooking on LPG
- High income – 85% cooking on LPG
- High income nonelec – 100% cooking on LPG
- Commercial sector[11] – all cooking done on LPG.

[10] It is not clear how much of firewood use in industry could be replaced with LPG as it may not be economical in some industries.

[11] 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

- Industrial sector[11] – 30% of firewood consumption is replaced with LPG by 2030.

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 56 LPG stove costs used[12]

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

This scenario does not necessarily save a very significant amount of fuel in Jinja – there is still the requirement for enduse energy, while wood and charcoal are replaced the energy requirement remains the same (for cooking and heating etc.), but the efficiency gain in the LPG burners versus an open three stone wood stove means somewhat less energy is required to meet the demand for services:

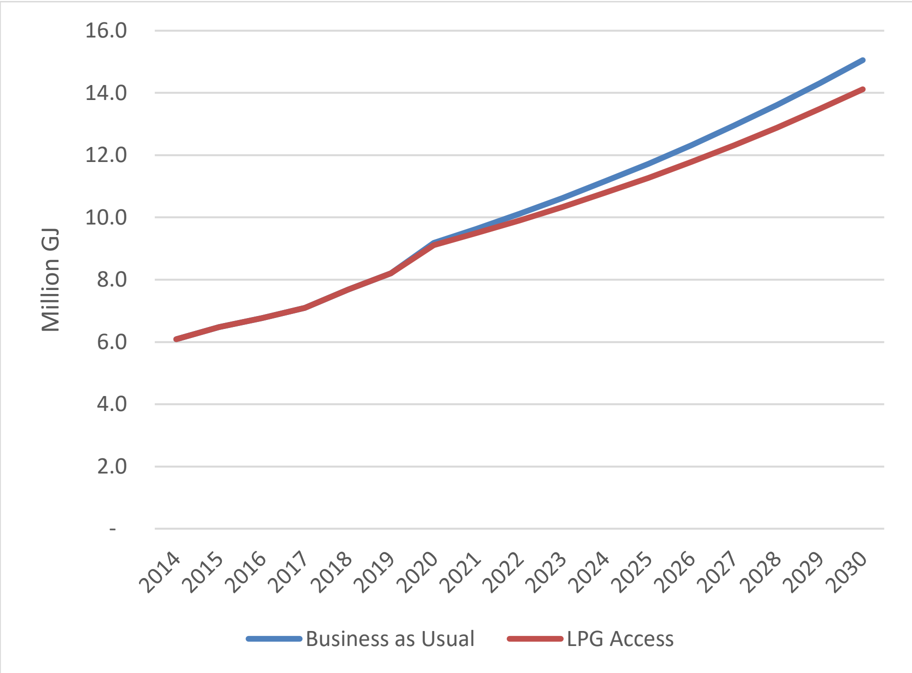


Figure 24 Energy consumption for Jinja for BAU and LPGA scenarios

Most of the energy consumption savings comes from commerce and households:

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.

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

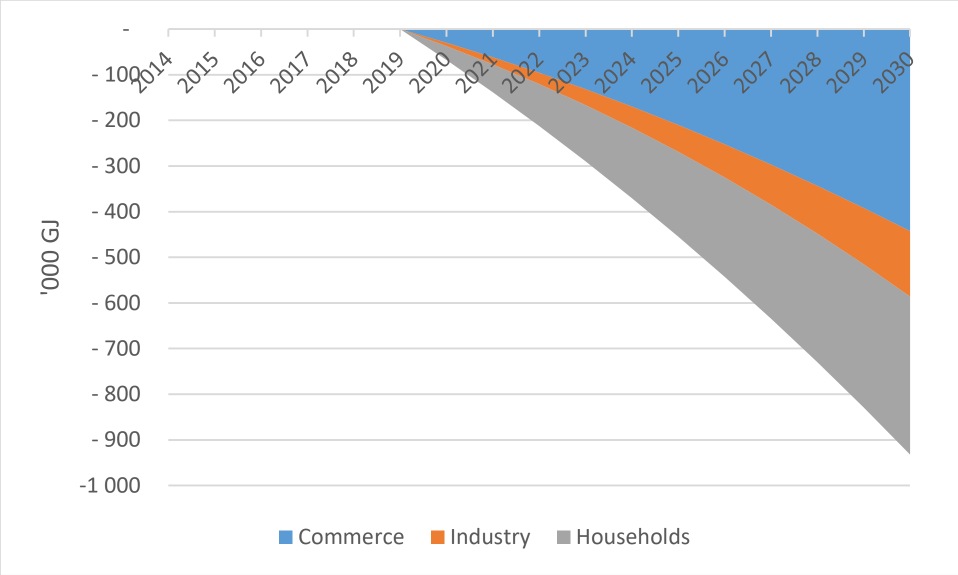


Figure 25 Energy consumption savings by sector for the LPGA scenario

The vast majority of fuel consumption savings is in wood:

