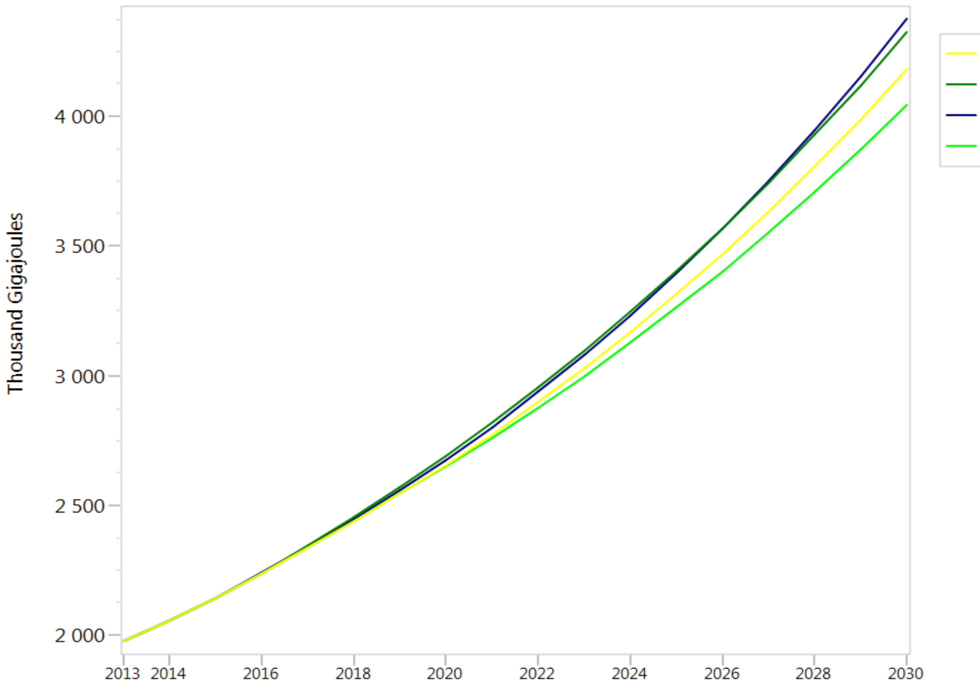
ENERGY FUTURES: THE 2030 OUTLOOK FOR GA EAST MUNICIPALITY

Dr. Simon Bawakyillenuo | Innocent S.K Agbelie



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SAMSET
Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions

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Knowledge for Development

Energy Futures: The 2030 OUTLOOK FOR Ga East Municipality

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SAMSET Project

Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions (SAMSET) is a 4-year project (2013-2017) supporting sustainable energy transitions in six urban areas in three African countries – Ghana, Uganda and South Africa. A fundamental objective is to improve the "knowledge transfer framework" so as to enhance research and capacity building efforts geared towards this challenging area.

SAMSET Ghana

This document is produced by the Ghana SAMSET team, led by Dr. Simon Bawakyillenuo and Mr. Innocent Komla Agbelie of the Institute of Statistical, Social and Economic Research (ISSER), University of Ghana. Dr. Bawakyillenuo is the country project coordinator (Lead) of the SAMSET project and generally researches on energy and the environment, energy policy, renewable energy, environmental policy, climate change and green economy. Mr. Agbelie is an economist and project assistant on the SAMSET project. His research interest lies in sustainable development, energy and green economy.

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1.0 Introduction

Energy futures is relevant for the development of sustainable energy strategies for various local governments – municipalities, cities, districts, etc. Different energy demand scenarios present local authorities with alternative energy perspectives of the future, thereby guiding them in their choice of the energy pathways for the future. Sustainable energy transitions are achievable based on the development of sustainable energy strategies that reflect the sort of energy futures desired by any local government. Therefore the application of appropriate modelling techniques under different unambiguous assumptions to produce different future scenarios is important in facilitating the sustainable energy transitions in Sub-Sahara African municipalities including, the Ga East Municipality (GEM).

GEM is one of six[1] beneficiary Sub-Sahara African municipalities on the SAMSET project and located in the Greater Accra Region of Ghana. GEM was selected based on its rapid urbanisation rate and the numerous energy related challenges it is confronted with. As part of the Ghana SAMSET work output, an energy survey was undertaken in GEM across all energy demand and supply sectors in 2013 to understand the state of energy in the municipality. The State of Energy (SoE) report[2] for GEM has since been produced from the gathered data. . However, the survey data also serves as input data, which is used to model different future energy consumption scenarios for all the energy sectors in the municipality for a specific time period.

This Energy Futures report for GEM, thus highlights the different energy consumption scenarios in the future for GEM, including the business as usual (BAU) and alternatives that take into account various energy efficiency policy intervention programmes. The Planning Unit of the Assembly will appreciate better evidence-based future scenarios emanating from scientific simulation methodologies to help them take informed policy decisions towards sustainable energy transitions. Discussed in the subsequent sections are the type of data used by the modelling tool for the simulation across the various energy sectors, description of the modelling tool and procedure, discussion of sectoral energy futures in relation to the BAU scenarios and finally, policy recommendations from the implications of the various scenarios are highlighted.

2.0 Data Needs, Data Types and Energy Sectors

The population of GEM was estimated to be 147,742 in 2010 (GSS, 2014). With a growth rate of approximately 3% per annum, the population of GEM was estimated around 161,441 living in 37,096 households by 2013. About 75% of the households are electrified and the households are classified based on standard Ghanaian land-use classification depending on the availability and degree of access to infrastructure and services (Bawakyillenuo & Agbelie, 2014). Based on these estimates, GEM's Gross Value Added (GVA) is estimated around GHC 437.5 Million in 2013, inferring from the nation non-oil GDP per capita of Ghana in 2013.

[1] SAMSET partner municipalities in Awutu Senya East and Ga East in Ghana; Kasese and Jinja in Uganda; and Cape Town and Polokwane in South Africa.
[2] Report available online at www.samsetproject.net

Data collection was primarily based on household, business, commercial and industrial surveys and interviews of institutions by the SAMSET-Ghana team. The data gathering process involved:

- Surveys: 590 households, 310 commercial businesses and 50 industrial businesses
- Focus groups
- Interviews with municipal staff
- Municipal records

In-depth details of these surveys are presented in the SoE reports[3] by Bawakyillenuo and Agbelie, 2014. The baseline year for this model is 2013 since the survey was carried out in 2013. In certain instances this dataset was augmented with data from existing literature and online sources. The scope of energy systems models, even of a bounded municipal area, covers a very broad range of activities, hence, it was also necessary to make assumptions in relation to issues.

The general form of a LEAP model involves the division of the energy demand side into typical economic sectors:

- Transport
- Municipal Services
- Households/Residential
- Industry
- Commercial
- Agriculture

On the other hand, the supply sectors are typically put under the node 'Transformation', albeit not exclusively, as shown below:

- Transmission and Distribution
- Electricity Production
- Oil Refining
- Charcoal Production

In order to build a model, data must be collected for the demand side sectors that captures the levels of output and energy intensity of producing that output categorised by technology and/or energy carrier for each of the typical services required in that sector, for instance lighting, heating, passenger transport etc.

3.0 Methodology: Modelling Tool

The model is developed based on the Stockholm Environment Agency's (SEI) Long range Energy Alternatives Planning System (LEAP) platform. LEAP is essentially an accounting type simulation model, although other uses and features have emerged as the product has developed. The rationale for the selection of LEAP as a tool for the SAMSET project has been documented in project outputs (Tait,

[3] SoE Reports available online at www.samsetproject.net

McCall, & Stone, 2014) and while the LEAP software tool itself a lot has been written about is well documented the tool by SEI (http://www.energycommunity.org). For the SAMSET project, LEAP is used to create a bottom-up data driven picture of Awutu Senya's energy system on both the supply and demand side, projecting a reference case into the future. Scenarios are then developed which to project how the municipality's driven interventions may alter the pathway of this reference case, reducing reduce energy consumption and mitigating mitigate $CO2$ emissions.

The general mathematical formula used in calculating the by which the energy consumption of the services in a sector is calculated is via a simple accounting formula as outlined below in a general but not overly mathematically formal way below for the sake of communicating across disciplines. For the sake of simplicity's sake we will assume that a technology may be either a different means of doing the same thing, for example, travelling by bus or by car but also using a different energy carrier / fuel for example travelling using such as a petrol fuelled car or an electric car.

For a given year in the time horizon of the model we have the following:

Energy Consumption of a Sector = (equal) The Sum of all the Energy Consumptions of Services Required by the Sector. This is expressed as follows.

$E_S = \sum (\theta_i X \eta_i X O_S)$ ……Equation 1

Where:

E_S = The Energy Consumed by a Service in a given year

θ_i = Share of Service supplied by Technology i

η_i = The energy intensity (equivalent to efficiency) of Technology I in units of energy required per units output for example MJ/[passenger km] or GJ/[ton steel]

O_S = The output of a service required in a given year in physical units for example, passenger km of passenger transport, tons of steel or GJ of heating

This simple structure offers considerable advantages in developing scenarios of shifts to new technologies because the modeller can easily change the relative shares (θ_I) of technologies that supply a service at a given future output ($O_{S)}$ and the impact on emissions and energy consumption can be quickly assessed.

For a bottom-up model to be reliable, the assumed activity levels and energy intensities used in services need to be calibrated so that the total energy consumed in the model in the base year, which we define as an historical year, agrees with the total energy known to have been supplied to the system in that year (Mccall and Tait, 2016). This total energy data typically comes from recorded total electricity sales and petroleum fuel sales obtained from the major utilities. Acquiring this data and validating it is therefore an important first step in the modelling process.

In the model developed for GEM, all fuels sold within the municipality, with the exception of transport fuels, are assumed to be consumed within the boundary and thus, count toward its emissions levels. The representation of transport in a spatially bounded scope such as a municipality is inherently problematic. Given the commuting behaviour to Accra and traffic passing through, it is reasonable to assume that a significant portion of petrol and diesel that is sold within GEM transits the boundary while fuel from elsewhere enters the municipality daily (Mccall and Tait, 2016). In this framework an attempt is made to represent intra-boundary and inter-boundary trips either being generated in or attracted to GEM and corridor trips, of which GEM is neither the origin nor destination, but which refuel there. LEAP's tree structure allows the user to include or discard these sub-nodes in reporting results depending on the scope of interest. The LEAP model was created to represent all major sectors of GEM as a bottom up simulation model, and this was calibrated with known fuel sales (mainly liquid fuels and electricity) within the municipal boundary. The main drivers for this model are population and economic growth (one local, and one regional).

