DRAFT

MALAWI ENERGY DEMAND ASSESSMENT REPORT

GOVERNMENT OF THE REPUBLIC OF MALAWI

Ministry of Natural Resources, Energy and Environment

Department of Energy Affairs

IAEA

January 2011

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations and Acronyms

ACM	-	Agriculture, Construction and Mining
BEST	-	Biomass Energy Strategy
CCODE	-	Centre for Community Development and Empowerment
DoE	-	Department of Energy Affairs
DSM	-	Demand Side Management
EAD	-	Environmental Affairs Department
ENPEP	-	Energy and Power Evaluation Program
ESCOM	-	Electricity Supply Corporation of Malawi
GDP	-	Gross Domestic Product
GoM	-	Government of Malawi
GSD	-	Geological Surveys Department
GWh	-	Giga Watt-hour
HIPC	-	Highly Indebted Poor Countries
IAEA	-	International Atomic Energy Agency
KUP	-	Kayelekera Uranium Project
LPG	-	Liquified Petroleum Gas
MAED	-	Model for Analysis of Energy Demand
MDPC	-	Ministry of Development Planning and Cooperation
MERA	-	Malawi Energy Regulatory Authority
MESSAGE	-	Model for Energy Supply Systems and their General Environmental
FINPLAN	-	Model for Financial Analysis of Electric Sector Expansion Plans
MGDS	-	Malawi Growth and Development Strategy
MNREE	-	Ministry of Natural Resources, Energy and Environment
NEP	-	National Energy Policy
NGO	-	Non-Governmental Organisation
NSO	-	National Statistical Office
PHC	-	Population and Housing Census
PIL	-	Petroleum Importers Limited
R&D	-	Research and Development
SCADA	-	Supervisory Control And Data Acquisition
SIMPACTS	-	Simplified Approach for Estimating Impacts of Electricity Generation

Units of measurement (Refer to appendix B for conversion)

GWh	-	Gigawatt hour
kTOE	-	kilo tons of Oil Equivalent
KW	-	Kilowatt
MW	-	MegaWatt
tkm	-	ton-kilometer
TOE	-	Tonnes of Oil Equivalent
Wh	-	Watt-hour

SUMMARY

1.0 Objective and Scope of the Study

The International Atomic Energy Agency (IAEA), which is an organ of the United Nations, assists its Member States in the area of energy and electricity planning studies through its Planning and Economic Studies Section. Malawi became a member of IAEA in 2008. The Government of Malawi (GoM), through the Ministry of Natural Resources, Energy and Environment, submitted to IAEA a project proposal on strengthening national capability for energy planning. The project proposal was approved and the project kicked off in 2009. Through the project, a study was conducted whose main objectives were as follows:

- to assess present and future energy demand for Malawi covering the period from 2008 to 2030, and
- to build local capacity in energy planning

2.0 Implementation of the Study

The Ministry of Natural Resources, Energy and Environment, through Department of Energy Affairs (DoE), established a Working Team on the Study which comprised officers from various institutions. The Department, in collaboration with IAEA, organised a number of training sessions on energy planning for the Working Team which were facilitated by Expert Missions. The training sessions, among others, covered the use of IAEA modelling tools, development of scenarios, projection of future energy demand, and writing of energy demand assessment report. The Study was conducted between April 2009 and January, 2011.

3.0 Methodological Approach

To assess present and future energy demand for the country, an energy balance for the base year (2008) was constructed. In order to project the future energy demand, consistent set of assumptions were made to develop scenarios with base year input data.

To construct the energy balance, data on energy consumption from the main economic sectors was collected. Other important parameters considered were total Gross Domestic Product (GDP), GDP structure, demographic data and macro-economic data, among others.

The following factors were also considered in the study: Government policies especially those contained in the overarching policy document of Malawi Growth and Development Strategy (MGDS), industrial development, demographical changes, life-style changes, technology choice and management etc.

The Agency's modeling tools were used in the Study, and these were: MAED-D for assessment of energy in general and MAED-El for assessment of electricity.

4.0 Major Assumptions

4.1 Demography

Population growth is an important factor in determining future energy demand. It was assumed in the Study that the population growth rate for Malawi will go down following past long-term trend from 2.8% in 2008 to 1.9% in 2020 and 1.5% in 2030. According to these projections, the population was assumed to increase from 13.077 million in 2008 to 16.847 million in 2020 and 19.696 million in 2030.

4.2 Economy

The level and structure of the country's economy is another important driver of the future energy demand. In the past 20 years i.e. from 1988 to 2008, the average GDP growth rate was 3.7%. However, for the past 5 years (2004 – 2008), the country has achieved an average annual GDP growth rate of 7.0%. It was assumed that the growth rate will remain the same within the study period (2008 – 2030) for the Reference Growth Scenario. Average annual GDP growth rates of 10% and 5% were assumed for the Accelerated Growth and Moderate Growth Scenarios respectively.

5.0 Energy Balance for the base year

The total energy demand for Malawi in the base year (2008) was 4,125.97 kTOE as presented in Table 1 below.

Economic Sectors	**Kerosene**	**Motor Fuels**		**Coal**	**Electricity**		**Solar Systems**	**Traditional Fuels**	**Total**
		Petroleum Products (Gasoline & Diesel)	**Ethanol**		**Specific[1]**	**non-specific[2]**			
Agriculture	-	49.5		1.5	6.30	0.70	-	110.00	**168.0**
Construction	-	5.00			-	-	-	-	**5.00**
Mining	-	0.8			2.85	0.15	-	-	**3.8**
Manufacturing	-	2.00		96.19	25.30	6.73	-	50.00	**180.22**
Services	1.00	-		0.99	13.19	10.30	1.10	80.00	**106.58**
Transportation	-	198.45	8.68		-	-	-	-	**207.13**
Household	14.64	-			18.39	20.91	1.30	3,400.00	**3,455.24**
Total	**15.64**	**255.75**	**8.68**	**98.68**	**66.03**	**38.79**	**2.40**	**3,640.00**	**4,125.97**

Table 1: Energy Balance for the base year (kTOE)

[1] Specific use of electricity refers to those electricity uses that are non-substitutable such as lighting and powering electric appliances

[2] Non-specific use of electricity refers to those electricity uses that can be substituted such as heating, processing and cooking.

6.0 Key Findings

6.1. Total energy demand projections

The total energy demand projections for the three scenarios are shown in Figures 1 and 2 below. Figure 1 shows the range of energy demand projections of the three scenarios. Figure 2 shows the final energy demand by energy form under Reference Scenario.

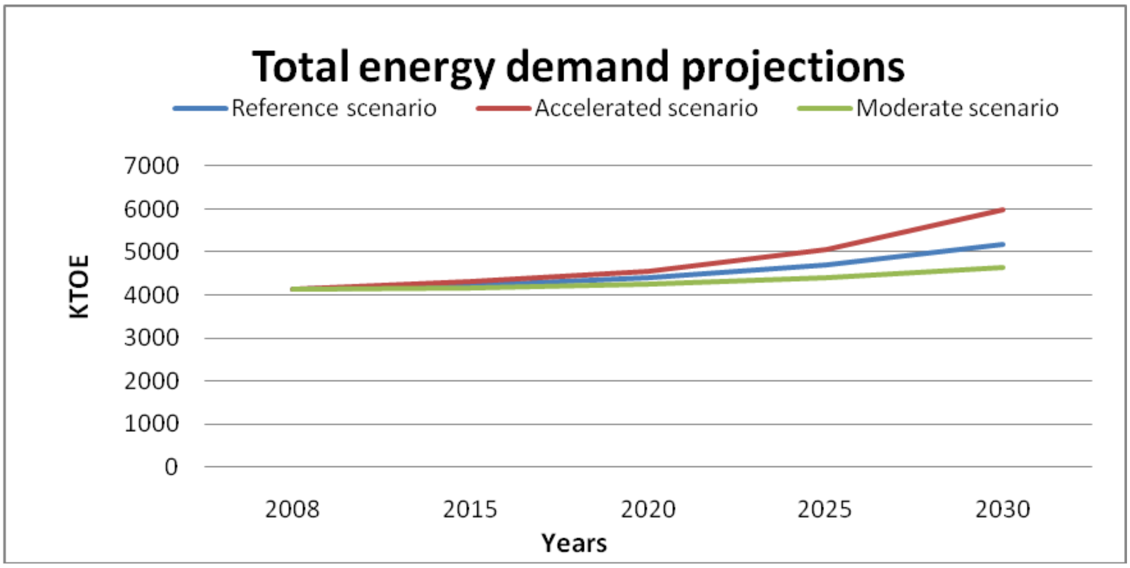
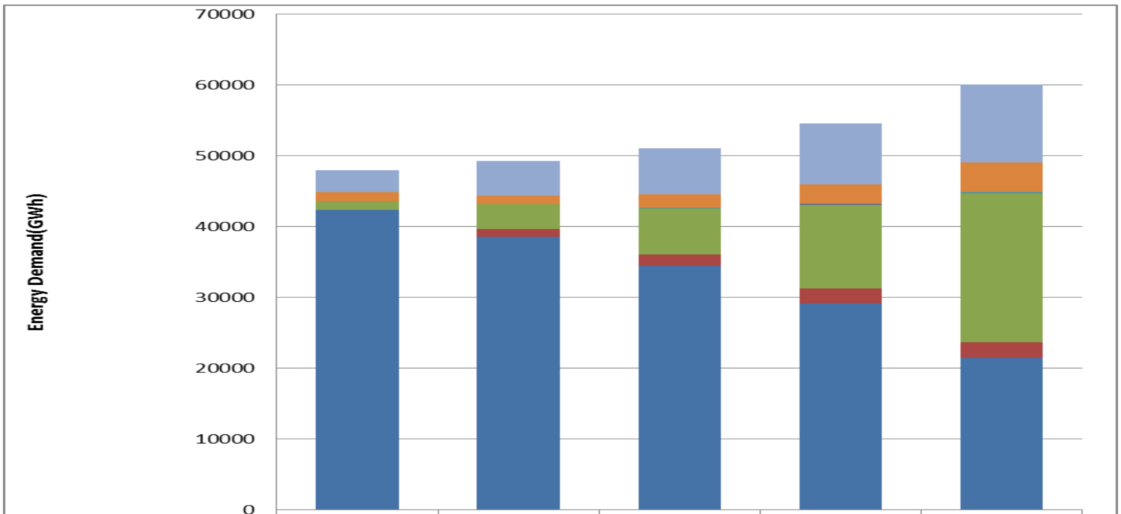


Figure 1: Total energy demand projections

The total energy demand will grow from about 48,000GWh to 60,000GWh by 2030. Electricity, motor fuels (gasoline and diesel), fossil fuels (coal and kerosene), solar thermal and soft solar will increase by 17, 4, 3, 5 and 13 times respectively. Usage of modern biomass will grow from 0 to 2225 GWh in the same period. Consumption of traditional fuels will decrease by half in 2030 from the base year consumption of 42,333GWh.