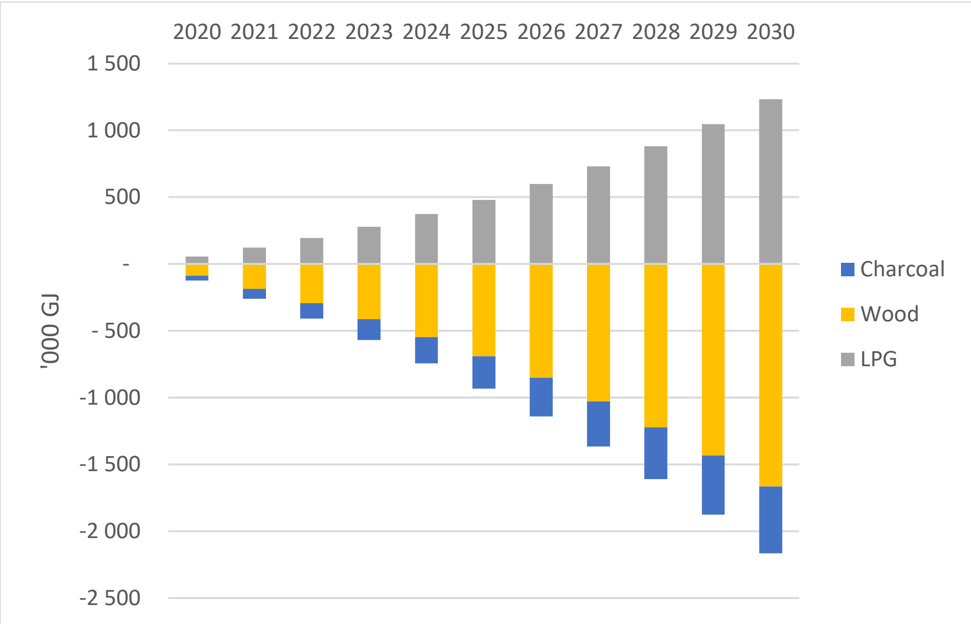


Figure 26 Energy consumption differences for fuels in LPGA scenario

The uptake in LPG in this scenario however, leads to a large increase in costs to Jinja – mainly from the fact that LPG per unit of energy is still very expensive (see figure below), with a total of 207 Billion more UGX per year in 2030:

Table 57 Nett cost of fuels (Million UGX per year) from LPGA scenario

	2020	**2025**	**2030**
Electricity	136	880	1 719
Kerosene	-5	-37	-80
LPG	10 811	91 364	235 803
Wood	-1 076	-8 434	-20 293
Charcoal	-732	-4 889	-10 118
Total	**9 135**	**78 885**	**207 031**

This increase in costs is due to the fact that LPG is still more expensive per unit of energy than wood or charcoal as shown in the chart comparing fuel costs below:

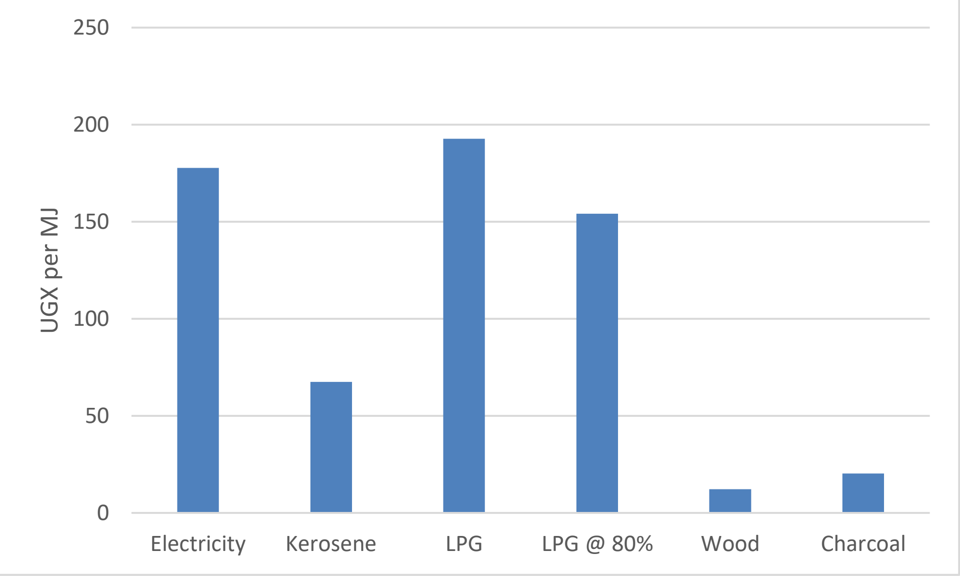


Figure 27 Fuel costs in UGX per MJ for Jinja in LPGA scenario

9.11 Electrification of Households

In this scenario, city energy consumption and particularly HH consumption when electrified is investigated. In this scenario, HH's are not just electrified but also consume more electricity for their needs.

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 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 58 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 58 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 59.

Table 59 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	1 878	528*
H-Non-Electrified	5 888*	
L-Electrified	2 314	
L-Non-Electrified	1 370	
M-Electrified	3 364*	106
M-Non-Electrified	2 373	

* 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 60.

Table 60 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	56%	44%
H-Non-Electrified	100%	0%
L-Electrified	100%	0%
L-Non-Electrified	100%	0%
M-Electrified	98%	2%
M-Non-Electrified	100%	0%

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 61.