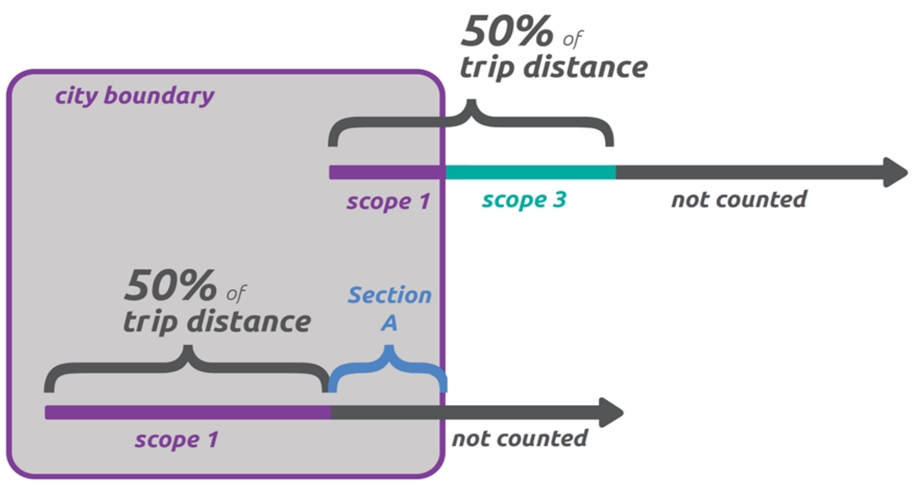
In a collaborative effort to develop practical methodologies for local scale GHG emission inventories, The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) has developed a standardised approach to deal with these issues (World Resources Institute, 2014). This protocol recommends that data and models be organised in different scopes which tackle the spatial problem in different ways as follows:

Scope 1: Only trips that originate and end within the boundary are included. Upstream emissions embedded in energy carriers like petrol diesel and electricity are excluded.

Scope 2; Upstream emissions from electricity supply are added

Scope 3: Transboundary trips originating and ending within the bounded area are included in scope 3. A few methods may be considered but ideally the method of induced activity is preferred whereby 50% of the total trip length that occurs outside the boundary is accounted for as shown below in Figure 1. Trips that pass through the bounded area are excluded completely in this methodology. It is however recognised that in general sophisticated traffic models for a city are required to track transboundary trips to this level of detail.

Figure 1: Induced activity method for accounting for transboundary trips in GHG inventories



Source: Mccall and Tait (2016)

4.0 Sectoral energy futures

This section discusses various energy future scenarios estimated using the LEAP modelling tool discussed in the preceding section with the aid of the baseline input data that was gathered across all energy sectors in 2013 during the GEM energy survey by SAMSET Ghana. Details of the modelling tool, assumptions and modelling procedures have been extensively covered in the GEM modelling technical reports by Mccall et al., (2016). Beginning the section is the BAU future scenario under various assumptions followed by the energy efficiency interventions scenarios.

4.1 Business as usual (BAU)

With accounting multi-sectorial models such as this one, population and economic growth are the main elements which are assumed to drive the overall levels of activity, thereby influencing energy consumption of the municipality. Recent economic growth rates for Ghana are shown in Table 1.

Table 1: Recent economic growth rates for Ghana

Growth Rates - %	**2009**	**2010**	**2011**	**2012**	**2013**
GDP at current market prices	21.3	25.8	29.9	25.3	24.7
GDP at constant 2006 prices (%)	4	8	15	8.8	7.1
Non-Oil GDP at constant 2006 prices	**4**	**7.7**	**9.6**	**8.1**	**6.5**

Source: Ghana Statistical services (2014)

The average non-oil GDP growth rate between 2009 and 2013 for Ghana was 7.2%. GEM is in close proximity to Accra the capital, which is a major centre for Ghana’s economy hence, the local economy of GEM would closely track that of the country. Based on the recent socio-economic performance of the country, the following assumptions were made for the modelling taking into account economic growth, population growth and fuel prices;

- Up to 2020, economy will grow at national rates of 7.2% on average – this is the average of non-oil GDP over the last 5 years.
- Between 2020 and 2030, economy will ‘slow’ somewhat to 6.5% on average.
- The population of GEM is expected to grow at 3.1%
- Assuming an exchange rate of GHC2.31 to 1USD in 2013, the following fuel prices are assumed in the ASEM model:
    - **Table 2: Per unit fuel prices in 2013 in GEM**

Fuel	**Per unit**	**2013**
Petrol	litre	1.11
Diesel	litre	1.06
LPG	kg	1.18
Charcoal	kg	0.27

- Electricity cost adopted from the Public Utilities Regulatory Commission (PURC) were mapped to households and non-residential customers in ASEM as:
    - **Table 3: Electricity prices for GEM in 2013 and 2014**

	Grouping	GH Pesewas	USD Existing	USD new approved
ASEM users:	**kWh**	**2013**	**2013**	**2014**
HH3	0-150	13.54	0.06	0.11
HH2	151-300	20.19	0.09	0.16
HH1	Avg. 301-600 and 601+	24.08	0.10	0.19
Industry	Avg. 301 – 600 and 600+	36.76	0.16	0.29
Formal Comm.	601+	42.43	0.18	0.33
Informal Comm.	0-300	25.27	0.11	0.20

Source: Mccall and Tait (2016)

- It is assumed the electricity price will remain constant in real terms from 2015 onwards (i.e. no change after adjusting for inflation).

Other relevant assumptions for the business as usual model with respect to the various sectors are stated below.

Transport Sector

- The demand for private transport passenger-km is driven by population and income (GDP/capita) growth while the demand for public transport passenger-km is driven by the growth in the population without access to a car.
- It is assumed that the Bus Rapid Transport (BRT) system will come into effect in GEM by 2020, with about 10% of bus and *trotro* (mini commercial vehicles) users switching to BRT in 2020, and that about 40% of bus and *trotro* passengers switch to BRT by 2025. This scenario also assumes that the buses operate at about 10% more efficiently (fuel wise) than standard buses in GEM even with the same occupancy – owing to new engines on the BRT buses.
- Private transportation - light vehicles and motorbikes are assumed to retain the operating characteristics of the base year – no change in occupancy rates, and similar fuel efficiencies.
- The passenger corridor component is assumed to follow GDP per capita, which itself is an approximation to national economic growth figures.
- Freight tonne-km for light trucks is driven by local industry growth
- Freight tonne-km for medium and heavy trucks are assumed to grow with GDP (which is directly proportional to national and regional economic growth rates).

Household Sector

- The composition of household categories is projected to change. Specifically, it is assumed that there will be no change in the shares of 2nd and 3rd class households and the greatest change will come from increased service delivery within the 1st class household category as shown below in Table 4.
    - **Table 4: Changes in household composition by category in GEM**

	Share in 2014	**Project share in 2030**
HH1 Electrified	63%	75%
HH1 Unelectrified	21%	11%
HH1 Electrified	4%	4%
HH1 Unelectrified	1%	1%
HH1 Electrified	7%	7%
HH1 Unelectrified	2%	2%
	100%	100%

Source: Mccall and Tait (2016)

Local government sector – GEMA

- Municipal sector floor space is projected to grow at 10% of the household growth rate, while the diesel consumption from municipal vehicles is assumed to follow household growth rates (with an elasticity of 1) as they serve more households through time.
- The water treatment system operated by the municipality is assumed to consume more energy in line with the growth of the city population – treating more water as the population grows.
- Embedded generation by diesel and petrol generators is assumed to follow the overall floor space growth rate for the municipality.

Commercial sector

- The formal sector commercial floor space is assumed to grow at 90% of the economic growth rate for the formal sector.
- The informal commercial sector, however, which makes up a significant part of the economy, is assumed to follow population growth rates since the informal sector by nature is driven largely by the inability of the formal economy to create new jobs (Osei-Boateng and Ampratwum, 2011).
- Embedded generation capacity for the commercial sector is assumed to follow the overall floor space growth rate above.

Industrial sector

The following growth rates for the various industry categories in Ga East are assumed:

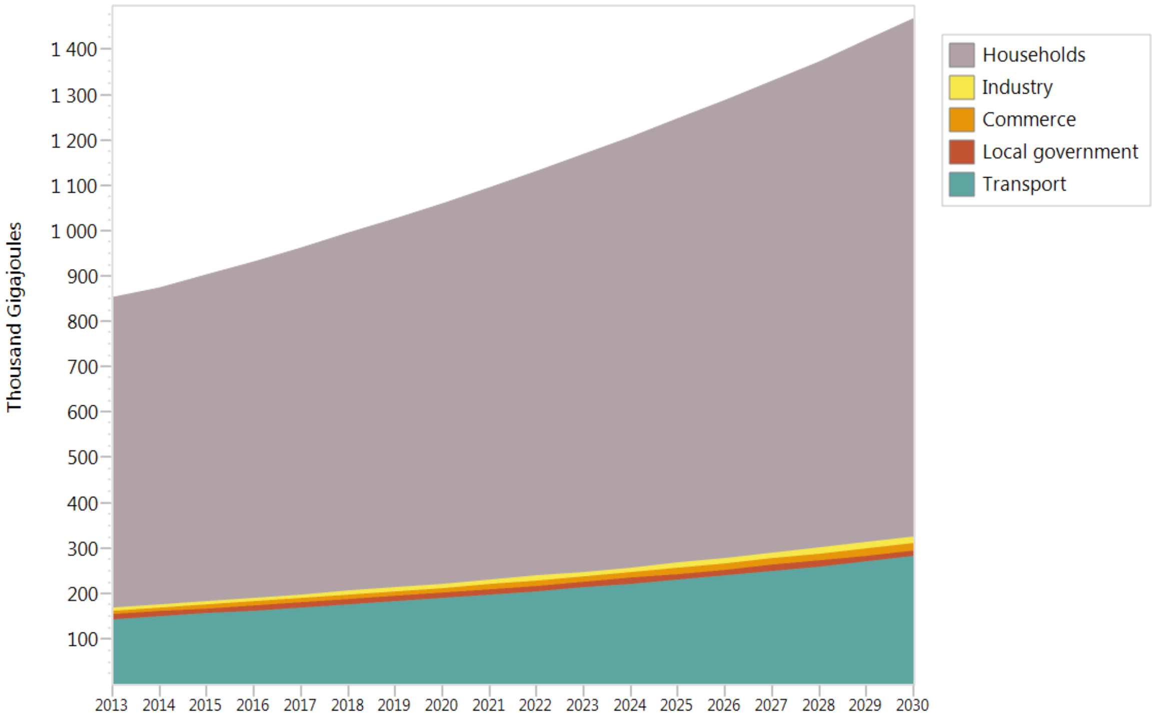
- Construction – follows GDP growth with 0.8 elasticity
- Manufacturing – follows GDP growth with 0.8 elasticity
- Water and sanitation – assumed to grow in line with the population growth rate

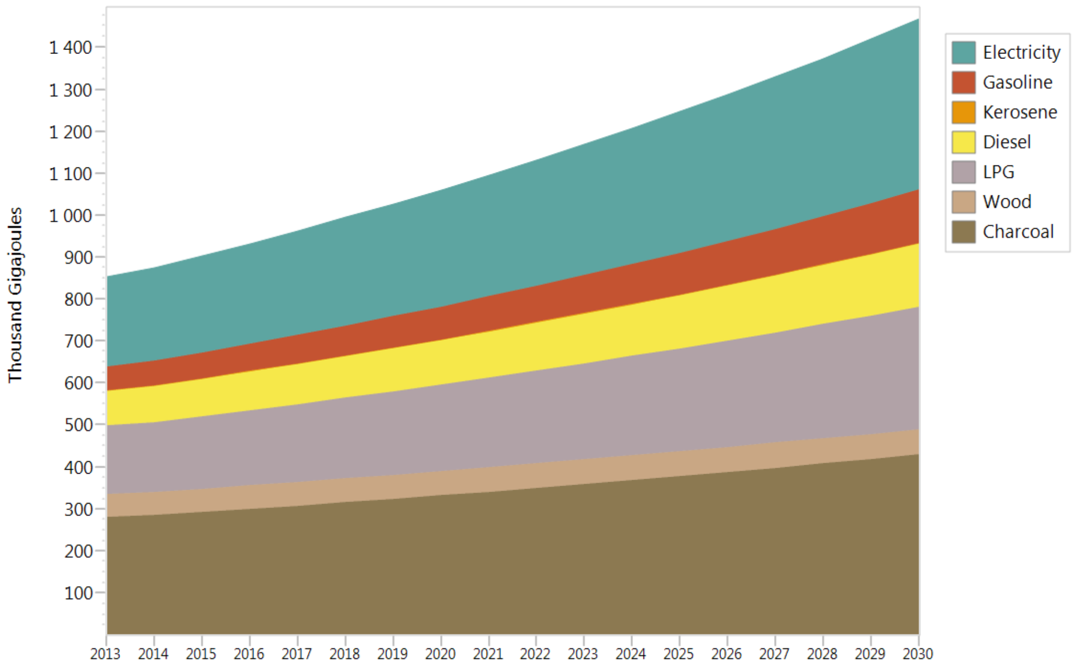
Furthermore, the overall capacity of embedded diesel and petrol generators is assumed to follow the sector's output through the years.