	2008	2015	2020	2025	2030
Motor fuels	3069	4881	6564	8538	10947
Fossil fuels	1330	1154	1833	2703	4215
Soft solar	16	69	106	156	215
Solar thermal	12	21	30	41	54
Electricity	1220	3448	6522	11789	20911
Modern biomass	0	1099	1586	2152	2225
Traditional fuels	42333	38590	34477	29170	21502

Figure 2: Final Energy Demand by energy form under reference scenario

6.2 Energy Demand by Sector

Final energy demand by sector is shown in Figure 3 below. There is a general increase in energy demand in all sectors with huge increases in industry and transport sectors. Energy demand in industry and transport will both increase by 3 times by 2030. However, household will still dominate the energy demand.

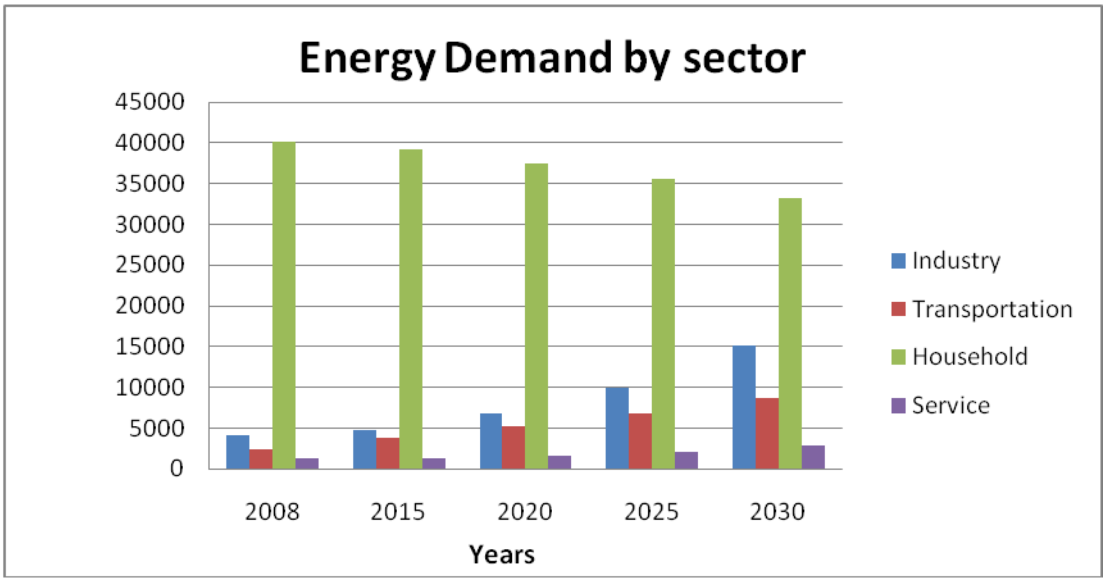


Figure 3: Final energy demand by sector

6.3 Projection of electricity demand

6.3.1 Projection of peak demand

Peak electricity demand was projected to reach 1374 MW in 2020 and 4274 in 2030 under Reference Scenario as given in Table 2 below.

YEAR	MODERATE SCENARIO	REFERENCE SCENARIO	ACCELERATED SCENARIO
2008	233	233	233
2015	700	740	789
2020	1257	1374	1532
2025	2141	2425	2847
2030	3622	4274	5352

Table 2: Projection of peak demand

6.3.2 Projection of electricity demand by sector

Figure 4 below shows final electricity demand by sector. There is general increase in electricity demand in all sectors with the highest increase in Agriculture, Construction and Mining (ACM). ACM will increase by more than 60 times with major contribution coming from mining. Demand for electricity in household, manufacturing and service sectors will increase by 23, 11 and 12 times respectively. Figure 5 shows the same information with ACM and manufacturing aggregated as industry sector.

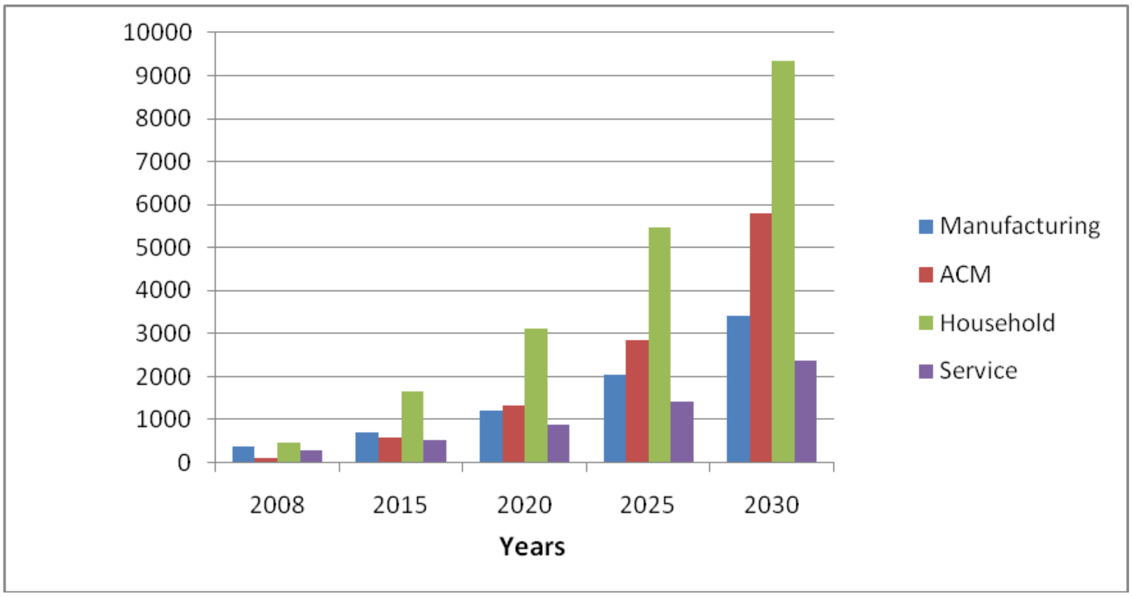


Figure 4: Final electricity demand by sector

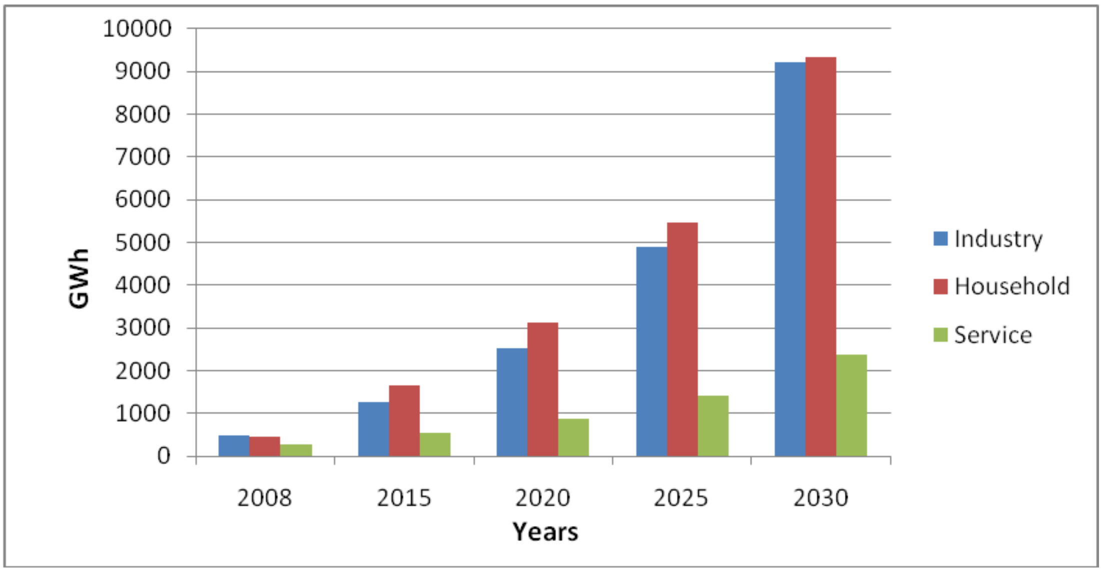


Figure 5: Final electricity demand with ACM and manufacturing aggregated as industry

7.0 Conclusions and Recommendations

The study analysed the entire energy system in Malawi in 2008 (the base year) and its progression in future years up to 2030, and is the first of its kind in the country. Two IAEA models were used in the study, namely MAED-D and MAED –El to assess the entire energy demand system and electricity demand respectively. It is hoped that the Working Team will continue using the models to update the energy demand for the country. The results of the

Study will be useful for energy planning in the country by both Government and various stakeholders.

The calculations in this study have shown that the electricity peak demand is expected to grow by 13%, 14% and 15% in the Moderate, Reference and Accelerated Growth Scenarios respectively. The analysis has also shown that the shares of the various end-use categories have a significant impact on the system load pattern i.e. load factor.

7.1 Main problems encountered and recommendations

In conducting this Study, the Working Team met two major challenges. The first challenge was related to data availability. The model required data in a specific format which in some cases was not in a way some institutions store their data. In some cases, data was not available which meant that the Team had to collect the required data during the limited time of the study period.

The second major challenge was time availability for the Working Team who were combining energy demand assessment work with their day to day responsibilities in their respective institutions. This meant that, at times, it was difficult to meet deadlines for some tasks as required by the study programme.

It is recommended that the data collection process should be institutionalised within the National Statistical Office which has the mandate of collecting data in the country. In addition to this, a data collection template should be developed by the Ministry of Natural Resources, Energy and Environment through the Department of Energy Affairs (DoE) and provided to relevant institutions which can assist in data collection.

There is need to have officers within DoE who would be working continuously on this work. The study should be reviewed every two years to consider new developments in the energy sector.