Table 61 Increase in electricity energy intensity for lighting in electrification scenario

Income Group	Lighting Electric intensity increase
H-Electrified	6%
L-Electrified	10%
M-Electrified	6%

Refrigeration

By 2030, all high income groups obtain a fridge, 75% of middle income groups, and 50% of low income groups.

Appliances

All HHs have and use appliances by 2030. However, there are more appliances per HH in this scenario – this increases the average energy intensity of HHs. This increase assumed is given in Table 62.

Table 62 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 by 2030. The assumed cooling appliance usages for HHs are:

High income – 50% (up from 25%)

Middle income – 25% (up from 14%)

Low income – 25% (up from 15%)

Scenario results

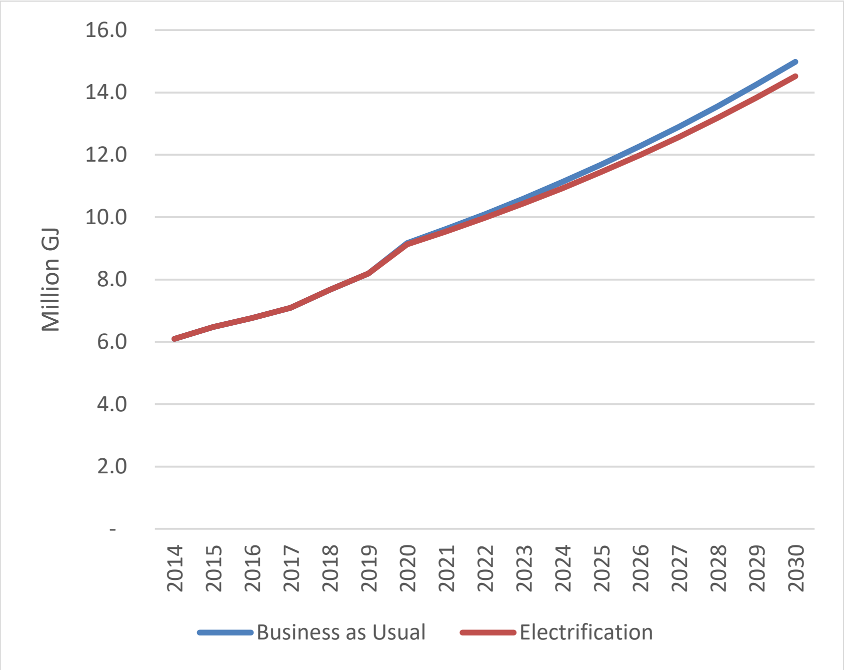


Figure 28 Final energy consumption for Jinja in the electrification scenario

Overall, the final energy consumption for Jinja by 2030 is only about 3% less than the BAU scenario. However, there is a large savings in wood and charcoal consumption in the household sector while the demand for electricity increases by 7.5 times by 2030. The majority of fuel savings is in charcoal energy. Figure 29 shows the difference in the HH sector in fuel consumption to the BAU scenario.

Figure 29 Final energy consumption difference of fuels in HH sector comparing BAU to electrification scenario

In this scenario, this equates to a total of 270 747MWh more electricity used by HHs between 2020 and 2030, but a reduction of 108 267 tonnes of charcoal and 35 640 tonnes of wood (see Table 63).

Table 63 Cumulative difference in energy consumption in HHs in the electrification scenario

Fuel	Units	2020	2025	2030
Electricity	MWh	2 446	67 338	270 747
Kerosene	kL	-36	-820	-2 806
LPG	Tonnes	30	653	2 140
Wood	Tonnes	-443	-10 314	-35 640
Charcoal	Tonnes	-1 374	-31 678	-108 267

With the increase in purchases of electricity, HHs will be spending 116 billion Shillings more over the 2020 to 2030 period overall as given in Table 64.

Table 64 Cumulative cost impact (million UGX) on HH sector for fuels in the electrification

Fuel	2020	2025	2030
Electricity	1 565	43 096	173 278
Kerosene	-89	-2 049	-7 015
LPG	269	5 958	19 510
Wood	-84	-1 949	-6 736
Charcoal	-801	-18 468	-63 120
Nett cost	**861**	**26 587**	**115 916**

9.12 Increased usage of 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 Jinja to just the High income group mode share (first column) given by the HH survey data as shown below:

Table 65 Passenger transport by trip and mode share for the different income groups in Jinja

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%	16%	10%	33%	36%	64%
Bicycle	0%	0%	0%	0%	3%	3%
Motorbike (personal/work)	0%	1%	5%	6%	0%	0%
Boda Boda (Motorcycle taxi)	42%	26%	48%	39%	45%	25%
Taxi (Special hire)	0%	0%	1%	1%	0%	0%
Minibus taxi	18%	15%	13%	8%	9%	5%
Bus	0%	0%	0%	0%	0%	0%
Company minibus/bus/truck	0%	0%	10%	6%	4%	1%

Own Car	33%	42%	13%	8%	2%	2%
Other (specify)	0%	0%	0%	0%	0%	0%

The comparison to the BAU scenario is given below. In the BAU scenario, on average there is a lot more boda boda usage and the use of other private vehicles (company owned ones), while in this scenario many more people are buying and using their own cars, and as a result of increased demand for mobility – more usage of minibus taxis.