Given the large difference in the contribution of transport sector to the difference assumptions around spatial scope of the model, separate sets of results assuming Scopes 1 and 3 methodologies for transport in the BAU scenarios are presented. GEM's BAU scenario energy demand by sector and fuel under scopes 1 and 3 are presented in Figures 2 and 3 below. Without full consideration for transboundary trip, the household sector is observed to account for about 80% of GEM's total energy consumption over the entire modelling period while the transport sector contributes about 15%. In total, about 1.45m GJ of energy will be demanded by 2030 mostly from charcoal, electricity and LPG fuels. Under this methodology (Scope 1), gasoline and diesel fuels account for about 21% of the total GEM's energy consumption by 2030 (Figure 2).

However, with full consideration for transboundary trips and inclusion of all local trips, the transport sector consumes about half the total energy of the GEM in the base year becoming increasingly dominant with time compared to Scope 1 methodology. The total energy consumption by GEM reaches about 2.8m GJ in 2030 largely due to the transport sector, which accounts for a little under two-third of the total GEM's energy consumption. Gasoline, diesel and LPG fuels account for 70% of the total GEM's energy consumption (Figure 3).

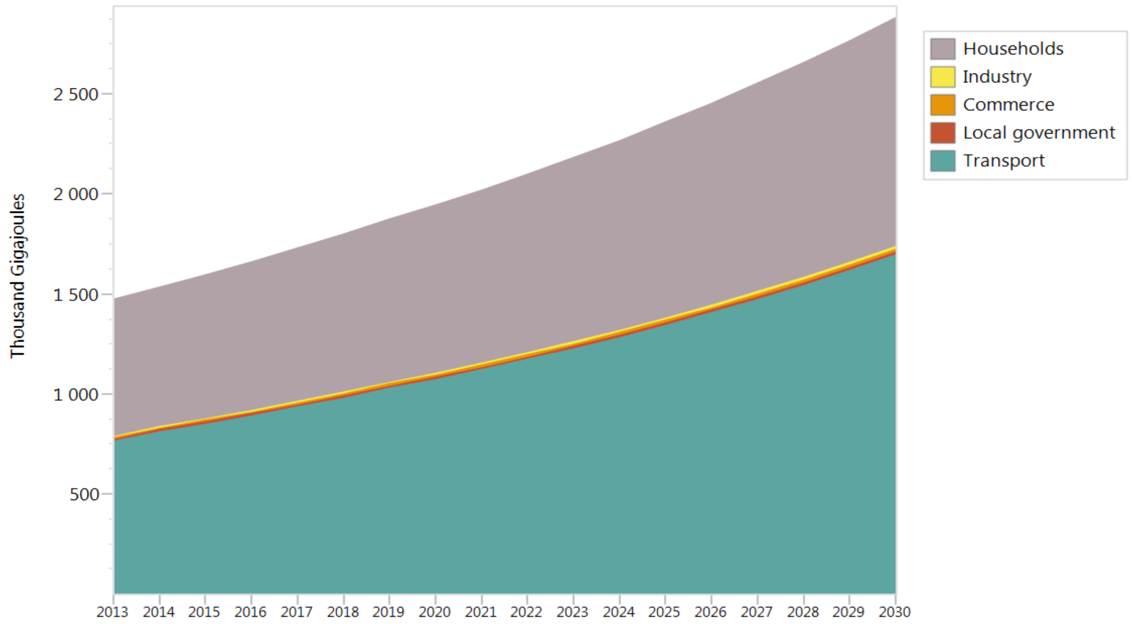
Figure 2: Ga East Municipality BAU scenario energy demand by sector (above) and fuel (below) for scope 1 methodology

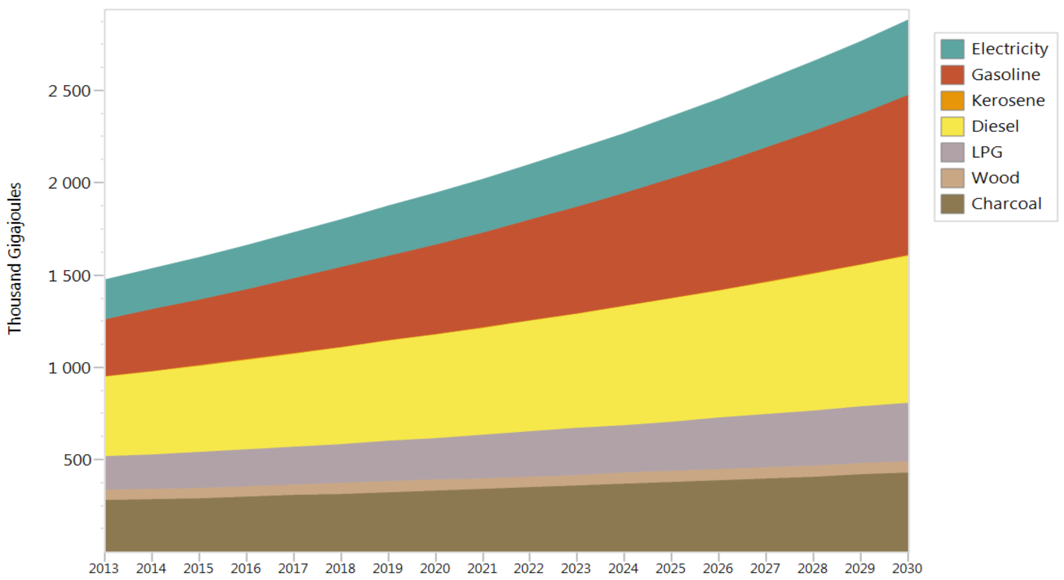




Source: Mccall and Tait (2016)

Figure 3: Ga East Municipality BAU scenario energy demand by sector (above) and fuel (below) for Scope 3 methodology

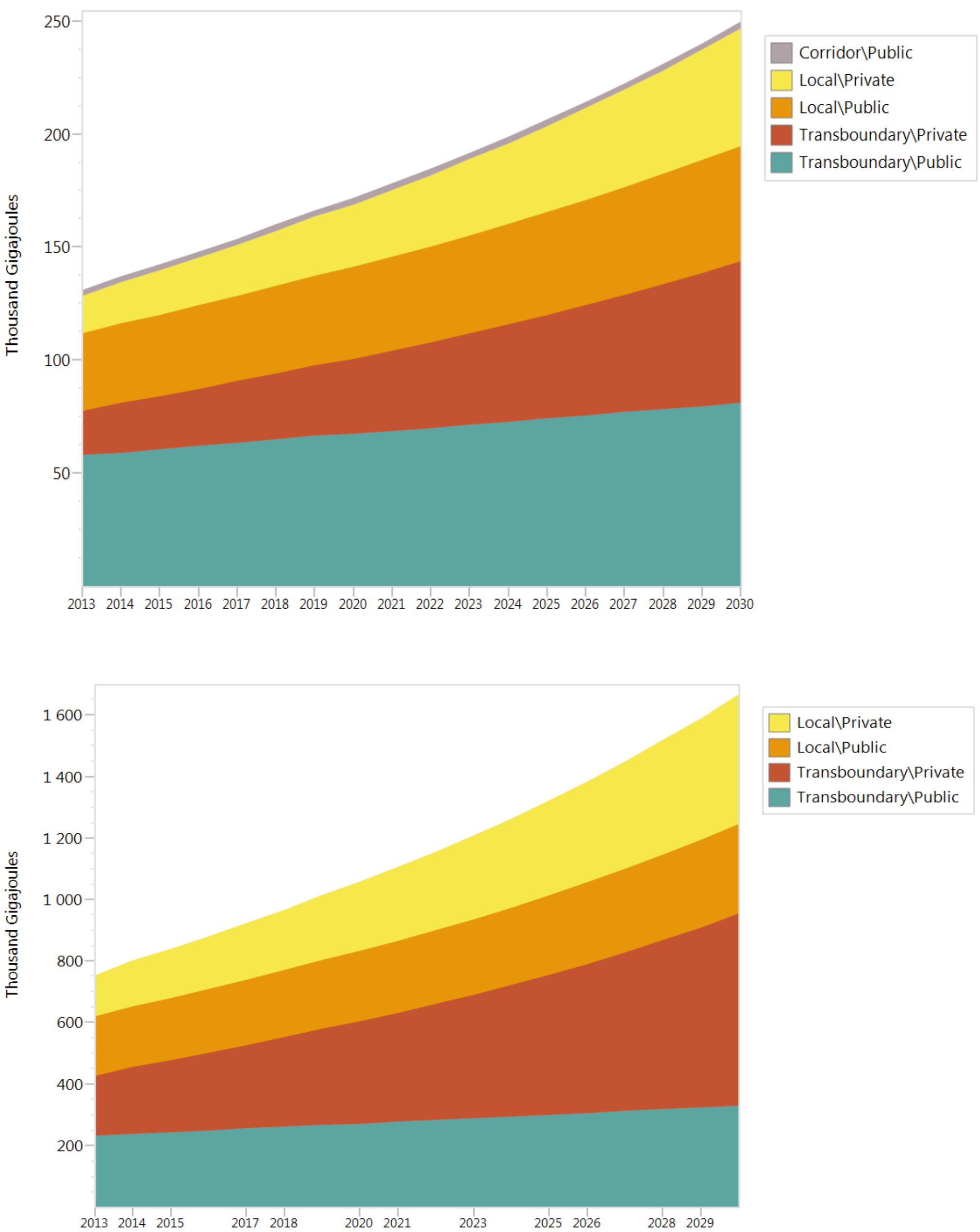




Source: Mccall and Tait (2016)