It is recommended that a further study should be conducted on sectoral and sub-sectoral electricity demand to gain more understanding on the consumption pattern. For instance, there is need to study electricity consumption in service, household, manufacturing, agriculture and mining sectors and sub-sectors.

It is also recommended that detailed profile data for various end-use categories should be collected. This data could help improve the projection of system peak demand and load patterns. It is further recommended that in the next update, a scenario of energy efficiency should be studied. This could help in understanding the savings that could be made in investment costs while delivering the same energy requirements.

7.2 Main policy recommendations from the Study

This study has shown that energy demand is growing faster than the supply. It is therefore, recommended that the following measures should be undertaken to contain the demand:

- Efficient use of energy and electricity should be promoted through fiscal and regulatory measures. This should include promotion of the use of energy efficient bulbs and appliances in both major consumers and the general public. The Government should ban importation, manufacturing and use of inefficient appliances. In addition to this, labelling of appliances should be mandatory and monitored by Malawi Energy Regulatory Authority (MERA) and Malawi Bureau of Standards (MBS). MERA should also promote time-of-use tariffs. Smart grid infrastructure should be developed and installed to manage electricity demand. Power utilities should implement measures to reduce technical and non-technical electricity losses.

- The Study has shown that in the foreseeable future, biomass energy will continue to dominate the energy mix of the country which is not acceptable. The use of biomass has adverse environmental impacts. It is therefore recommended that the country should promote use of modern energy sources such as liquefied petroleum gas (LPG), electricity, biofuels etc.

- Concerted efforts should be made to explore and develop additional local energy resources such as coal, hydropower and renewable energy. Exploration of hydro carbons should be undertaken urgently to reduce dependency on imported petroleum products. Efforts to plan for the development of nuclear power generation should start as soon as possible.

- The Government should promote both local and foreign private investment in the energy sector to ensure efficiency and effectiveness in energy supply. Potential areas for investment include hydropower generation, coal-fired power generation, wind power, solar, geothermal, biofuels, biomass-based power generation etc.

Chapter 1

INTRODUCTION

1.1. Background

The International Atomic Energy Agency (IAEA) has been assisting its Member States in the area of energy and electricity planning studies. The IAEA, through its Planning and Economic Studies Section, assists the Member States to build their capacities in a number of areas including:

- performing analysis for developing alternative strategies for sustainable energy development,
- evaluating energy-economic-environmental implications, and
- assessing potential contribution of nuclear energy in securing affordable and clean supplies of energy.

In addition to the above, IAEA develops and transfers planning tools tailored to circumstances in developing countries and train local experts in energy planning using the tools. IAEA also assists in analyzing national energy options and interpret results, establishing institutional set up for continued local planning activities, and studies done by Member States.

Malawi became a member of IAEA in September 2008 because of plans which were there to start mining uranium at Kayelekera in Karonga. The Kayelekera Uranium Project (KUP) started its operations in April, 2009. The Government of Malawi (GoM), through the Department of Energy Affairs (DoE), submitted to IAEA a project proposal on strengthening national capability for energy planning. The proposal was approved and the project kicked off in February 2009.

The project uses models developed by IAEA that provide a systematic framework for analyzing various issues covering social, economic, technical and environmental aspects of energy decisions. The models are MAED_D for analysis of energy demand in general and MAED_EL for analysis of electricity demand. The models consider the following economic sectors: Agriculture, Construction, Mining, Manufacturing, Household, Service and Transport for which energy demand was calculated at an aggregated level.

1.2. Objective and scope of the study

The objective of the study was to assess present and future energy demand for Malawi. An energy balance using data that was available in the base year i.e. 2008 was constructed to assist in assessing the present energy demand. In order to project the future energy demand, consistent set of assumptions were made to develop scenarios with base year input data.

To construct the final energy balance, data on energy consumption from the main economic sectors was collected. Other important parameters considered were total Gross Domestic Product (GDP), GDP structure, demographic data and macro-economic data, among others.

The following factors were considered in order to assess future energy demand: Government policies especially those contained in the overarching policy document of Malawi Growth and Development Strategy (MGDS), industrial development, demographical changes, life-style changes, technology choice and management etc.

1.3. Implementation of the Study

The Ministry of Natural Resources, Energy and Environment, through DoE, established a Working Team on the Study comprised of officers from different institutions. The Department, with support from IAEA, conducted three training sessions for the Working Team. The training sessions, among others, covered the use of IAEA models, development of scenarios, projection of future energy demand, and writing of a country report. The first training session, which was conducted in Blantyre in April 2009, was facilitated by Ms Kawther A. El Sheikh from Sudan; the second was again conducted in Blantyre in July 2009 and was facilitated by Messrs Bruno Mervin and Damir Pessut from Republic of South Africa and Croatia respectively; and the third was conducted in Lilongwe in November 2009 and was facilitated by Dr. Vladimir Urezchenko from Russia.

The Department is the secretariat responsible for the overall planning and implementation of the activities. For effective implementation of the activities, the following structures were put in place:

- National Steering Committee - to give guidance and supervision to the Working Team
- National Coordinator - responsible for planning and implementation of the activities
- Working Team - responsible for conducting the actual study including data collection and country report writing
- IAEA’s Programme Management Officer - to take care of managerial issues and official communications between the Agency and the DoE
- IAEA’s Technical Officer – to provide technical input from the Agency

DoE collaborated with various institutions in the study who each nominated an officer to be in the Working Team. The institutions are: Ministry of Natural Resources, Energy and Environment (MNREE); Ministry of Transport and Public Infrastructure; Ministry of Development Planning and Cooperation (MDPC); Environment Affairs Department (EAD); Department of Mines; Geological Surveys Department (GSD); National Statistical Office (NSO); the academia (The Malawi Polytechnic, Mzuzu and Livingstonia Universities); Malawi Energy Regulatory Authority (MERA); Electricity Supply Corporation of Malawi (ESCOM) Limited; Petroleum Importers Limited (PIL); and Non-governmental organisation (Centre for Community Development and Empowerment, CCODE). The names of officers who participated in this Study appear in Annex I. Writing and review of this report was done by the following people:

- Mr. L.B. Mhango, Deputy Director of Energy Affairs- Department of Energy Affairs; IAEA Project Counterpart
- Mr. J. Kalowekamo, Assistant Director of Energy Affairs - Department of Energy Affairs
- Mr. J. Namalima, Economist - Ministry of Natural Resources, Energy and Environment

- Mr. Y. Chawanje, Economist - Ministry of Natural Resources, Energy and Environment
- Mr. M. Mulimakwenda, Electrical Engineer - Electricity Supply Corporation of Malawi Limited
- Mr. K.T. Gondwe, Lecturer – Mzuzu University
- Ms. A. Miketa, Technical Officer – IAEA Headquarters, Vienna, Austria
- Mr. V. Urezchenko, IAEA Expert - Russia
- Mr. B. Mervin, IAEA Expert - Republic of South Africa
- Ms. Kawther A. El Sheikh, IAEA Expert - Sudan

Chapter 2

COUNTRY PROFILE

Figure 2.1: Map of Malawi

2.1. Geography and climate

Malawi is a landlocked country located in Southern Africa and lies between 9^o and 17^o south of the equator. It is bounded in the North and East by Tanzania; in the East, South and South-West by Mozambique; and in the West by Zambia. The country has a total area of 118,484 km^2, of which 20% is covered by water, mainly Lake Malawi (see Figure 2.1). It is divided into three administrative regions (Northern, Central and Southern), which, in turn, are divided into 28 districts. There are four major cities namely Lilongwe, Blantyre, Mzuzu and Zomba with population estimates of 674,448, 661,256, 133,968 and 88,314 respectively. Lilongwe is the capital city while Blantyre is the major commercial city.

The country has a subtropical climate with three seasons: 1) cool dry season (May - August, mean temperature of 17^0C, also referred to as Winter in this report), 2); a hot-dry season (September - October, mean temperature of 29^0C, also referred to as Post -winter in this report); and, 3) a warm- wet season (November – April, also referred to as Pre -winter in this report) - all these seasons have implications on energy consumption in terms of space heating, air conditioning and others. Average daily solar irradiation is 21.1 $MJ/m^2/day$. This climate allows for the growth of tropical and sub-tropical crops including cereals, tobacco, cotton, sugar and tea. The altitude ranges from almost sea level to over 3,000 metres above sea level. Rainfall ranges from 800 mm to over 2,500 mm per annum in low and highlands respectively.

2.2. Demography and major demographic policy issues

Malawi has a population of 13,077,160 (Malawi Population and Housing Census, 2008), and population growth rate is estimated at 2.8% per annum. About 84.7 % of the population resides in rural areas and the remainder in urban areas. Urban refers to the four major cities of Blantyre, Zomba, Lilongwe and Mzuzu (home to 12% of the population) and other urban district headquarters and gazetted town planning areas (home to the remaining 3.3% of the population).

In recent years, government has been promoting family planning methods and improved health delivery services, however, this has not contributed to the decrease in population growth rate as of now. In enforcing these policies, more emphasis has been on reduction of maternal and child mortality rates which have in fact contributed to population increase. For instance, urban population was at 2.0 million in 2008 up from 1.4 million in 1998. The actual labor force is about 6.4 million, with about 85% of it employed in the agricultural sector. And out of the actual labour force again, about 1 million is in the service sector.

2.3. Macro-economic situation and major economic policy issues

The Government has been implementing sound macro-economic policies and tough decisions to institute strict fiscal discipline since 2004. Since then, Malawi’s economic performance has continued to be remarkable. The country has, in the last 5 years, achieved Gross Domestic Product (GDP) annual growth rate averaging 7.0%, and the growth trend is shown in Figure 2.2 below.