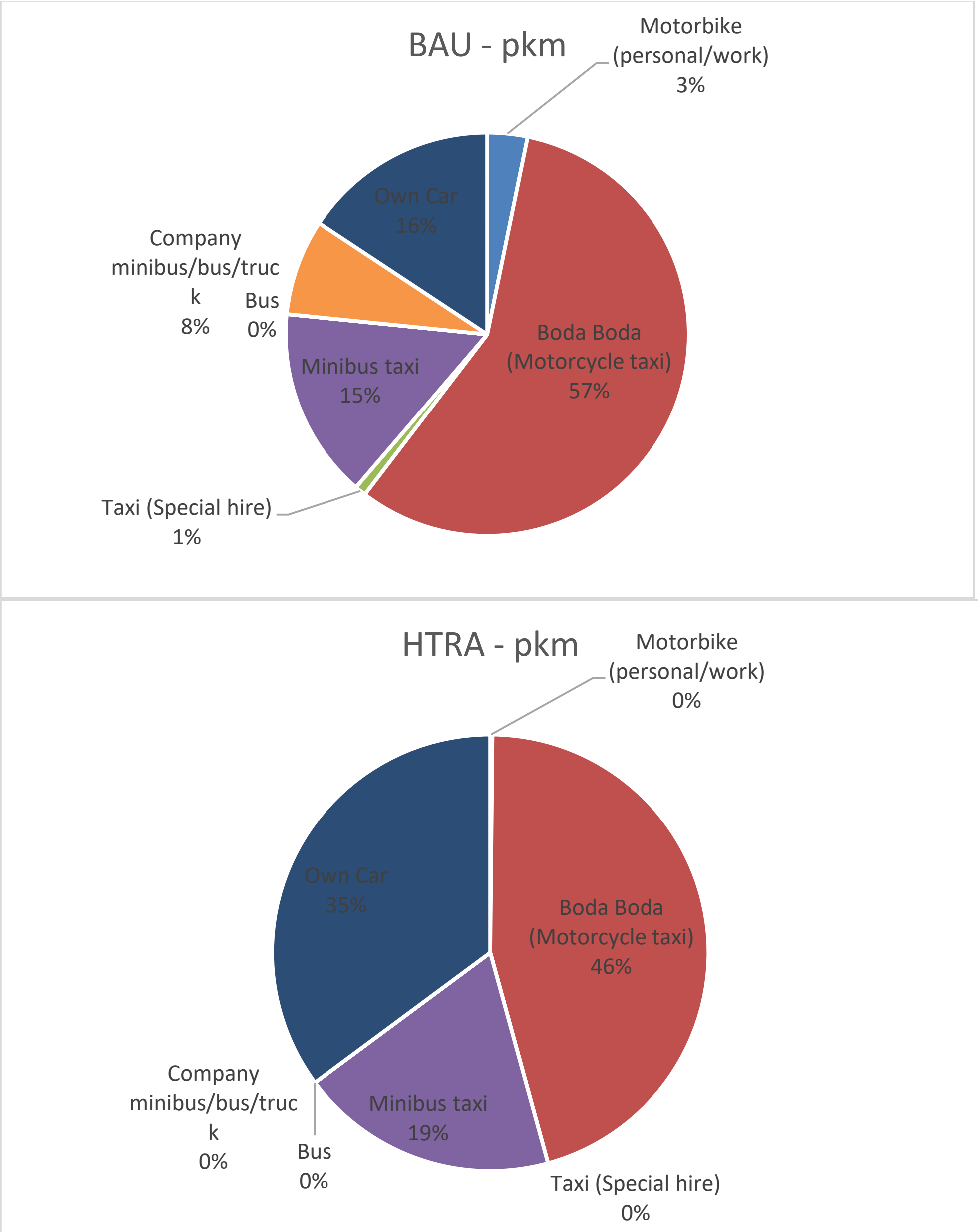


Figure 30 Comparison of BAU (above) motorised transport pass-km mode shares in 2014 compared to the HTRA (below) scenario in 2030.

As people use more transport and go further, the transport demand rises for both private and public transport. In this scenario this change compared to the BAU is more pronounced in the public transport sector than the private, this is shown in the figure below:

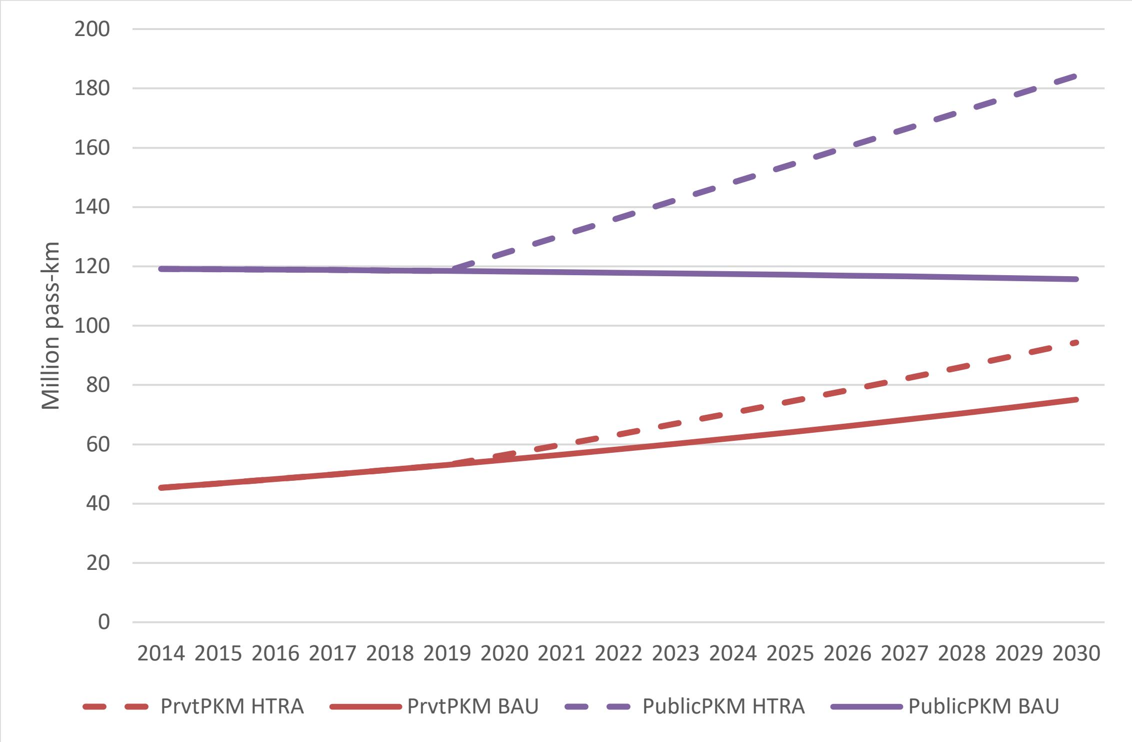


Figure 31 Passenger transport demand for the HTRA scenario and the BAU scenario compared

This increase in passenger-km overall means the roads of Jinja would become a lot more busy. Using 2014 as the year adjusted to one, then the roads would be 1.15X as busy in 2030 in the BAU, but 1.7X in the HTRA scenario. This would be a 46% rise in traffic levels effectively due to this change relative to the baseline. Much of this would be in the form of private vehicles, and it should be noted that there would be less usage of Boda's which wouldn't take up as much space, but would lead presumably to lower road accident incidents from Bodas.

From an energy perspective, this scenario would lead to an increase in fuel consumption due to the increase activity, but also due to lower overall energy intensity (more people using cars would lead to lower overall fuel efficiency). This would lead to an increase of 132 thousand GJ (or about 76%) more energy than the BAU:

Table 66 Fuel consumption (000 GJ) difference relative to the BAU scenario

	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Gasoline	8.9	18.4	28.5	39.3	50.7	62.9	75.8	89.4	103.7	118.7	134.5
Diesel	0.2	0.3	0.3	0.3	0.2	0.0	-0.3	-0.6	-1.1	-1.6	-2.3
Total	**9.1**	**18.7**	**28.8**	**39.6**	**51.0**	**62.9**	**75.5**	**88.7**	**102.6**	**117.1**	**132.2**
% increase relative to BAU	6.6	13.3	20.1	27.0	33.9	40.9	48.0	55.1	62.1	69.2	76.3

10. Discussion

This report detailed the methodology developed and used to create energy model representations of demand sectors in the Municipality of Jinja, Uganda, as well as the scenarios explored using the model.

From the data, it was found that Industry was the largest energy user in Jinja, and transport the next largest consumer. From a fuel perspective wood and charcoal are the dominate energy sources even in Industry, and makes up the vast majority in Households despite an electrification rate of around 66%.

Industry consumes a very significant amount of biomass in the form of wood, charcoal and biomass discards (mainly various grain husks from the vegetable oils industries) which would make industry fairly low emissions intensive – more so when the majority of electricity used is generated by hydro power is factored in.

The passenger transport sector representation in the LEAP energy systems model was based on data from a household survey undertaken by Uganda Martyrs University (UMU, 2016), (UMU, 2014). This included capture mode preference, trip frequency and trip time at a householder level. This data suggested that while liquid fuel sales for Jinja account for about 25% of all energy consumption in Jinja, transport of passengers and freight within the municipality can only account for around 10% of this fuel. The remaining fuel was attributed to a 'corridor' component whereby vehicles carrying people and or freight pass through Jinja stopping to refuel. In other words– the vast majority of transport fuel appears to be for the transportation of people and goods in and out of Jinja and not for the local population in Jinja, however more work and data collection on this will be needed to clarify this as the supply side data is highly uncertain as discussed in Section 10.1 below. This same trend was observed in the Ghanaian studies of Awutu Senya East (near Accra the main economic hub of Ghana) and for Ga East (also near Accra) for the SAMSET project. The processed data similarly implied that a majority of energy consumption was attributable to corridor transportation. From this work and that for the Ghanaian models, it appears that the corridor component is the main user of transportation energy. This may be due to the fact that the Municipalities studied were in close proximity to a large economic hub (Accra in the Ghanaian work) - Kampala in this study.