Figure 4 shows the estimated fuel consumption by the transport sector in GEM from 2013 to 2030 under scopes 1 and 3 methodologies. About 250,000 GJ of energy will be consumed in total by the transport sector in 2030 mainly from public transports within and outside the municipality boundary under scope 1 methodology. Private transports are also significant contributors to energy demand in GEM. Under scope 3 methodology, more than half of the 1.65m GJ of energy to be demanded by the transport sector in 2030 will hugely be as a result of transboundary passenger carriage (Figure 4)

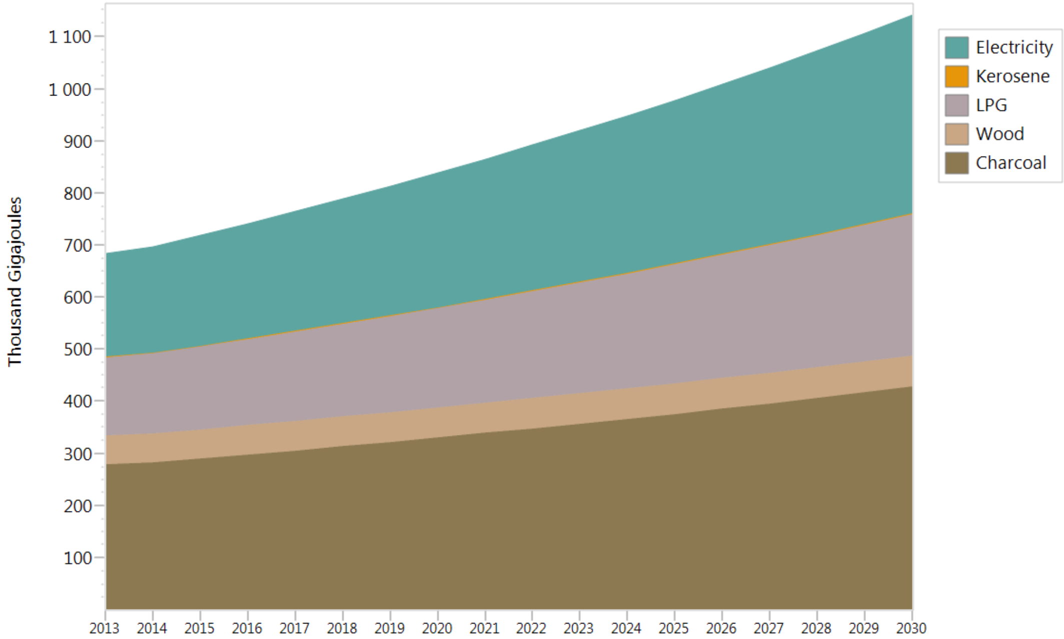
Figure 4: GEM transport sector energy demand by subsector for Scope 1 (above) and Scope 3 (below) methodologies



Source: Mccall and Tait (2016)

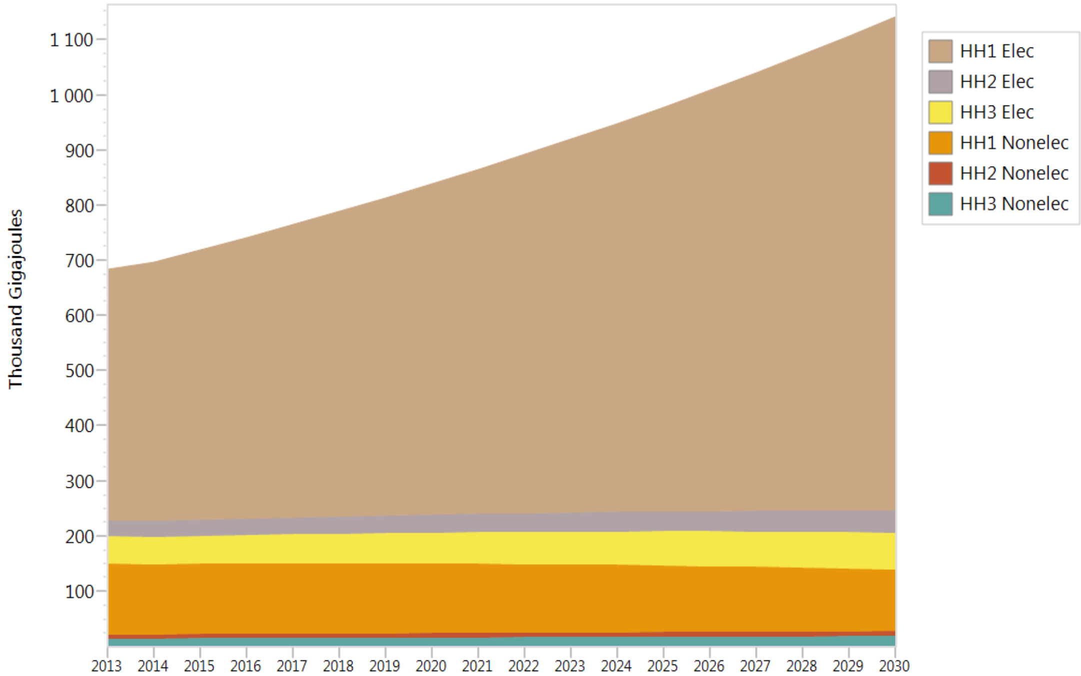
The household sector (largest sector in Scope 1 and second largest after the transport in Scope 2) is estimated to consume about 1.15million GJ of energy by 2030 with charcoal fuel accounting for almost 40% (420,000 GJ) of the total demand followed by electricity and LPG fuels (Figure 5). The model results further reveal that first class electrified households will be responsible for about 80% of the total household energy demand by 2030 followed by first class non-electrified households (Figure 6). This is as a result of the expected increase in first class households' composition in GEM.

Figure 5: Household energy consumption by fuel for Ga East in the BAU scenario



Source: Mccall and Tait (2016)

Figure 6: Energy consumption of the household subsectors of GEM in the BAU scenario

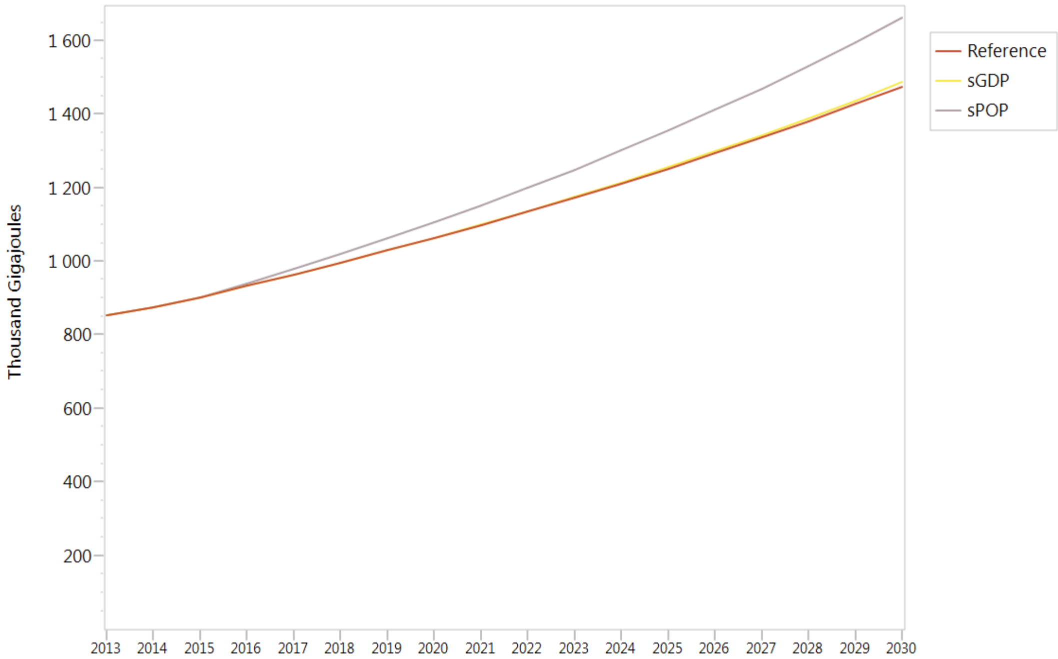


Source: Mccall and Tait (2016)

Further discussed under the BAU scenario are two sensitive assumptions; possible increase in the main key determinants, population and GDP growth, than assumed earlier. Explored in this scenario are: the sudden increase in population from 2016 where the municipality grows at 4% p.a instead of the 3.1% assumed earlier; and constant GDP growth rate – 7.4% until 2020, 6.5% thereafter- and continues to grow at 7.4% p.a.

Comparing the sensitivity scenarios to the reference scenario as depicted in Figure 7, it is observed that the energy consumption of GEM is more sensitive to population than to economic growth. GEM's total energy consumption shoots up by approximately 14% to about 1.65m GJ of energy by 2030 as a result of population increase but response only marginally to increase GDP.

Figure 7: Energy consumption of GEM in the sensitivity scenarios for population and economic growth rates increases (scope 1)

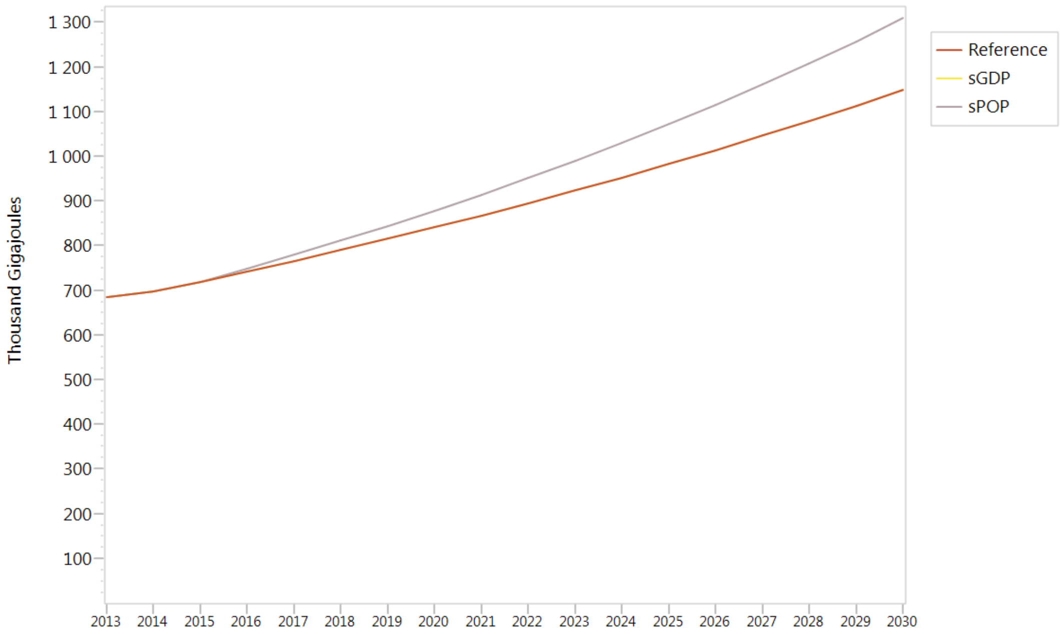


Source: Mccall and Tait (2016)

The largest energy consuming sector in GEM – the household sector, does not respond to the economic growth rates in the model, but responds significantly to the population increase as indicated in the Figure 8. The lack of change in the household sector energy consumption with GDP growth is due to the current model structure whereby the households are not inherently linked to GDP.