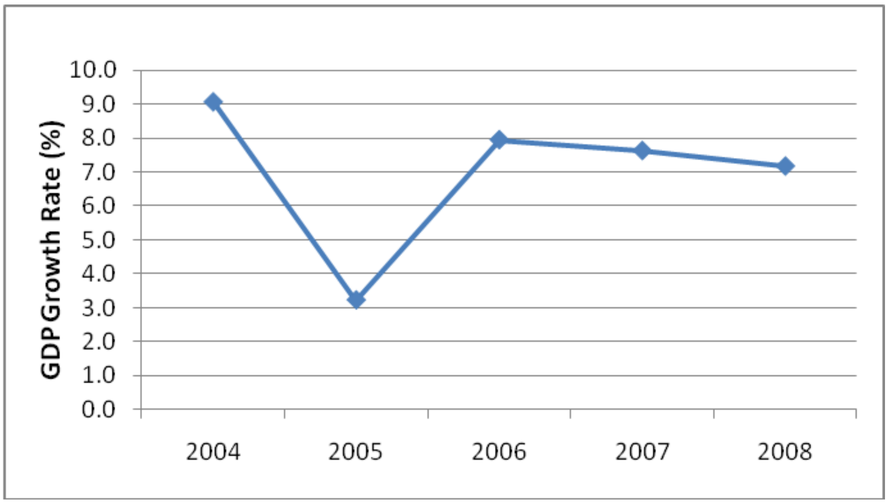


Figure 2.2: Annual GDP growth rate

However, in the past 20 years i.e. from 1988 to 2008, the average GDP growth rate was 3.7%. In 2008, the economy recorded a robust growth in real GDP of 9.7%, compared to 8.6 % in 2007. This growth rate is above the target of 6% for Sub-Saharan Countries.

The country's GDP and GDP per capita are US$3.67 billion and US$270 respectively. In terms of GDP contribution by economic sectors: service, agriculture, manufacturing, construction, energy and mining sectors contribute 50.5%, 34.1%, 8.3%, 4.7%, 1.5% and 0.9% respectively. The contribution of the mining sector to the GDP is expected to increase to 5% with the opening of uranium mining in mid-2009. The mine is expected to be producing on average 1,500 metric tonnes a year for the next ten years.

The Government has put in place policies to ensure stable macroeconomic conditions. In 2008, the economy maintained a single digit inflation rate of 8.7% mainly due to increased food availability on the local market, coupled with a stable exchange rate and lower fuel prices on the world market. Interest rates that had once reached a high figure of 35% in 2003 were reduced to 15% in 2008. This resulted in an increase in credit to the private sector from 30% of total credit to over 60%.

The total public debt, as a percentage of the GDP, decreased from 123.9% in 2004 to only 19.9% in 2008. Malawi also managed to reduce its domestic debt from 25% of GDP in 2004 to 11.5% in 2008. During the same period, foreign debt as a percentage of GDP, reduced from 112.6 % in 2004 to only 16.5% in 2008. This was a result of Malawi's qualification under the Highly Indebted Poor Countries (HIPC) that freed the country from its massive debt burden, which resulted in the release of the much needed resources for poverty reduction initiatives. Similarly, the budget deficit that had been as high as 7.8% of GDP in 2003/2004 Fiscal Year averaged less than 3% of GDP in the last 5 years (Annual Economic Report, 2009).

2.4. Major environmental policy issues

The National Environmental Policy calls for responsible management of the environment in order to prevent degradation of the environment; provide a healthy living and working environment for the people of Malawi; accord full recognition to the rights of future generations by means of environmental protection, and; conserve and enhance the biological diversity of Malawi. The National Environmental Policy, which was adopted in 2004, thus provides an overall framework through which sectoral policies are reviewed to assess their consistency with the principles of sound environmental management and sustainable development. Since its adoption, several environmental related policies have been developed and implemented including: forestry, fisheries, water, land use and management and energy policies.

Energy affects all aspects of development, including social, economic, and environment. No meaningful socio-economic development would be attained without sustained supply of energy to meet the demands of the household, commercial and industrial sectors. The demand for energy consumption for both domestic and industrial consumption is increasing which has put pressure on existing energy sources such as forests. The energy production process has potential impacts on the environment, particularly on deforestation, emissions, and change of landform. Malawi's energy balance is dominated by biomass which accounts for 97% of the total energy produced in the country (National Energy Policy, 2003). It is estimated that forest resources in Malawi are declining at a very alarming rate of 2.6% per annum. The energy sector's contribution to deforestation is mainly related to the wood obtained from unsustainable sources for charcoal production and firewood despite availability of policies and regulations prohibiting un-licensed production of charcoal and cutting of indigenous trees for fuelwood.

Since Malawi's electricity is mainly produced from hydropower, its production process does not negatively affect the environment. However, due to frequent power black-outs, the electricity market has witnessed an upsurge in the number of companies, institutions and household using standby generator-sets to meet part of their electricity needs, with a great potential in increasing emission levels.

The objective of the energy policy is to meet national energy needs with increased efficiency and environmental sustainability.

Chapter 3

END USE-ENERGY TECHNOLOGIES AND EFFICIENCIES

This sub-section describes major end-use technologies i.e. household cooking devices, refrigerators, lighting, electric motors, automobiles and key industrial processes used in various sectors in Malawi and their energy efficiencies. Major policy issues or national initiatives related to the end-use technologies and energy efficiency are also discussed.

3.1 Household cooking devices

A large number of firewood users in Malawi (91%) cook on traditional three-stone cookstoves with 10 - 14% efficiency resulting in very high energy losses. To address this problem, GoM devised and is promoting strategies aimed at expanding the use of improved ceramic firewood stoves in poor urban households and at reducing the proportion of households using three stone cookstoves.

About 90% of charcoal consumers use ceramic charcoal stoves with 30% efficiency while others use traditional metal stoves with 20% efficiency. It is the GoM policy to continue promoting improved ceramic charcoal stoves for urban households' use through publicity campaigns, institutional capacity and technical support to non-governmental organizations (NGOs).

3.2 Household refrigerators

A substantial number of households in Malawi use refrigerators. Some refrigerators run on electricity and others on kerosene. There are also a few refrigerators in the country that run on solar power. Most of the refrigerators are not energy efficient, and to this end, GoM intends to promote the introduction of a domestic appliance efficiency labeling through legislation. GoM will also support research and development (R&D) in fabrication of low-cost refrigeration and other appliances.

3.3 Lighting

Generally, devices for lighting in Malawi are those with low levels of efficiency. About 90% of electric bulbs used in households are of incandescent type, which are of low efficiency compared to those of fluorescent type. A large number of households, mainly in rural areas, use one-wick kerosene lamps or hurricane lamps, which are also relatively inefficient. This presents an opportunity for energy conservation, and in this regard, GoM intends to put in place an energy management program aimed at promoting efficient lighting devices.

3.4 Electric motors

In Malawi, electric motors are mainly used to run conveyor belts in industry and they consume a lot of electricity. For instance, electricity consumption is relatively high in tobacco industry due to use of electric motors. To this end, GoM, through its energy management programme, will continue pressing industries to subject their installations to energy audits as part of their demand side management (DSM) activities.

3.5 Automobiles

Malawi imports 100% of its automobile petroleum products (gasoline and diesel). However, gasoline is blended with locally produced ethanol at a ratio of 90:10 (to be revised to 80:20 in the near future). The transport sector in general accounts for 3.8% of total energy consumption and 43% of the total commercial energy consumption.

In view of the above, GoM promotes efficient use of liquid fuels and gas in the transport sector by, among other means, discouraging importation of inefficient large capacity luxury engines in vehicles and machinery through taxation. GoM also provides advice to other stakeholders on efficiency of alternative modes of transport and assistance in the formulation of fiscal and transportation policies to promote energy conservation and efficiency.

3.6. Key industrial processes

Key industrial processes in Malawi include, smelting, sterilizing, cleaning and water heating. Industry, mining and construction together account for 2% of total energy consumption**.** However, they use 19% of the country's commercial energy.

To ensure energy efficiency in industry, GoM presses industries to subject their installations to energy audits, promote energy efficiency awareness among industrial and commercial energy consumers and encourage the use of energy efficient practices. For instance, it is cheaper to heat water with steam than with electricity. A well-designed industrial plant would use electricity for lighting, running electric motors and powering computers, and steam for sterilizing, cleaning and water heating.

To this end, GoM is planning of establishing energy efficiency norms and standards for commercial buildings and equipment, and implement energy efficiency programs to reduce consumption by the general public and government institutions.

Chapter 4

FINAL ENERGY BALANCE FOR MALAWI

4.1. Final energy balance: retrospective and general overview

Latest final energy balances for Malawi were not readily available, and the only credible energy balance is for 1996 adapted from the *Household Energy Consumption Survey* (1996). Since this is the only credible energy balance available, it has been referred to in this study for comparison purposes. In 1996, the total energy consumption was 2741.32 kTOE and the annual per capita energy consumption was estimated at 0.29 TOE which compares unfavourably with the per capita average of about 2 TOE for upper middle income countries and 5 TOE for high income countries. The energy consumption by sector is illustrated in Figure 4.1 below. The household sector is the dominant energy consumer seconded by the agricultural sector.

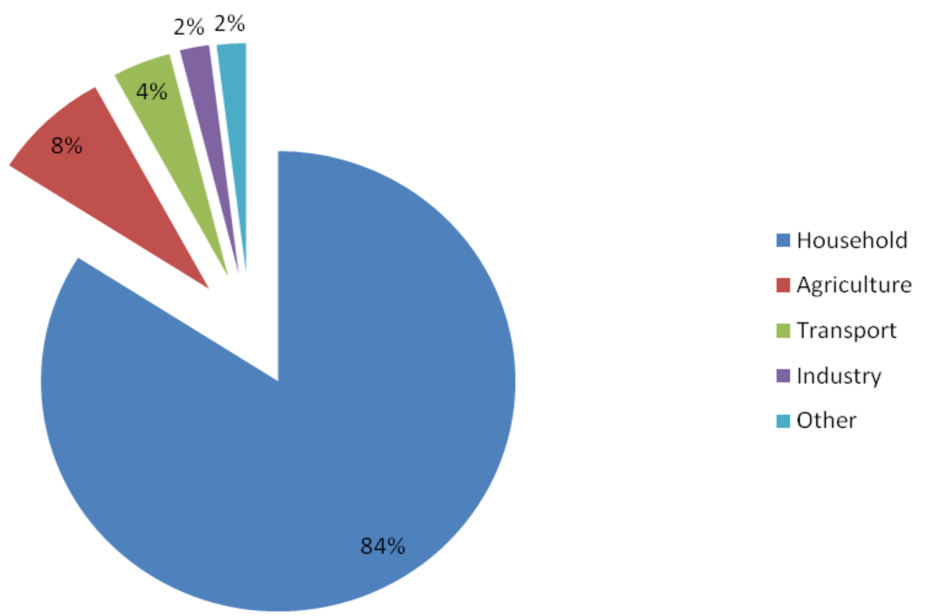


Figure 4.1: Energy Consumption by sector- 1996

The total commercial energy consumption in 1996 was 191.89 kTOE. The commercial energy sources included liquid fuels, electricity and coal. Of the total commercial energy consumption, transport was the major consumer followed by industry and mining. This is portrayed in Figure 4.2 below. The transport sector is also the largest consumer of liquid fuels in Malawi. Liquid fuels and gas account for almost two-thirds of the commercial energy consumption in the country.