Households consume mainly wood and charcoal despite being in an urban environment and having a 66% electrification rate. The population growth rate for Jinja was found to be very low of around 0.2% pa from the census data. It should be noted that this is the household sector of Jinja, while it was noted from SAMSET partners that the surrounds of Jinja have been growing at a much faster pace and contributing to activity within Jinja – such as commerce and transport. In this methodology for the household sector of Jinja, only the households of Jinja are considered in order to keep within the scope of work and to reduce complexity and maintain reliability of the models.

It was found from the HH survey data that households that indicated they had an efficient charcoal stove or wood stove, used a lot more (per person) than those whom indicated they did not have an efficient stove. That is – the 'efficient' stove was found to use more fuel than regular stoves/open fire places. Communication with the SAMSET partners confirmed that it is often the case where a household does not know how to use an efficient stove properly. It may also be the case where the stove breaks or fractures in some way – making it less efficient but the household may continue to use it. As discussed in the limitations section, more data on this is required.

The commercial sector accounted for about 7% of energy consumption in Jinja and about 80% of this was in wood and charcoal, with about 15% being electricity. Commerce however, was lacking in data for informal activities. Schools and restaurants contributed the most of the known energy consumption sectors – with the remaining fuel being used in the unknown sectors simply designated as 'other' – possibly this is largely the informal commercial sector of shops, restaurants, and others.

An electrification scenario was explored where HHs are connected to the grid if they were not already, but in this scenario they begin to use electricity more –displacing candles, charcoal, wood, kerosene, and so on. It was found from the survey, that electrified HHs typically didn't use a lot of electricity for their everyday energy needs. In this electrification scenario, the overall energy consumption of Jinja would not change a whole lot – decreasing about 3% by 2030, but this would save a total of 108 000 tonnes of charcoal and 36 000 tonnes of wood by 2030. This scenario resulted in an increase in costs to Jinja HH's – about 115 Billion shillings cumulatively by 2030 due largely to the cost of electricity compared to biomass fuel.

Investigating efficient charcoal and wood stoves in Jinja - a scenario was created where more people use efficient charcoal and wood stoves (and where they are used properly so as to be efficient). This scenario showed that there could be in the region of 5 Billion shillings saved on fuel costs cumulatively between 2020 and 2030 for Jinja. Motivation for this scenario was based from the SE4ALL and BEST strategies in Uganda directed at better utilisation of biomass in the country. However, the results indicate even with all users of charcoal and wood using efficient stoves the BEST target of half of current biomass consumption would not be reached. The consumption of wood would almost flat-line in this scenario between 2020 and 2030 but not reduce to less than half of the 2015 or 2020 levels. The growth rate of the economy assumed in this scenario means that the demand growth for charcoal and wood will outstrip the savings incurred from replacing all inefficient stoves. A switch to other fuels would then be necessary to meet the BEST targets for biomass.

An LPG access scenario where LPG fuel is utilised more and more in households, commerce and industry by 2030 was investigated. With the assumed uptake of the fuels in this scenario it was found that while overall energy consumption dropped (LPG stoves are more efficient), the cost of the fuel would increase the cost to Jinja drastically – in the region of 200 billion shillings per year. This is mainly due to the high cost of LPG.

A transport scenario was investigated that modelled the impact of more of the population undertaking motorised trips, particularly using private vehicles for transport. This assumed that with rising incomes, a greater share of households would assume the travel behaviour observed for high income respondents in the household survey. This includes an increase in motorised trips, both public and private, and a much lower share of walking trips. The result was an increase overall for private passenger-km's of 69% and public transport by 56% resulting in a 76% increase in transport energy demand relative to BAU by 2030. This equates to over 3 million additional litres of petrol per annum Aside from the cost and GHG impacts, a scenario like this would impact road congestion, accidents and air pollution.

It's important in the case of transport however to be mindful of the relationship between trips, trip time and economic activity. Transport not only facilitates the movement of goods but enables the human interactions that drive economic activity. In this sense more trips, including motorised trips, are positive for the social and economic wellbeing of the population. The goal of sustainable transport is rather to minimise the impact of these trips and maximise their time efficiency. Where trips are potentially walkable within a short time therefore, the urban environment should enable this through investment in the pedestrian environment. Where sufficient demand and urban density exists for high quality formal public transport then this is a worthy investment but small buses and taxis are often more appropriate economically in much of the urban environment. Private cars can proliferate very quickly where incomes are rising placing a large burden on road infrastructure and inhibiting the economy through congestion, a situation very evident in the capital city Kampala. The true cost of private transport includes the road infrastructure for efficient transit and fuel and parking taxes should be used to try and balance infrastructure and demand for infrastructure while facilitating public motorised transport as an alternative. In a developing context this means trying to strike a balance between informal (and usually efficient paratransit – bodas and minibuses) and an expanding and not excessively subsidised formal network. In this complex system context the quite crude modelling scenarios undertaken in this study are guidelines for the impacts of decisions but larger infrastructural decisions require much more detailed assessment. The travel survey data collected is however very valuable as a starting point for local planning and along with that collected for Kasese has given an overview of the transport situation that compared sensibly between income groups and across districts.