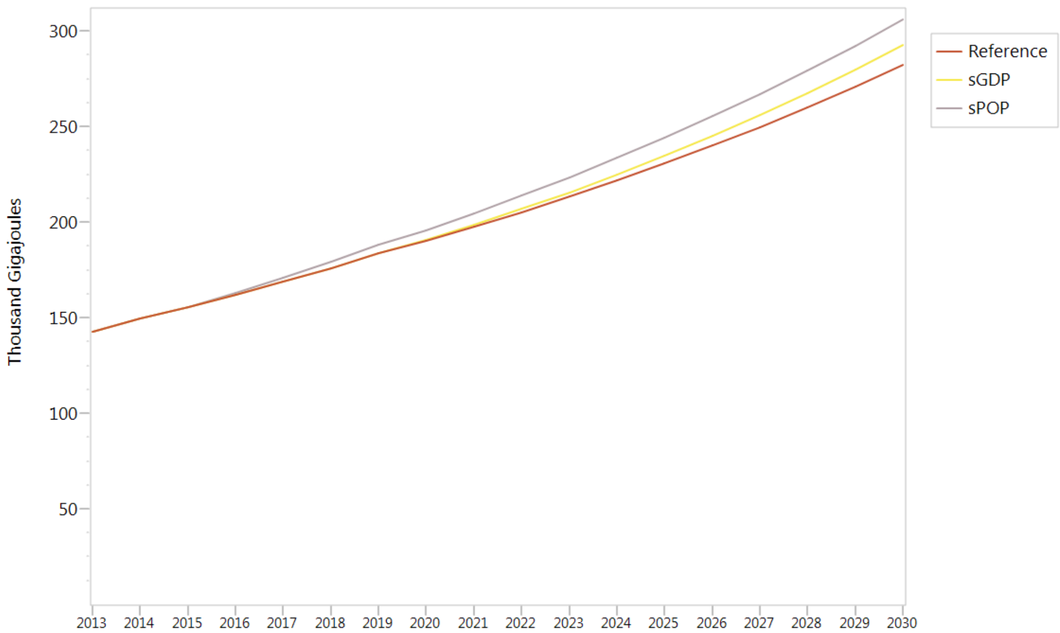
The second largest energy consuming sector in GEM – the transport sector, responds to both population and economic growth (Figure 9). All subsectors of the passenger transport sector respond to population more than the economic growth rates. This is a result of the fact that the majority of demand comes from public transport and an increase in population (without an increase in GDP) leads to more public transport, while the same increase in GDP will have a comparably smaller impact on the use of private transportation.

Figure 8: GEM household sector energy consumption for the sensitivity scenarios



Source: Mccall and Tait (2016)

Figure 9: Transport sector energy consumption in GEM for the sensitivity scenarios tests (scope 1)



Source: Mccall and Tait (2016)

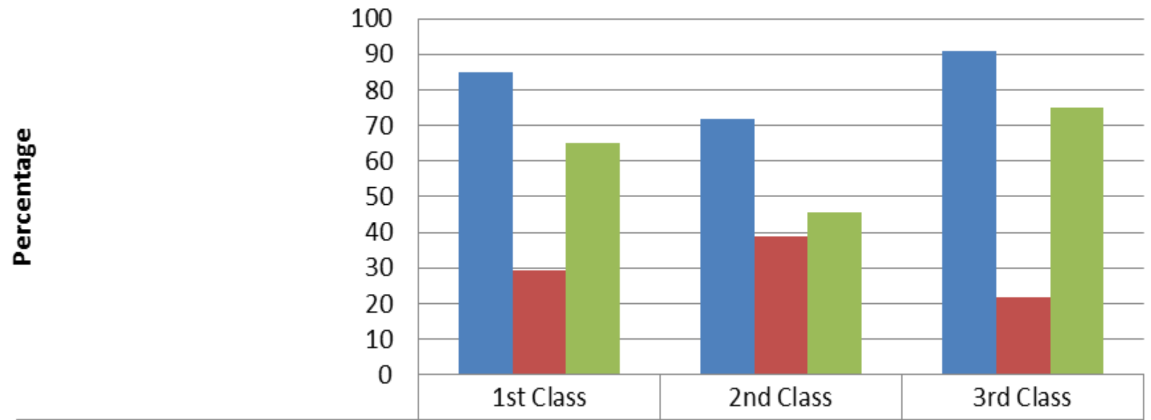
4.2 Efficiency Intervention Scenario

This sub-section looks at the future energy consumption model of GEM taking into consideration three different energy efficiency programmes promoted by the national government and pioneered through the national energy institutions like the Energy Commission of Ghana. The energy efficiency interventions include promotion of the use of energy efficient cook stoves and access to modern fuels i.e. electricity and LPG. GEM's energy consumption dynamics are modelled based on relevant assumptions with regards to these energy efficient programmes.

4.2.1 Efficient cookstoves scenario

The energy efficient (EE) cookstove locally called *Gyapa* uses about 50% less charcoal than the old traditional charcoal stove. The proportion of electrified and non-electrified households who have knowledge of EE cookstoves, the proportion using energy efficient cookstove and the proportion who wish to use EE cookstoves as revealed in the 2013 GEM Energy survey are shown in Figures 10 and 11.

Figure 10: Awareness and use of the Gyapa cook stove in electrified households in GEM



	1st Class	2nd Class	3rd Class
% who have knowledge of efficient cook stove	85.13	72	91.11
% who use efficient cook stove	29.22	38.89	21.95
% who wish to use efficient cook stove	65.11	45.45	75

Source: ISSER SoE Surveys in ASEM and GEM (2014)

Figure 11: Awareness and use of the Gyapa cook stove in non-electrified households in GEM

	1st Class	2nd Class	3rd Class
% who have knowledge of efficient cook stove	87.27	85.71	76.92
% who use efficient cook stove	23.71	0	40
% who wish to use efficient cook stove	79.45	100	83.33

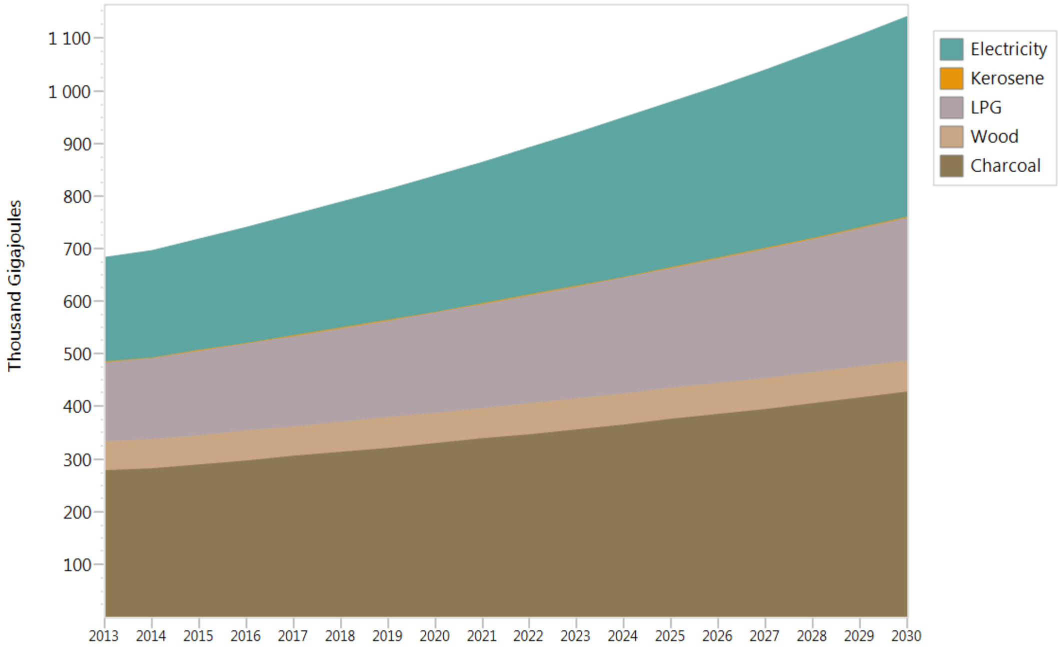
Source: ISSER SoE Surveys in ASEM and GEM (2014)

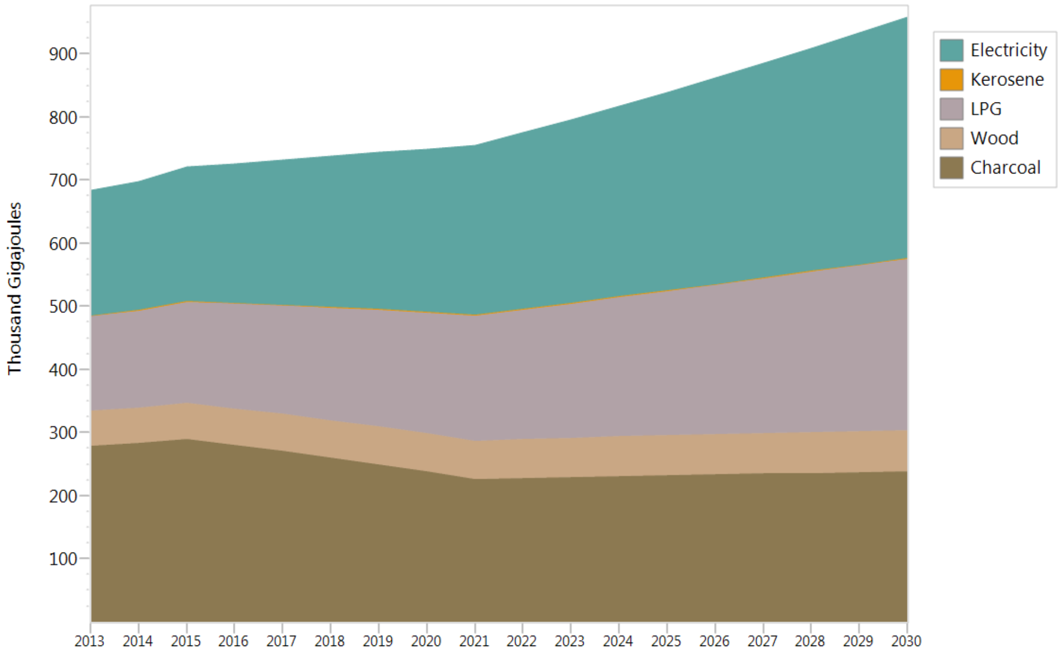
Additional key assumptions with respect to this EE programme include (upholding the earlier assumptions on population and GDP growth rates):

- A roll out programme of *Gyapa* cookstove to the household sector of GEM begins in 2016, and by 2021 (a 5 year programme) all households that indicated in the survey that they wished to have a Gyapa, start to use one.
- By 2030, it is assumed majority of remaining households who do not obtain *Gyapa* by 2021 are able to do so by 2030 hence an estimated 90% of all HHs that use charcoal cook using Gyapa by 2030.
- It is assumed that the *Gyapa* cookstoves are 50% more efficient than the traditional/old charcoal stove.
- *Gyapa* cookstove costs 10 USD and have a 3 year life span

Figure 12 shows the estimated energy consumption by the household sector with the energy efficient cookstove scenario compared to the BAU reference scenario. It is observed in the figure (lower chart) that charcoal consumption flattens up from 2021 to 2030 where almost all households are using energy efficient stoves. Instead of the 550,000 GJ of charcoal estimated to be consumed by 2030 under the BAU, the EE cookstove usage will reduce charcoal consumption to about 280,000 GJ. This ultimately translates into significant reduction in total energy consumption in GEM to about 950,000 GJ as depicted in Figure 13.