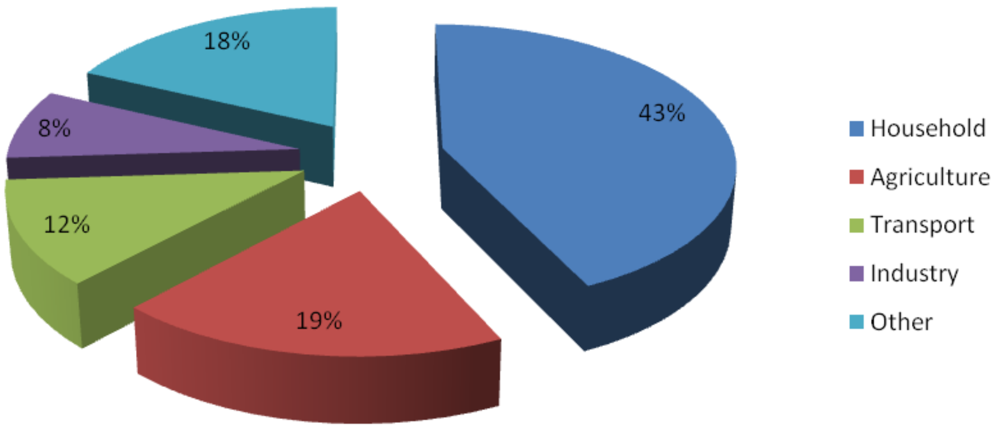


Figure 4.2: Commercial energy usage by sector, 1996

Table 4.1 presents time series data on total electricity consumption from 2001 to 2008. This is also portrayed graphically in Figure 4.3 below. Based on these figures, the average annual growth rate for total electricity consumption between 2001 and 2008 is 4.4%.

Table 4.1: Time series data on total electricity consumption (2001-2008)

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Total electricity consumption (kTOE)	77.78	76.03	80.63	85.38	90.73	92.58	95.42	104.80

Source: ESCOM Limited

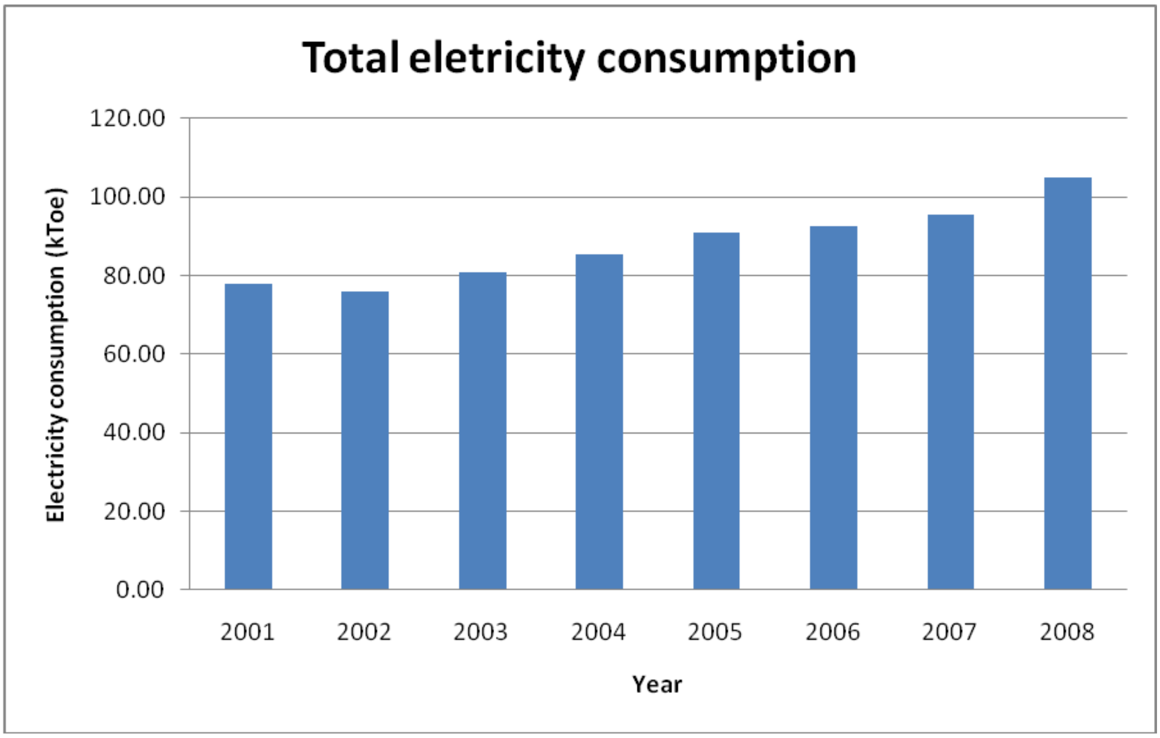


Figure 4.3: Time series data on total electricity consumption (2001-2008)

4. 2. Final energy balance table for the base year

4.2.1 Institutional framework for collecting energy and electricity statistics

DoE is responsible for collection of energy data. The Department collects data on biomass energy, coal and solar but for electricity and petroleum products data, the Department relies on MERA, ESCOM Ltd and PIL.

Demographic and GDP data is collected by the Ministry of Development Planning and Cooperation (MDPC) through its National Statistical Office (NSO). The Ministry publishes Economic Reports on annual basis, and a Population and Housing Census Report every decade.

However, no credible energy balance has been constructed and published since 1996 because of lack of comprehensive structure for consistent energy data collection. Since then efforts to collect energy data have been made through various stand-alone studies such as Biomass Production and Marketing Survey (1997), Inventory of Solar Installations (2005) and Biomass Energy Strategy Study (2008). The most comprehensive data collection exercise was done in 2009 which led to the construction of the energy balance table for this Study.

4.2.2. Final energy balance table covering final-energy use

The final energy balance for Malawi in the base year (2008) was 4,125.97 kTOE as presented in Table 4.2 below. The primary energy data for the construction of the energy balance table was obtained from various data sources as presented in Section 4.2.1 above. The data was processed and aggregated by the Working Team to suit the format of IAEA analytical model i.e. MAED-Inp-Prep-D. The model computed the data and came up with the final energy balance for Malawi in the base year.

Table 4.2: Energy Balance for the Base Year (kTOE)

Economic Sectors	Kerosene	Motor Fuels		Coal	Electricity		Solar Systems	Traditional Fuels	Total
		Petroleum Products (Gasoline & Diesel)	Ethanol		Specific[3]	non-specific[4]			
Agriculture	-	49.5		1.5	6.30	0.70	-	110.00	**168.0**
Construction	-	5.00			-	-	-	-	**5.00**
Mining	-	0.8			2.85	0.15	-	-	**3.8**
Manufacturing	-	2.00		96.19	25.30	6.73	-	50.00	**180.22**
Services	1.00	-		0.99	13.19	10.30	1.10	80.00	**106.58**
Transportation	-	198.45	8.68		-	-	-	-	**207.13**
Household	14.64	-			18.39	20.91	1.30	3,400.00	**3,455.24**
Total	**15.64**	**255.75**	**8.68**	**98.68**	**66.03**	**38.79**	**2.40**	**3,640.00**	**4,125.97**

Figure 4.4 below shows percentage share of total energy consumption by energy sources in the base year. The shares are based on figures presented in Table 4.2 above. The figure shows that there is high penetration of traditional fuels while solar is the lowest.

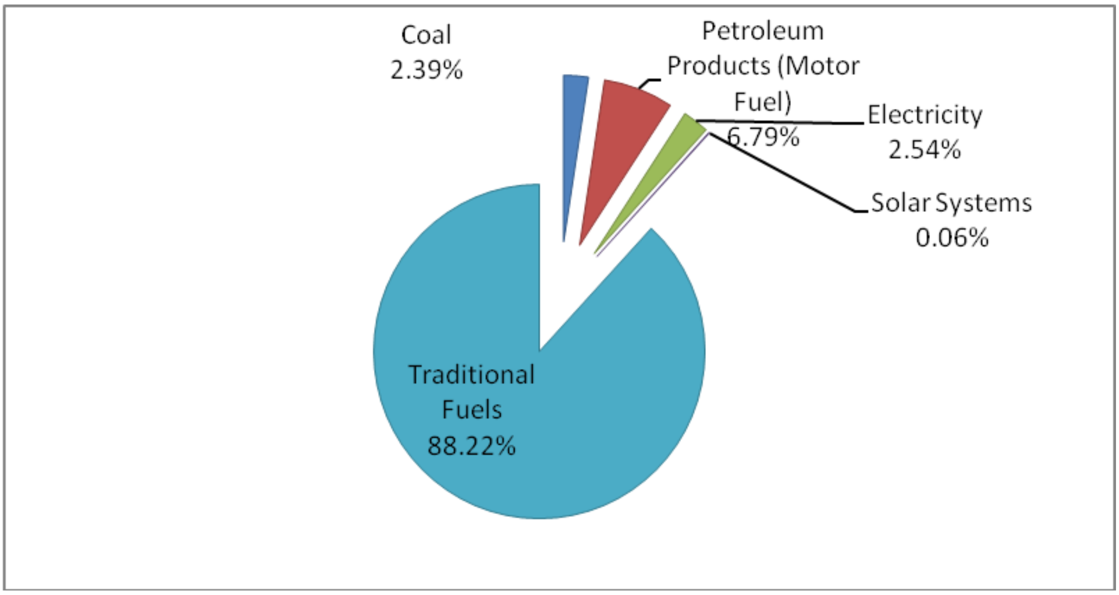


Figure 4.4: Total Energy Consumption in 2008

[3] Specific use of electricity refers to those electricity uses that are non-substitutable such as lighting and powering electric appliances

[4] Non-specific use of electricity refers to those electricity uses that can be substituted such as heating, processing and cooking.