10.1 Limitations and future work

The HH survey provided a large amount of detail for the creation of the Household sector in this work and the transport sector. The survey was conducted at 206 Households in Jinja. In this work the households were split into various income groups and by electrification. These subdivisions of households were thus derived from a smaller sample - a subset of the 206 surveyed, and may not be a good representation of these household income groups.

Trends in household energy consumption behaviour over time is critical for the scenarios and understanding energy consumption changes, behaviour, and trends. A future data collection/survey on appliance usage in HHs would be necessary for more accurately representing the household scenario projections.

The industry sector is a very significant player in Jinja's energy profile, and while a large amount of data was collected for these industries more data is required. From this data and the assumptions used, the electricity consumption for the industrial entities in the survey sample only accounted for about 33% of the reported sales to industry. Smaller manufacturers and industries were not part of the data collection and would be priority for data collection in the future. Future surveys of the industry sector should distinguish between road transport and stationary uses of liquid fuels – like motors and gensets.

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 10% 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 Jinja from outside and passing through would greatly increase the detail of this transport component.

The supply side data collected for petroleum fuels was also highly uncertain and may account for some of the mismatch between supply and demand in the data. In the event, it was not practical to scale up the sales of a sample of retail fuel stations to the full number as was done because of the large variance in volumes between stations. The data for some stations seemed highly approximate adding to uncertainty. Furthermore, the absence of clear metadata indicating the following made processing the data extremely difficult:

- The primary source of each sales figure and the credentials of the stakeholder if that was the source
- The context of the data collection e.g. workshop discussion, personal consultation
- The perceived degree of accuracy of the primary source.
- Validation checks by the data collection team e.g. per capita fuel use compared to a national or regional figure from another source

Quantitative data collection by stakeholder consultation can be highly problematic particularly when it is passed between parties in a project team. Future work should conduct direct training sessions with local project partners stressing the importance of metadata and validation. The pitfalls of sampling methodology also need to be clearly communicated with education in basic statistical techniques before data collection commences.

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12. Appendix

12.1 Commercial sector

Table 67 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 68: Calculated total fuel consumption for commercial surveyed entities by appliance type

	Lighting				Appliances	Refrigerator	Cooling				Cooking
	Incandescent	CFL	Paraffin Lamp	Solar	Appliances	Fridge	Fan	ACSplit	AC ducted	AC-wall	Electric
	kWh	kWh	L	unit	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Schools	4 320	31 428	144	-	132 766	8 360	5 222	-	-	1 620	-
Tertiary	-	11 405	-	-	118 401	3 960	1 617	-	-	-	-
Banks	-	27 372	-	-	23 820	-	544	-	86 020	-	-
Banks Small	-	-	-	-	-	-	-	-	-	-	-
Hotels	-	38 642	-	-	109 896	35 354	20 667	-	84 816	-	-
GuestHouses	9 314	10 346	-	1 704	12 496	5 324	3 548	-	-	-	-
Restaurants	-	14 225	-	-	40 896	20 160	4 808	-	-	-	-