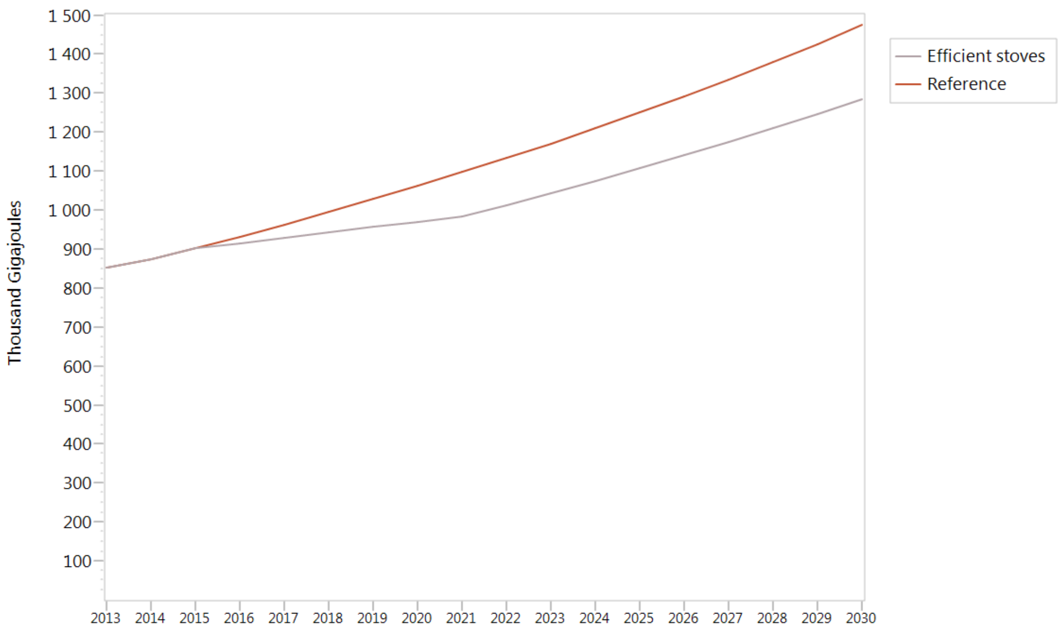
Figure 12: The household sector energy consumption by fuel in the reference scenario (above) and efficient cook stove scenario (lower)





Source: Mccall and Tait (2016)

Figure 13: GEM total energy consumption for reference and household efficient cook stoves scenario



Source: Mccall and Tait (2016)

The total cumulative fuel savings and costs savings arising from using EE cookstove, given assumed prices, are presented in Table 5. This can be set against the cost of a rebate or replacement program but it should be borne in mind that this comparison would not include the externality costs arising from indoor air pollution and contribution to climate change which is another area in which this type of model can be improved. From Table 5, GEM will likely save 9,296 tonnes, 31,487 tonnes and 61,051 tonnes of charcoal by 2020, 2025 and 2030 respectively, representing GHS 2.3m, GHS 7.7m and GHS 14.9m in those years.

Table 5: Cumulative Fuel and Cost savings for Efficient cook stoves

	2016	2020	2025	2030
Tonnes charcoal saved	582	9,296	31,487	61,051
Cost Impact (GHS million)*	0.14	2.3	7.7	14.9

* This is the savings relative to the reference scenario

Source: Mccall and Tait (2016)

4.2.2 *Efficient refrigerator scenario*

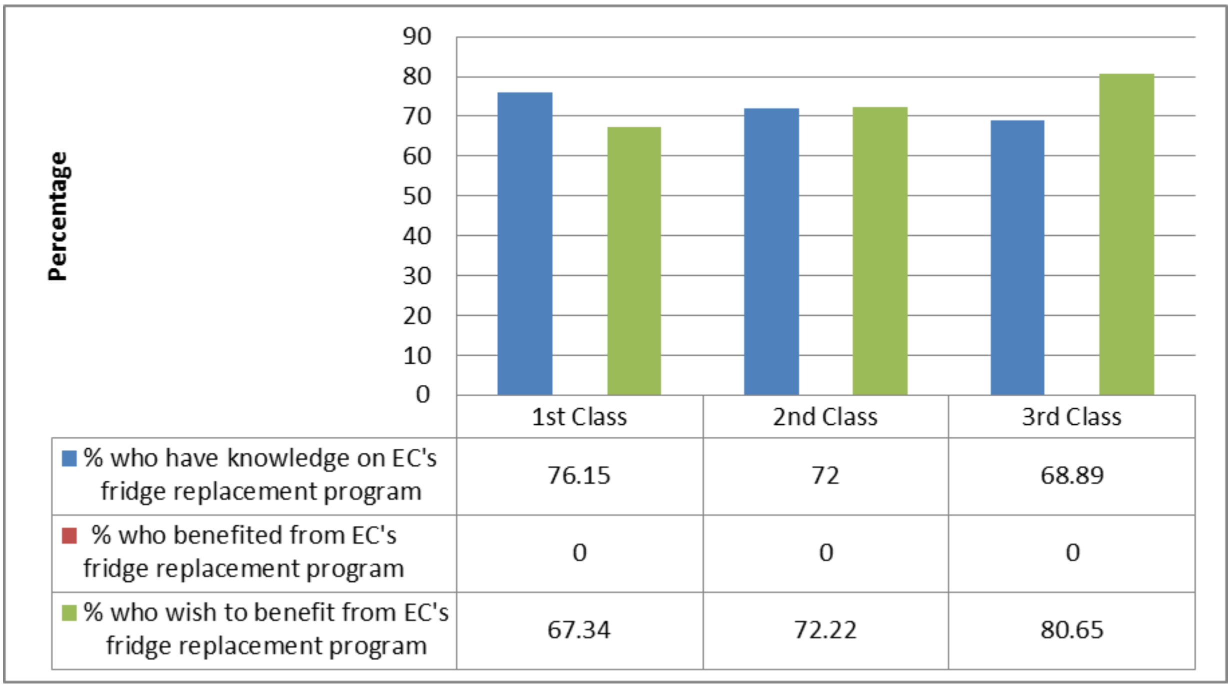
The Energy Commission of Ghana leads the promotion of the use of energy efficient refrigerators introduced in Ghana since 2011. The new fridges were expected to consume 250kWh a year as compared to the old inefficient ones which consumed about 1200kWh a year on average. The SAMSET energy survey shows that fairly half of first and second class households own new refrigerators while only 29% of third class households own new refrigerators. However, for these new refrigerators, less than 35% had the energy efficiency labels on them at the time of their purchase implying the new refrigerators may not necessarily be energy efficient (Table 6). The 2014 energy survey results further reveal little or no patronage of the Energy Commission's efficient refrigerators promotion programme in GEM as shown in Figure 14.

Table 6: GEM's refrigerator ownership and efficient fridge penetration

	Survey of GEM fridge ownership		Fridges with EE label '1'
	New	Second hand	
HH1	50%	48%	30%
HH2	52%	48%	20%
HH3	29%	68%	17%

Source: Mccall and Tait (2016)

Figure 14: Efficient fridge awareness and usage in GEM



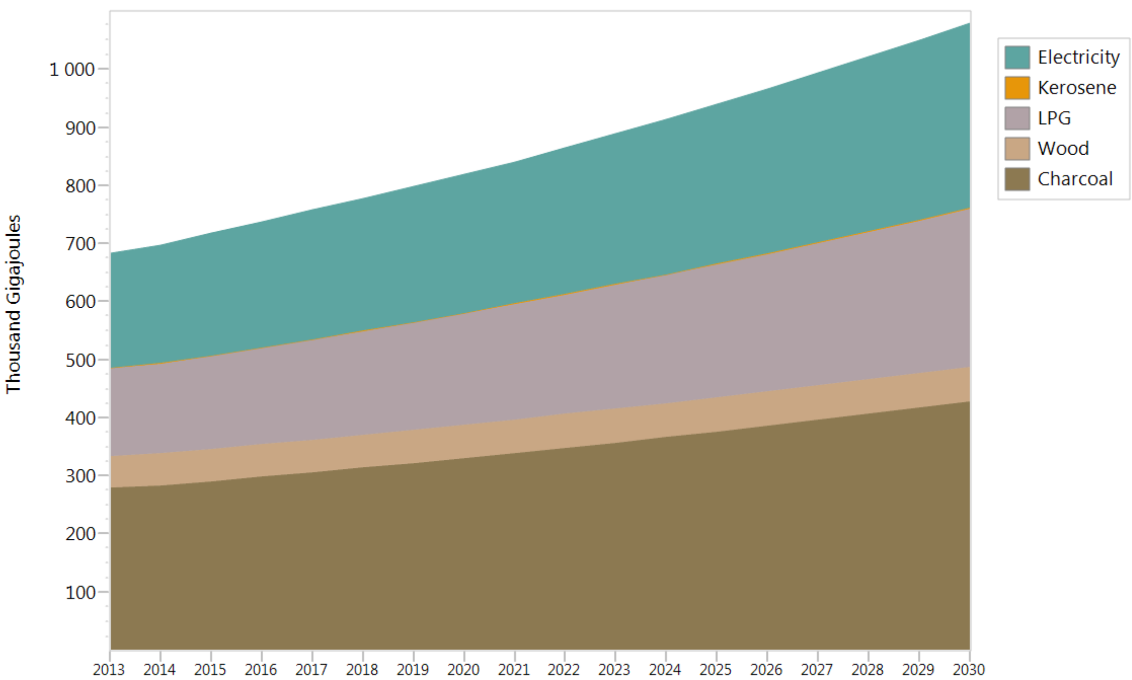
Source: ISSER SoE Surveys in ASEM and GEM (2014)

The key additional assumptions considered under this scenario include:

- Assumption of a new programme, which makes it affordable to participants to buy or replace their old fridges with efficient new ones (specifically marked with efficiency label 1) begins in 2016 and is completed by 2021.
- This replacement programme affects all those that wished to have benefited from the programme, but did not as indicated in the survey results presented above.
- The remainder of households who do not participate in this programme, buy or replace their fridges between 2021 and 2030.
- New fridges are assumed to be 80% more efficient than old inefficient fridges
- New fridges on average are 444 USD in 2013 and have a 15 year lifespan
- Old inefficient fridges are assumed to be 173 USD and have a 7.5 year life span.