Some of the assumptions used in order to come up with figures in the energy balance table are explained below:

Coal

The total coal production in the country in 2008 was 49.34kTOE and it was assumed that this whole amount was consumed locally. According to the Department of Mines, a similar amount of coal was imported and consumed in the country. Based on this, coal consumption in 2008 was estimated to be 98.68 kTOE. The Working Team assumed that 98% of the total coal is consumed in the manufacturing sector and the remainder in the service sector.

Liquid fuels

In the base year, a total of 280.07 kTOE of liquid fuels was consumed. This was comprised of 255.75 kTOE diesel and gasoline, 15.64 kTOE kerosene and 8.68 kTOE ethanol. Out of the total consumption, 271.39 kTOE was imported in form of diesel, gasoline while the remainder was ethanol which is produced locally from sugar molasses and is blended with petrol at a ratio of 1:9. The split of this consumption by sector was done based on data obtained from oil companies and is hereby presented in Figure 4.5 below.

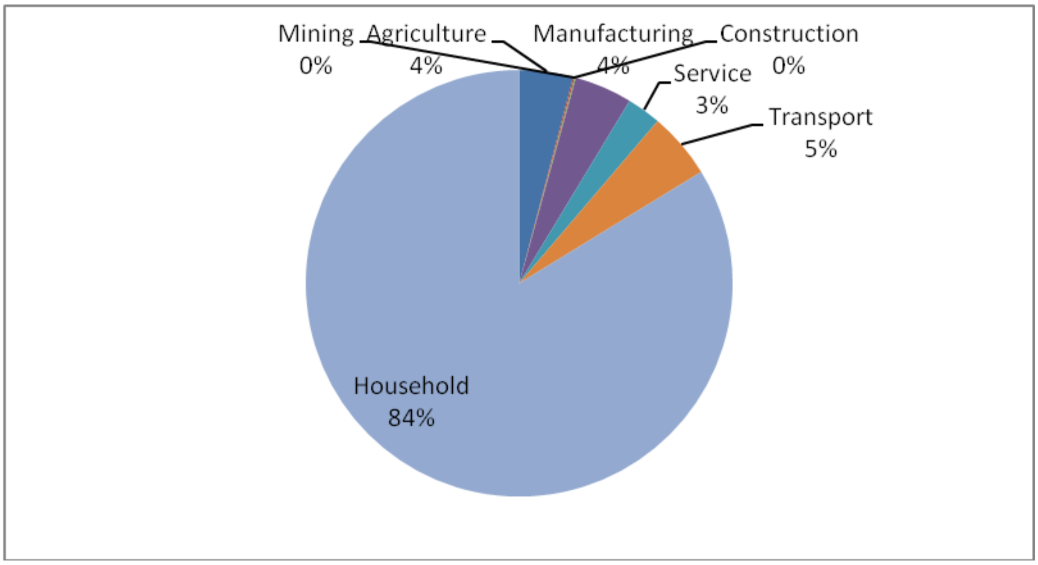


Figure 4.5: Shares of Petroleum Products Consumption by Sector

Electricity

The initial data on electricity statistics was obtained from ESCOM Ltd. The format in which ESCOM collects data is in household, general, light industry (power low voltage) and heavy industry (power medium voltage). However, for purposes of analysing the economic sectors used in this study, the data was re-arranged by the Working Team. The total electricity consumption in 2008 was 104.82 kTOE. The shares for each sector were estimated by the Working Team as shown in Figure 4.6 below.

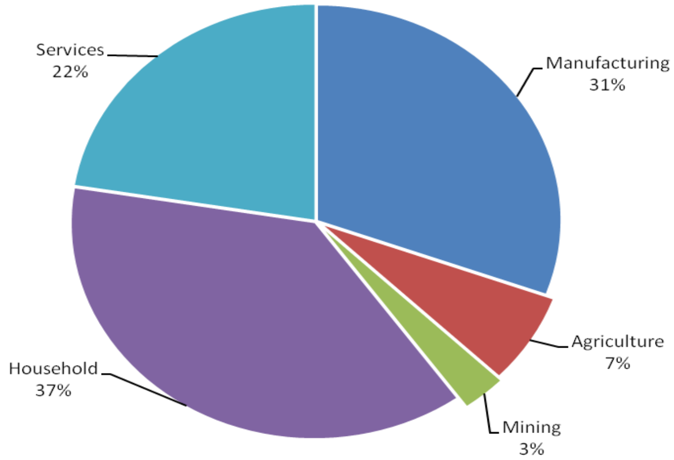


Figure 4.5: Shares of Electricity Consumption by Sector

Solar systems

The data on solar was estimated based on a survey conducted in 2005 by DoE which categorized solar energy utilization in households, schools, rural hospitals and other services.

Traditional fuels.

Data on final consumption of traditional fuels was obtained from the Malawi Biomass Energy Strategy (BEST, 2009). The shares into various sectors were estimated based on the Malawi Energy Policy (2003) and are as presented in Figure 4.7 below.

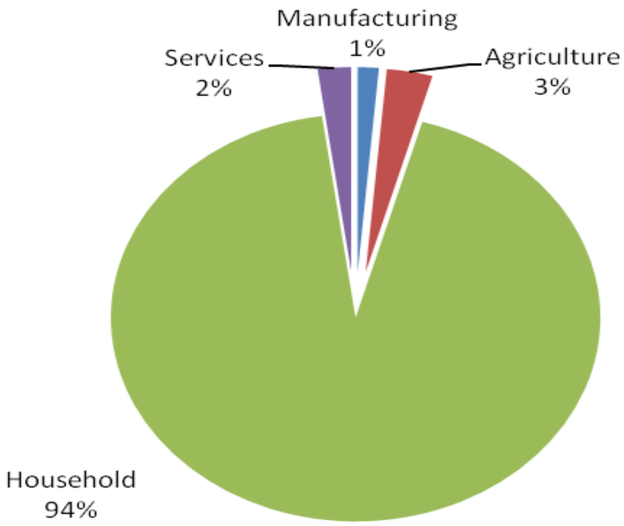


Figure 4.7: Consumption of Traditional Fuel by Sector

Chapter 5

ENERGY DEMAND SCENARIOS

5.1. Methodological description - MAED-D model

MAED - D is a simulation model designed for evaluating the energy demand of a country or world region in the medium and long term. The model is based on "scenario approach" which is viewed as a consistent description of a possible long-term development pattern of a country, characterized mainly in terms of long term direction of governmental socio-economic policy.

In summary the MAED- D methodology comprises the following sequence of operations:

(i) Disaggregation of the total energy demand of the country or region into a large number of end-use categories in a coherent manner;

(ii) Identification of the social, economic and technological parameters which affect each end-use category of the energy demand;

(iii) Establishing in mathematical terms the relationships which relate energy demand and the factors affecting this demand;

(iv) Developing (consistent) scenarios of social, economic and technological development for the given country;

(v) Evaluation of the energy demand resulting from each scenario.

This approach takes especially into account the evolution of the social needs of the population, such as the demand for space heating, lighting, transportation, air conditioning, and this as a function of the distribution of population into urban and rural areas; the industrial policies of the country (development stressed on certain types of industries); and the country's policies concerning transportation, housing etc., as well as the technological development. It also takes into account, the evolution of the potential markets of each form of final energy: electricity, fossil fuels (coal, gas, oil), solar etc.

Six economic sectors are considered in MAED-D: Agriculture, Construction, Mining, Manufacturing, Service (including transport) and Energy. Agriculture, Construction, Mining, Manufacturing and Service sectors can be further subdivided into up to ten subsectors to allow grouping of the economic branches with similar energy intensities. Energy sector is used only to describe the GDP formation. Its energy inputs, for conversions to other final energy forms, are not accounted for by the MAED model, which deals only with the final and useful energy demand projection.

The evolution of the structure of GDP formation is one of the driving factors of greater importance in the model. The GDP formation structure, expressed in terms of the share of the value added contribution to GDP by each sector, is specified directly as part of the scenario.

Likewise, the shares of value added by each subsector in the total value added by each main economic sector are also specified directly as scenario elements.

The energy demand is calculated separately for four major aggregated sectors: Industry, Transportation, Service and Household. The calculation of the energy demand of each of these sectors is performed in a similar manner. According to this procedure, the demand for each end-use category of energy is driven by one or several socio-economic and technological parameters, whose values are given as part of the scenarios.

5.2. Selection of study time frame and base year

The time frame was selected to be from 2008 to 2030 with 2008 as the base year. The year 2008 was considered as a normal year economically and politically, with no significant distortions in GDP structure and energy consumption patterns in the country. The intermediate years for the study are 2015, 2020 and 2025. These were selected to give a medium and long –term analysis of energy demand. These years are also in tandem with time frame in the National Energy Policy (2003) set for achieving national targets for the energy sector. For instance, access to electricity is set at 30% in 2020.

5.3. Reconstruction of the detailed energy balance table

Methods of data estimation and data sources for the reconstruction of the detailed energy balance table for the base year are explained in the sections below for the four energy consuming sectors (Industry, Transport, Household and Service). The final energy balance table for the base year is as presented in Table 4.2 above.

5.3.1. Energy use in Agriculture, Construction and Mining Sectors

5.3.1.1 Definition of sub-sectors in agriculture, construction, and mining sectors

In the base year, Agriculture, Construction and Mining sectors are not disaggregated into sub-sectors. For this reason, the energy use in these sectors is not presented according to sub sectors.

5.3.1.2 Energy intensities

Table 5.1 below shows energy intensities of motor fuels, electricity specific uses and thermal uses in the Agriculture, Construction and Mining sub-sectors. The intensities are calculated from the total energy balance and the value added in the sectors.

Table 5.1: Energy Intensities (kTOE/US$)

Item	Agriculture	Construction	Mining
Thermal use (useful energy)	12.92	0.00	4.95
Electricity for specific use	5.47	0.00	94.02
Motive power	42.96	31.43	26.39

5.3.1.3 Penetration of energy carriers

Penetration of energy carriers into useful thermal energy in Agriculture, Construction and Mining sub-sectors is shown in Table 5.2 below. Traditional fuels, fossil fuels (coal) and electricity are the main energy carriers used for thermal purposes in Agriculture and Mining. Thermal usage in construction was considered negligible hence not included in the analysis. There is high penetration of traditional fuels for thermal energy in Agriculture sub-sector. Only electric energy is used for thermal purposes in Mining.