12.2 Households

12.2.1 R 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))
```

12.2.2 Residential enduse detail output from R scripts

Table 69 HH enduse technology shares and energy intensities for Jinja

Share of these HHs with this technology	Intensity Units per HH	Technology Name	EndUse	Income Group	Electrification	Units
3	91	Charcoal*	Appliances	Low income	Electrified	Kilogramme
52	104	Charcoal*	Appliances	Low income	Non_Electrified	Kilogramme
60	130	Charcoal*	Appliances	Middle income	Non_Electrified	Kilogramme
5	208	Charcoal*	Appliances	Middle income	Electrified	Kilogramme
100	408	Electricity	Appliances	High income	Electrified	Kilowatt-Hour
50	137	Electricity	Appliances	High income	Non_Electrified	Kilowatt-Hour
33	12	Electricity	Appliances	Low income	Non_Electrified	Kilowatt-Hour
90	246	Electricity	Appliances	Low income	Electrified	Kilowatt-Hour
40	9	Electricity	Appliances	Middle income	Non_Electrified	Kilowatt-Hour
100	309	Electricity	Appliances	Middle income	Electrified	Kilowatt-Hour
95	1281	Charcoal	Cooking	Middle income	Electrified	Kilogramme
100	1202	Charcoal	Cooking	High income	Electrified	Kilogramme
50	1350	CharcoalImpStove	Cooking	High income	Electrified	Kilogramme
50	1055	CharcoalRegStove	Cooking	High income	Electrified	Kilogramme
16	610	FirewoodRegStove	Cooking	Low income	Non_Electrified	Kilogramme
19	1319	Firewood	Cooking	High income	Electrified	Kilogramme
19	1319	FirewoodRegStove	Cooking	High income	Electrified	Kilogramme
44	53	LPGStove	Cooking	High income	Electrified	Kilogramme
2	4500	FirewoodImpStove	Cooking	Low income	Non_Electrified	Kilogramme
18	1878	Firewood	Cooking	Low income	Electrified	Kilogramme
28	995	CharcoalRegStove	Cooking	Low income	Electrified	Kilogramme
88	916	Charcoal	Cooking	Low income	Electrified	Kilogramme
20	4500	Firewood	Cooking	Middle income	Non_Electrified	Kilogramme
18	1878	FirewoodRegStove	Cooking	Low income	Electrified	Kilogramme
73	1237	CharcoalImpStove	Cooking	Middle income	Electrified	Kilogramme
100	2160	Charcoal	Cooking	High income	Non_Electrified	Kilogramme
60	879	CharcoalImpStove	Cooking	Low income	Electrified	Kilogramme
100	2160	CharcoalImpStove	Cooking	High income	Non_Electrified	Kilogramme
100	672	Charcoal	Cooking	Middle income	Non_Electrified	Kilogramme
19	2018	FirewoodRegStove	Cooking	Middle income	Electrified	Kilogramme
35	513	CharcoalRegStove	Cooking	Low income	Non_Electrified	Kilogramme
87	544	Charcoal	Cooking	Low income	Non_Electrified	Kilogramme
52	564	CharcoalImpStove	Cooking	Low income	Non_Electrified	Kilogramme

60	400	CharcoalRegStove	Cooking	Middle income	Non_Electrified	Kilogramme
2	123	LPGBurner	Cooking	Middle income	Electrified	Kilogramme
20	4500	FirewoodRegStove	Cooking	Middle income	Non_Electrified	Kilogramme
22	1423	CharcoalRegStove	Cooking	Middle income	Electrified	Kilogramme
19	2018	Firewood	Cooking	Middle income	Electrified	Kilogramme
40	1080	CharcoalImpStove	Cooking	Middle income	Non_Electrified	Kilogramme
17	964	Firewood	Cooking	Low income	Non_Electrified	Kilogramme
3	728	Electricity	Cooking	Low income	Electrified	Kilowatt-Hour
2	156	Electricity	Cooking	Low income	Non_Electrified	Kilowatt-Hour
25	566	Electricity	Cooking	High income	Electrified	Kilowatt-Hour
4	2123	Electricity	Cooking	Middle income	Electrified	Kilowatt-Hour
2	3	KeroseneStove	Cooking	Low income	Non_Electrified	Liter
13	25	KeroseneStove	Cooking	Low income	Electrified	Liter
4	16	KeroseneStove	Cooking	Middle income	Electrified	Liter
50	18	KeroseneStove	Cooking	High income	Non_Electrified	Liter
25	166	Electricity	Cooling	High income	Electrified	Kilowatt-Hour
15	108	Electricity	Cooling	Low income	Electrified	Kilowatt-Hour
14	122	Electricity	Cooling	Middle income	Electrified	Kilowatt-Hour
100	243	CFT	Lighting	High income	Electrified	Kilowatt-Hour
14	68	TorchBattery	Lighting	Low income	Non_Electrified	Kilowatt-Hour
98	95	CFT	Lighting	Middle income	Electrified	Kilowatt-Hour
6	45	TorchBattery	Lighting	High income	Electrified	Kilowatt-Hour
50	68	TorchBattery	Lighting	High income	Non_Electrified	Kilowatt-Hour
3	655	FT	Lighting	Low income	Electrified	Kilowatt-Hour
3	55	SolarLamp	Lighting	Low income	Non_Electrified	Kilowatt-Hour
5	36	SolarLamp	Lighting	Middle income	Electrified	Kilowatt-Hour
13	109	SolarLamp	Lighting	High income	Electrified	Kilowatt-Hour
98	48	CFT	Lighting	Low income	Electrified	Kilowatt-Hour
1	131	Halogen	Lighting	Middle income	Electrified	Kilowatt-Hour
10	626	FT	Lighting	Middle income	Electrified	Kilowatt-Hour
6	1966	FT	Lighting	High income	Electrified	Kilowatt-Hour
50	36	SolarLamp	Lighting	High income	Non_Electrified	Kilowatt-Hour
80	146	KeroseneLamps	Lighting	Middle income	Non_Electrified	Liter
75	184	KeroseneLamps	Lighting	Low income	Non_Electrified	Liter
15	194	KeroseneLamps	Lighting	Low income	Electrified	Liter
10	200	KeroseneLamps	Lighting	Middle income	Electrified	Liter
10	31	Candles	Lighting	Low income	Non_Electrified	Megajoule
6	14	Candles	Lighting	High income	Electrified	Megajoule
14	21	Candles	Lighting	Middle income	Electrified	Megajoule
20	20	Candles	Lighting	Low income	Electrified	Megajoule
6	27	LPG	Refrigeration	High income	Electrified	Kilogramme

2	27	LPG	Refrigeration	Low income	Non_Electrified	Kilogramme
28	274	Electricity	Refrigeration	Low income	Electrified	Kilowatt-Hour
38	274	Electricity	Refrigeration	Middle income	Electrified	Kilowatt-Hour
63	274	Electricity	Refrigeration	High income	Electrified	Kilowatt-Hour
13	54	Electricity	WaterHeating	High income	Electrified	Kilowatt-Hour
5	152	Electricity	WaterHeating	Low income	Electrified	Kilowatt-Hour
5	205	Electricity	WaterHeating	Middle income	Electrified	Kilowatt-Hour

*Charcoal appliances here are charcoal ironing boxes/stoves