Figure 15 below depicts GEM's household energy consumption with the assumed EE refrigerator scenario. This scenario basically affects the electricity consumption of the household sector, which ultimately affects the entire energy consumption of the GEM. From the figure, the total household energy consumption falls to about 1.08m GJ of energy by 2030 due to the energy efficient refrigerator scenario compared to 1.15m GJ under the from BAU scenario.

Figure 15: Household sector fuel consumption in the efficient fridges scenario



Source: Mccall and Tait (2016)

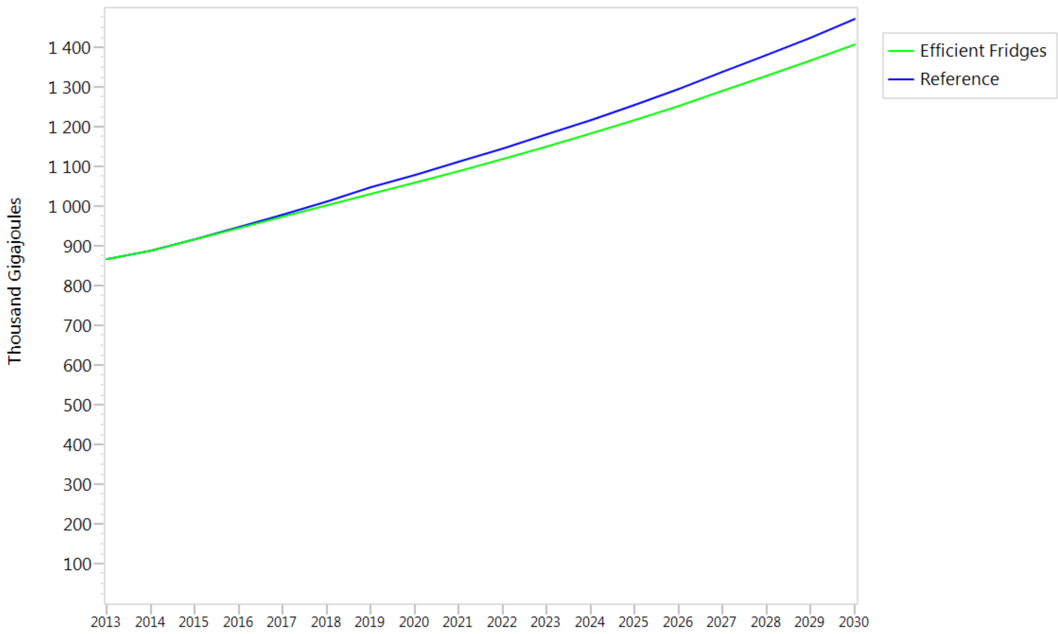
As shown in Figure 16, the energy efficient refrigerator adoption assumption reduces the total GEM energy consumption to 1.4m GJ from the BAU scenario level of 1.48m GJ by 2030. In terms of real cumulative energy savings, about 15.5m kWh, 58.8m kWh and 131.4m kWh of electricity will be saved in 2020, 2025 and 2030 respectively as a result of the energy efficient refrigerator adoption assumption. In monetary terms, about 3m GHS, 11.3m GHS and 25.3m GHS will be saved in these years if the energy efficient adoption assumptions hold through to 2030 (Table 7).

Table 7: Cumulative energy and cost savings of the efficient fridges scenario

	2016	**2020**	**2025**	**2030**
kWh saved	928 377	15 459 651	58 840 041	131 394 800
GHC saved	178 805	2 977 529	11 332 592	25 306 638

Source: Mccall and Tait (2016)

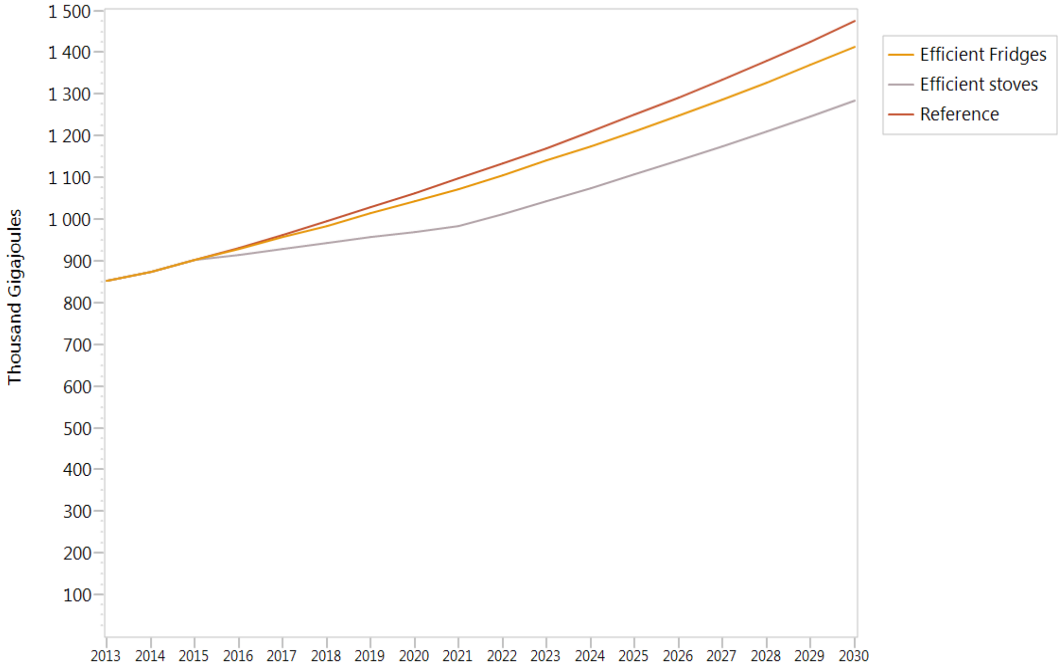
Figure 16: Total Ga East Municipality energy consumption comparing reference scenario and efficient fridges scenario (scope 1)



Source: Mccall and Tait (2016)

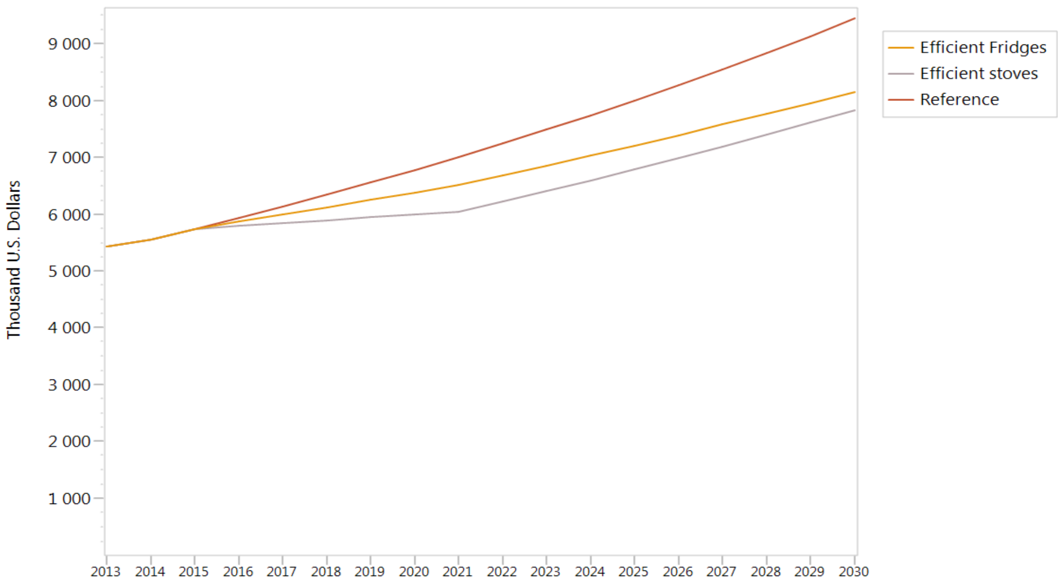
In comparison with the energy efficient cookstove scenario, the energy efficient refrigerator scenario has a smaller impact due to the fact that cooking is a dominant energy end-use in GEM compared to refrigeration. As observed in Figure 17, the margin of fall in households' energy consumption due to the energy efficient cookstove scenario is larger than the fall due to the efficient refrigerator scenario. The monetary savings for the two scenarios are, however, very comparable due to the increase in electricity costs in the BAU scenario (Figure 18).

Figure 17: Energy consumption for GEM comparing household scenarios



Source: Mccall and Tait (2016)

Figure 18: Total cost to GEM comparing the household scenarios



Source: Mccall and Tait (2016)

4.2.3 Household Access to modern fuels

Explored under this scenario is the impact of households increased access to modern energy (LPG and electricity) on fuel consumption in the household sector. The SoE report for GEM shows that significant proportion of households use LPG for cooking relative to electricity, which many perceived to be expensive. The model thus, assumes that most households would prefer to cook using gas (LPG) than electricity going into the future, as presented in Table 8.

The number of households utilising clean fuels increases in this scenario starting in 2020 through to 2030.Thus, the average intensity for the clean fuels increases while the average intensity for charcoal (the majority of non-clean fuel use) will decrease (Table 9). The numbers for electricity and LPG intensities come from the study by Cowan (2008), while the charcoal intensities change is an assumption that the average intensity usage will drop by 75% as most cooking is done on LPG (and electricity for some households) while some still use charcoal for cooking.

Table 8: Shares for households using fuels for cooking in the access to modern fuels for cooking scenario

	HH class	End use	Shares in % for 2030 (2013)		
			Electricity	**LPG**	**Charcoal**
Electrified	HH1	Cooking	30 (0)	100 (82)	20 (81)
		Other appliance use	85 (50)		
	HH2	Cooking	30 (0)	100 (76)	30 (92)
		Other appliance use	70 (40)		
	HH3	Cooking	10 (0)	100 (64)	30 (100)
		Other appliance use	55 (22)		
Non-electrified	HH1	Cooking		100 (41)	50 (94)
		Other appliance use			
	HH2	Cooking		100 (15)	50 (96)
		Other appliance use			
	HH3	Cooking		100 (15)	50 (96)
		Other appliance use			

Source: Mccall and Tait (2016)

Table 9: The average energy intensity for each fuel type for cooking in the access to modern energy scenario