Table 5.2: Penetration of energy carriers into A-C-M

	Agriculture	Mining
Electricity	0.047	1.000
Traditional Fuels	0.887	0.000
Fossil fuels (coal)	0.066	0.000
Total	1.000	1.000

5.3.1.4 Average efficiencies of energy carriers

The average efficiencies of electricity, fossil fuels and traditional fuels, are 100%, 66% and 12%, respectively (NEP, 2003).

5.3.2. Energy use in the manufacturing sector

5.3.2.1 Definition of sub-sectors in the manufacturing sector

The manufacturing sector was further sub-divided into four sub-sectors based on energy intensities. The same breakdown was used to split the GDP for the sub-sectors. In the base year, the total manufacturing sector contributed 8% to the GDP. The sub-sectors and their contribution to GDP are shown in Table 5.3 below.

Table *5.3: Manufacturing sub-sectors and their contribution to GDP structure*

Manufacturing sub-sector	**Examples**	**GDP share (%)**
Basic Materials	Wood and Wood Products, Cement, Chemicals including Plastic Products, Steel Industries, Gas industry, Ceramics, Lime and others	12
Equipment & Machinery	Fabricated Metal Products, Machinery and Equipment	25
Non-Durable Goods	Food, Beverages and Tobacco processing, Textile, Wearing Apparel & Leather	53
Miscellaneous	Handicraft, Other Manufacturing Industries	10

The shares of the final energy consumption in the manufacturing sub-sectors for the base year were assumed to be as shown in Table 5.4 below.

Table 5.4: Shares of the final energy consumption in the manufacturing sector (%)

Manufacturing Sub-sector	Fossil Fuels	Motor Fuels	Electricity	Traditional Fuels
Basic Materials	55	30	25	10
Machinery and Equipment	18	20	20	0
Non Durables	27	50	50	80
Miscellaneous	0	0	5	10
Total	**100**	**100**	**100**	**100**

5.3.2.2 Energy intensities in the manufacturing sub-sector

The intensities of motor fuels, electricity specific uses and thermal uses by the manufacturing sub-sector are shown in Table 5.5 below. The intensities are calculated from three variables, these are: 1) the shares of final energy consumption presented in Table 5.4 above, 2) the total fuel consumption from the energy balance and, 3) the GDP structure per manufacturing sub sector.

Table 5.5: Energy intensities in Manufacturing sub sectors (kWh/US$)

Manufacturing Sub Sector	Motor Fuels	Electricity Specific Use	Thermal Uses
Basic Materials	0.208	0.833	10.1721
Machinery & Equipment	0.067	1.013	1.316
Non Durable Goods	0.079	1.194	2.263
Miscellaneous	0.0	0.666	0.901

5.3.2.3 Shares of thermal energy demand by temperature range

Table 5.6 below presents shares of thermal energy demand by temperature range (steam generation, furnace and direct heating, space and water heating) in the manufacturing sub-sectors. The shares were obtained by considering processes in each manufacturing sub-sector and the temperature ranges at which they operate. For example, space and water heating processes are in low temperature range; steam generation processes are in medium temperature range while furnace and direct heating processes are in high temperature range.

Table 5.6: Shares of useful thermal energy consumption in the Manufacturing sub-sectors

Temperature Range (%)	Basic Materials	Machinery and Equipment	Non Durables	Miscellaneous
Low	22	70	27	31
Medium	48	30	73	69
High	30	-	-	-

5.3.2.4 Penetration of energy carriers into useful thermal energy demand

Table 5.7 shows penetration of energy carriers into useful thermal energy demand in the total manufacturing sector. Fossil fuels contribute about 66.6% of the total useful thermal energy demand in the high temperature range. In the medium temperature range, fossil fuels mainly coal (63.2%) is used in boilers for steam generation. Traditional fuels and electricity have significant shares in the low and high temperature ranges respectively. These penetrations were obtained through calculations which were done based on the assumptions made in the energy balance.

Table 5.7: Penetration of energy carriers into useful thermal energy demand(%)

Energy carrier	**Low Temperature (Space & Water Heating)**	**Medium Temperature (Steam Generation)**	**High Temperature (Furnace)**
Electricity	1.2	1.2	31.9
Traditional Fuels	37.6	35.6	1.60
Fossil Fuel	61.1	63.2	66.6

5.3.2.5 Efficiency of the energy carriers by temperature range

The efficiency for electricity in the manufacturing sector is 1 for all temperature ranges while for traditional fuels it varies from 0.1 to 0.15. For fossil fuels, the efficiency varies from 0.65 in low temperature range to 0.35 in the high temperature range.

5.3.3 Energy use in the Service Sector

5.3.3.1 Definition of the sub-sectors in the Service Sector

The service sector comprises a wide range of sub-sectors, and these include:

- transportation
- Education
- accommodation and food services
- wholesale and retail trade
- real estate
- finance and insurance
- public administration and defence
- information and communication technology
- human health and social work
- professional
- scientific and technical activities.

However, in this report, transportation sub-sector has been considered separately because of its high fuel (motor fuels) consumption. The rest of the sub-sectors are considered together as service sector.

5.3.3.2 The number of active labour force and floor areas

It is assumed that 15% of the total labour force is employed in the service sector. This assumption was derived from the fact that about 80% of the total labour force is employed in the agriculture sector (MGDS, 2005) and that the service sector is the next major employer. The service sector contributes about 50% to GDP.

There is no published data on floor area per employee. Nevertheless, the floor area per employee was estimated based on typical office space and total labour force in the service sector in Malawi. Total floor area was calculated from a product of floor area per employee and total labour force in the service sector. The number of active labour force in the service sector and floor areas are shown in Table 5.8 below.

Table 5.8: Number of active labour force and floor areas

Item	**Unit**	**2008**
Share of service sector labour force in the total labour force	%	15.00
Floor area per employee	m^2/employee	8.00
Service sector labour force	Million	0.68
Total floor area	million m^2	5.44

5.3.3.3 Space heating requirements

Malawi is located in the tropical region and therefore space heating is needed only for a short period of the year (May to August). During this time, the total floor area in the service sector i.e. 100% of 5.44 million square metres requires space heating but only 30% is assumed to be actually heated. Based on these, space heating requirement was calculated to be 17.75 kWh/m^2/year as shown in Table 5.9 below.

Table 5.9: Space heating in service sector

Item	**Unit**	**2008**
Share of area requiring space heating	%	100.0
Area actually heated	%	30.0
Specific space heating requirement.	kWh/m^2/yr	17.75

5.3.3.5 Share of air-conditioning in service sector

Most of the buildings in Malawi require air conditioning from September to December when temperatures are usually high. However, prevalence of air conditioners is still low due to, among other reasons, initial and operating costs and lack of electricity supply in some areas. It was therefore, assumed that share of area actually air-conditioned is 20%. Based on total floor area and assumptions made on shares of floor area requiring air-conditioning, specific cooling requirement was calculated to be 39.9 kWh/m^2/year. Table 5.10 below presents this in a summary form.

Table 5.10: Shares in air-conditioning

Item	Unit	2008
Floor area requiring air conditioning	%	100.00
Air-conditioned floor area	%	20.00
Specific cooling requirement	$kWh/m^2/yr$	39.9

5.3.3.6 Energy intensities for electricity specific uses and other thermal uses

Table 5.11 below shows energy intensities for electricity specific uses and other thermal uses in the service sub-sector. The intensities are calculated from the total energy balance and the GDP contribution of the sector..

Table 5.11: Energy intensities in the service sector

Item	Electricity	Other thermal
Services (kWh/US$)	0.08	0.125

5.3.3.7 Penetration of energy carriers into space heating and other thermal uses

Electricity, traditional fuels and fossil fuels are energy carriers used for space heating and other thermal uses in the service sector. Space heating uses 100% electricity. In terms of other thermal uses, 52.2%, 42.4% and 5.4% of electricity, traditional fuels and fossil fuels respectively are used.

5.3.3.8 Contribution of solar installation to thermal use

Some facilities such as hospitals and lodges use solar energy for water heating but its contribution to thermal usage is negligible. However, there is potential to increase the solar usage for water heating. There is also potential for solar thermal usage in cooking.

5.3.3.9 Fuel efficiencies

The efficiency for traditional fuel varies from 10% to 15% while that for modern biomass and fossil fuels is 25% and 65% respectively.

5.3.4. Energy use in freight transportation

5.3.4.1. Definition of transportation modes and fuels

Generally, transport is defined as a means of moving people (passengers) and goods (freight) from one place to another. Freight transport modes are categorized as follows: road, rail, air and water/marine. Sub-modes under road category are large trucks, medium trucks, and small trucks. These are categorized because they consume different volumes of fuel per unit of distance travelled. Only lake boat is considered under water transport mode. Table 14 below summarizes the transport modes, sub-modes and fuel used by each mode.

Table 5.12: Transport modes, sub-modes and fuel type

Mode	Sub modes	Fuel Type
Road	Large Trucks	Diesel
	Medium Trucks	Diesel
	Small Trucks	Diesel
Rail	Train	Diesel
Air	Air Plane	Jet fuel
Water/Marine	Lake boat	Diesel

5.3.4.2 Freight demand by modes and sub-modes

The demand for freight transportation in the base year was estimated at 3.82 billion ton-kilometres. Table 5.13 below shows how the demand for freight was calculated. The data on totals in each mode was obtained from the Ministry of Transport and Public Infrastructure while the numbers in italics are estimates made by the Working Team.

Table 5.13: Freight Transportation Activity

Mode	Fuel	Fleet			Annual vehicle mileage	Annual vehicle activity	Average load factor	Annual freight activity
		Total in freight	Fraction of operating	Operating in freight				
Unit		10^3	Fraction	10^3	10^3km/ Vehicle	10^6vehicle -km	Ton/vehicle	10^9 ton-km
Train	Diesel	0.010	*1.00*	0.010	*31.00*	0.30	*400*	0.12
Air plane	Jet fuel	0.012	*1.00*	0.012	*62.00*	0.74	*55*	0.04
Lake boat	Diesel	0.001	*1.00*	0.001	*52.00*	0.05	*150*	0.01
River boat	Diesel	0.000	*1.00*	0.00	*9.00*	0.00	*0.30*	0.00
Big truck	Diesel	5.73	*0.80*	4.58	*10*	45.80	*15.0*	0.69
Medium truck	Diesel	12.32	*0.80*	9.85	*15*	147.82	*7.0*	1.03
Small truck	Diesel	25.95	*0.80*	20.76	*15*	311.36	*3.0*	0.93
Total freight transportation activity								2.82

5.3.4.3 Modal split of freight transportation

Figure 5.1 shows annual freight activities of various modes of freight transportation as defined above. It can be seen in the figure that of all freight transport, medium, small and big trucks constitute 95.56%. In Malawi, although small trucks are in majority as shown in Table 5.14 above, there is more freight activity by medium trucks.