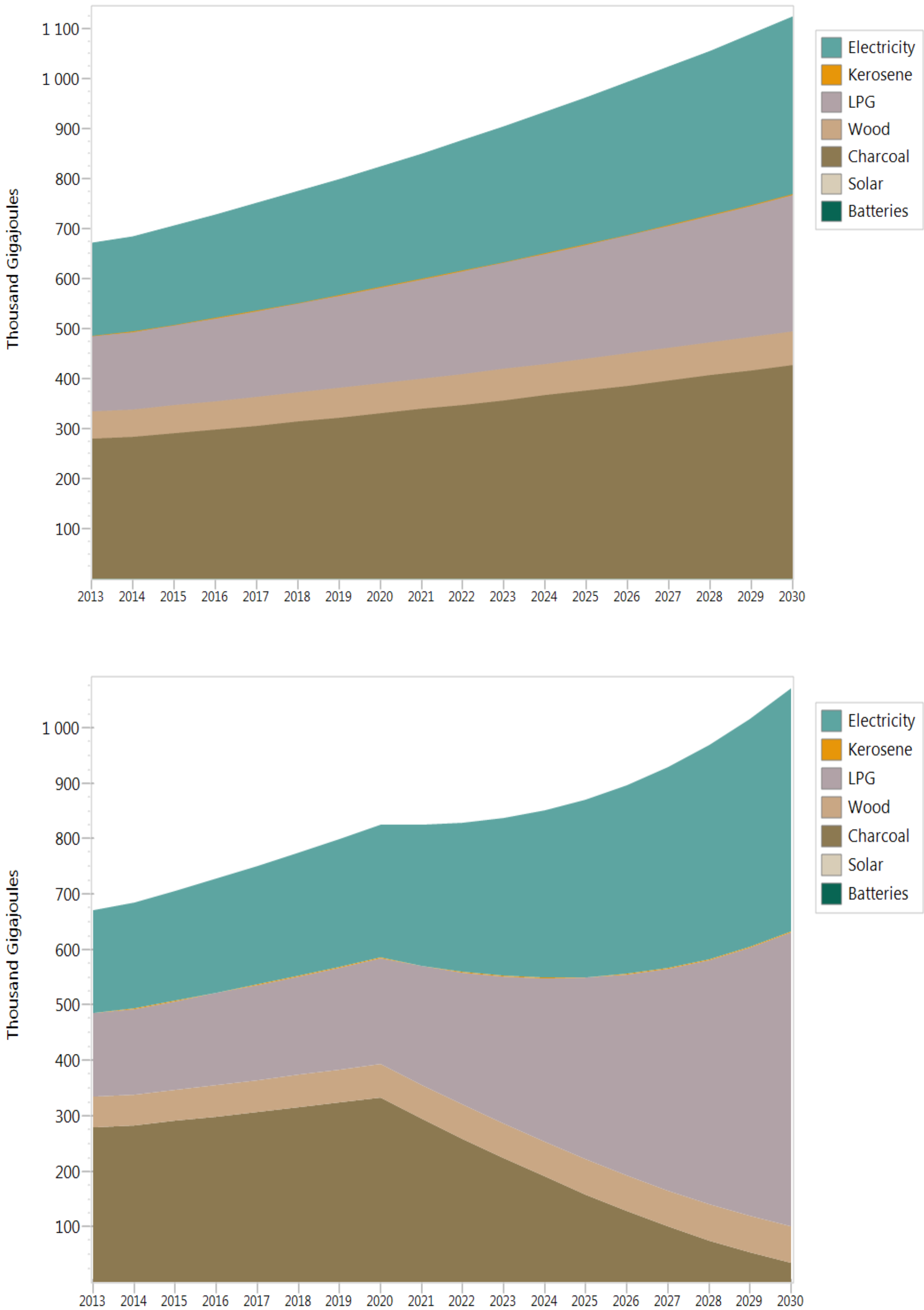
	HH class	End use	Intensity value GJ/HH for 2030 (2013) Electricity	LPG	Charcoal
Electrified	HH1	Cooking	3.5 (1.5)	6.5 (5.1)	1 (7.7)
		Other appliance use	1.7 (1.7)		
	HH2	Cooking	3 (1.5)	5.5 (3.5)	0.75 (7.6)
		Other appliance use	1.1 (1.1)		
	HH3	Cooking	3 (1.5)	5 (2.9)	0.75 (7.6)
		Other appliance use	1.5 (1.5)		
Non-electrified	HH1	Cooking		4 (2.1)	2.25 (12.2)
		Other appliance use			
	HH2	Cooking		3.5 (0.5)	1 (7.9)
		Other appliance use			
	HH3	Cooking		3.5 (0.5)	1 (7.9)
		Other appliance use			

Source: Mccall and Tait (2016)

The modelling results for increased access to modern energy scenario is shown in Figure 19 below in comparison with the BAU scenario. Total household energy consumption clearly increased for the access to modern energy scenario relative to the BAU scenario mainly on account of LPG and electricity consumption. From 2020, LPG consumption will likely increased from about 200,000 GJ to about 550,000 GJ by 2030 under the increased access to modern energy scenario compared to about 280,000 GJ of LPG consumption by 2030 under the BAU scenario. Similarly, electricity consumption increases to about 450,000 GJ by 2030 relative to the 350,000 GJ in 2030 under the reference scenario (BAU).

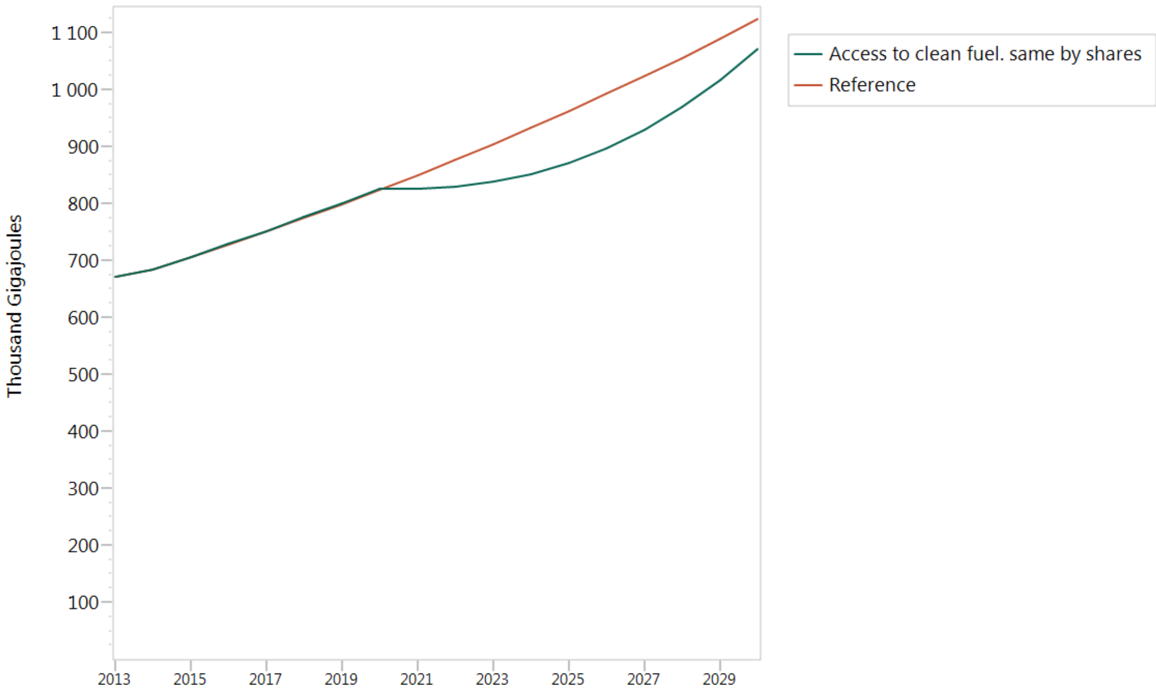
On the contrary, charcoal consumption decreases by about 90% under the increased access to modern energy scenario relative to the BAU reference scenario. The net result is a decrease in total fuel consumption of about 50,000 GJ in the year 2030 clearly depicted in Figure 20.

Figure 19: The household energy consumption by fuel for the reference scenario (above) and the access to modern energy scenario (below)



Source: Mccall and Tait (2016)

Figure 20: Total fuel consumption for the household sectors for GEM for the access to clean fuels scenario compared to the reference scenario



Source: Mccall and Tait (2016)

GEM household sector's energy consumption impact is presented in Table 10 below showing a large increase in consumption of LPG (about 25 thousand tonnes) and electricity (about 104 thousand tonnes) while charcoal consumption decreased significantly through to 2030 (Table 10).

Table 10: Scenario cumulative impact results for access to clean fuels for cooking in GEM

		2021	2025	2030
Electricity	MWh	1135	21500	103904
LPG	Tonnes	328	5819	25794
Charcoal	Tonnes	-1193	-22604	-79589

Note: positive numbers indicate increase consumption, negative a decrease in consumption
Source: Mccall and Tait (2016)

5.0 Conclusion and Recommendations

The population growth of GEM estimated at about 3% in 2010 coupled with the overall positive performance of the entire country will translate into accelerated energy demand in GEM in the future. Per the LEAP modelling results based on the 2013 SoE data, in relation to the BAU scenario, the entire GEM will demand a total of about 1.45m GJ of energy (without full consideration for transboundary trips) and 2.8m GJ of energy (full consideration for transboundary trips) by 2030. The household and transport sectors remain the energy intensive sectors with charcoal, electricity and LPG the dominant fuel types to be consumed by 2030 under the business as usual scenario (scope 1) and gasoline and diesel coming strongly under scope 3 methodology when full consideration is given to transboundary trips.

This energy consumption trend can change on the basis of sustainable energy efficiency programmes. If all households that wished to use energy efficient cookstoves acquire them by 2021 and the remaining households acquire them by 2030, about 31 and 61 thousand tonnes of charcoal, representing GHS 7.7 million and GHS 14.9 million would be saved by 2025 and 2030 respectively, reducing GEM's total energy consumption from about 1.45m GJ to 1.3m GJ in 2030. Similarly, if all households that wished to use EE refrigerators acquire them by 2021and all remaining households acquire them by 2030, about 59m kWh and 131m kWh, representing about GHS 11 million and GHS 25million would be saved by 2025 and 2030 respectively, translating into a marginal reduction in GEM's total energy consumption by 2030. If efforts are directed towards expanding access to modern energy like the LPG and electricity fuels, this will have significant impact on ASEM's total energy consumption through the increase in households' LPG and electricity consumption to about 25,794 tonnes and 103904 MWh respectively by 2030, with charcoal consumption reducing by 79589 tonnes in the same year, giving a boost to environmental gains.

The various scenarios presented above sections drum home the need for policy interventions and actions from the local authority of GEM to support the sustainable energy futures for GEM by 2030. Against this backdrop, the following recommendations have been advanced to guide the municipality in its quest to develop in a sustainable energy pathway

- Promote the patronage and use of energy efficiency cookstoves in GEM. The energy efficient cookstove as observed above, has a significant effect in reducing households' energy consumption of charcoal and overall GEM's energy consumption. Education through practical demonstration of the use of this technology in the presence of households could instil total belief, trust and mass patronage of the technology in GEM.
- Promotion of the use of energy efficient refrigerators in GEM. To ensure large scale usage of efficient refrigerators in ASEM so as to bring about the desired reduction effects in total energy consumption by 2030, it will require collaborative efforts with the Energy Commission of Ghana (EC), academics and donor agencies to roll-out effective education and awareness creation on the energy efficient refrigerators. This should include functional demonstration and effective media advertisements that will convince potential users of the technology
- Increase access to modern fuel types; electricity and LPG. Though a little out of the direct jurisdiction of Ga East Municipal Assembly (GEMA), the local authority can still influence

accessibility to these fuel types through working closely with relevant players including the Electricity Company of Ghana, EC and other private players. Education and promotion of renewable energy (especially solar and biogas) among households and commercial sectors can lead to increased accessibility to electricity while granting permits to deserving oil firms for the establishment of LPG service stations in the municipality can promote usage among households

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