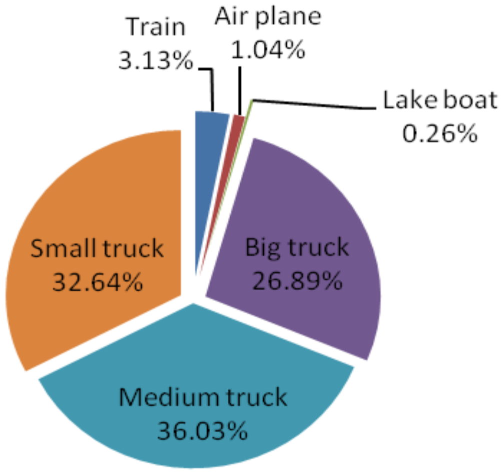


Figure 5.1: Modal split of Freight Transportation

5.3.4.4 Energy intensities of freight transportation

Table 5.15 below presents fuel consumption per 100 ton-kilometers for the various modes. The values were assumed by the Working Team based on knowledge of the freight transportation in the country.

Table 5.15: Energy Intensity of Freight Transportation

Sub mode	**2008 (litres/100 ton km)**
Diesel train	2.30
Air plane	10.00
Lake boat	0.40
Big Truck	3.00
Truck medium	4.00
Truck small	5.00

5.3.5. Energy use in the passenger transportation

5.3.5.1 Definition of passenger transportation modes and fuels

Passenger transportation modes are sub-divided into intercity and intra city transport activities because of differences in fuel consumption. Fuel consumption per kilometre is higher in intracity than in intercity. In this report, intracity is considered as transportation within the major cities while intercity is long distance transportation. In both inter and intracity, most people travel by road using either public or private transportation.

5.3.5.2 Distance travelled per day

The demand for passenger transportation activity in intercity and intracity in the base year was estimated at 3.92 and 5.30 billion passenger-kilometres respectively. Tables 5.16 and5.17 below show how the demand was calculated. The data on totals in each mode was obtained from the Ministry of Transport and Public Infrastructure and Transport while the numbers in italics are estimates made by the Working Team. Based on the figures in Tables 5.16 and 5.17, on average, one person travels 0.79 km per day in intercity and 9.32 km per day in intra city (see Appendix C for calculations).

Table 5.16: Intercity passenger transportation activity

Mode	Fuel	Fleet		Operating in Intercity	Annual vehicle mileage	Annual vehicle activity	Average load factor	Annual passenger activity
		Total in Intercity	Fraction of operating					
Unit		10^3	Fraction	10^3	10^3km/vehicle	10^6veh-km	passenger/vehicle	10^9passenger-km
Car	**Diesel**	3.84	*0.9*	3.46	*15*	51.84	*2.7*	0.14
Car	**Gasoline**	5.76	*0.9*	5.18	*15*	77.76	*2.7*	0.21
Moto-bike	**Gasoline**	9	*0.7*	6.3	*10*	63	*1.5*	0.09
Big bus	**Diesel**	1.43	*0.9*	1.28	*30*	38.48	*40.0*	1.54
Medium bus	**Diesel**	2.1	*0.9*	1.89	*30*	56.7	*26.0*	1.47
Small bus	**Diesel**	0.6	*0.9*	0.54	*30*	16.2	*15.0*	0.24
Air plane	**Jet fuel**	0.002	*1.0*	0.002	106	0.21	*60.0*	0.01
Boat	**Diesel**	0.001	*1.0*	0.001	73	0.07	*150.0*	0.01
Train	**Diesel**	0.001	*1.0*	0.001	62	0.06	*500.0*	0.03
Total intercity passenger transportation activity								**3.76**

Table 5.17: Intra city passenger transportation activity

Mode	Fuel	Fleet		Operating in urban	Annual vehicle mileage	Annual vehicle activity	Average load factor	Annual passenger activity
		Total in Urban	Fraction of operating					
Unit		10^3	Fraction	10^3	10^3 km/vehicle	10^6 vehicle-km	Passenger per vehicle	10^9 passenger-km
Car	Diesel	15.36	*0.9*	13.82	*10*	138.24	*2.5*	0.35
Car	Gasoline	23.04	*0.9*	20.74	*10*	207.36	*2.5*	0.52
Moto-bike	Gasoline	1	*0.95*	0.95	*10*	9.50	*1.5*	0.01
Medium bus	Diesel	0.08	*0.90*	0.07	*30*	2.03	*26.0*	0.05
Small bus	Gasoline	8.4	*0.9*	7.56	*30*	226.80	*15*	3.40
Small bus	Diesel	2.4	*0.9*	2.16	*30*	64.80	*15*	0.97
Total intracity passenger transportation activity								**5.30**

5.3.5.3 Load factors for intercity and intra-city transportation

Table 5.18 shows load factors for intercity and intra-city passenger transportation. These factors are based on Working Team's knowledge of passenger transportation system as well as Road Traffic Directorate rules of carriage in public roads in Malawi. Large buses have the highest intra city load factor as compared to other sub-modes. Train using diesel has the highest intercity load factor.

Table 5.18: Inter and Intra city average Load Factors

Mode	Average load factors (passengers/vehicle)	
	Intercity	**Intra city**
Car	2.70	2.50
Moto-bike	1.5	1.5
Big bus	40.00	-
Medium bus	26.00	26.00
Small bus	15.00	15.00
Air plane	60.0	-
Boat	150.00	-
Train	500.00	-

5.3.5.4 Modal split of intracity passenger transportation

Small buses, using gasoline and diesel, are the major passenger transportation in Malawi. As shown in Figure 5.2, they together constitute 82.5%. Motor bikes contribute the smallest percentage to the total passenger transportation.

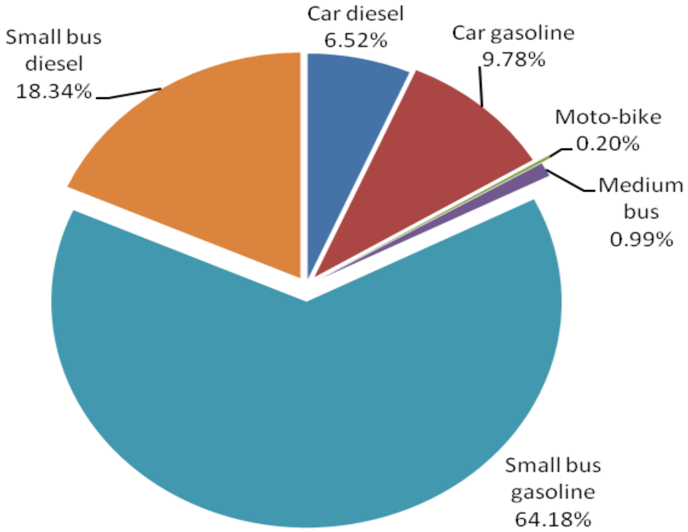


Figure 5.2: Modal split of intra city passenger transportation by activity

5.3.5.5 Car ownership and distance travelled by car for intercity transportation

On average, each car in Malawi serves about 303 persons and covers 3000 km per year. Comparing this with other African countries, for instance Kenya and Burkina Faso who did a similar study under IAEA, it is found out that in Kenya and Burkina Faso, one car covers 4767 and 1750 km per year respectively.. But in terms of car ownership, one car serves more people in Malawi than in Kenya and Burkina Faso where it serves 72 and 140 persons respectively.

5.3.5.6 Energy intensities of passenger transportation

The energy intensities for various modes in intercity and intra city passenger transportation are shown in Table 5.19 below. Diesel train has the highest energy intensity of all passenger transportation modes in the country while motor-bike has the least.

Table 5.19: Energy Intensity of Intercity and Intra city Passenger Transportation

Mode	Fuel	Unit	Specific fuel consumption	
			Intercity	Intra City
Car	Diesel	litres/100km	10	13
Car	Gasoline	litres/100km	9	10
Moto-bike	Gasoline	litres/100km	3	3
Big bus	Diesel	litres/100km	25	-
Medium bus	Diesel	litres/100km	15	35
Small bus	Gasoline	litres/100km	-	18
Small bus	Diesel	litres/100km	13	14
Air plane	Jet fuel	litre/100 seat km	6	-
Boat	Diesel	litres/100km	100	-
Diesel train	Diesel	litres/100km	228	-

5.3.6. Energy use in household sector

5.3.6.1 Classification of households

Households in the rural areas are classified largely as village houses. They are predominantly built with semi-permanent materials. On the other hand, the household sector in urban areas has been classified into four categories based on their energy consumption, and these are:

a) Villa

b) High consumption house

c) Regular house, and

d) Traditional dwellings

The villa is assumed to have the highest energy consumption while the traditional dwellings have the least energy consumption.

5.3.6.2 Heating degree-days and share of dwellings requiring space heating

Heating degree days refer to the cumulative number of days within the calendar year at which the temperature is less than 18°C. Malawi has 135 degree days. During these days, all households in both urban and rural areas require space heating.

5.3.6.3 Dwellings sizes, cooling and heating requirements

Number of dwellings

There are 435,000 and 2,458,000 dwellings in urban and rural areas respectively as shown in Table 5.20 below. These figures were calculated based on data presented in the *Malawi Population and Housing Census* Report.

Table 5.20: Demographic Information and number of dwellings

Item	Unit	2008
Population	Million	13.08
Urban population	%	15.32
Average urban household size	Persons	4.61
Urban Households	Million	0.44
Rural population	%	84.68
Average rural household size	Persons	4.51
Rural Households	Million	2.46

Urban dwellings, cooling and heating requirements

Information on dwelling sizes, cooling and heating requirements in urban areas is shown in Table 5.21 below. This information was based on calculations and assumptions made by the Working Team.

Table 5.21: Household energy variables

Item	**Share of dwellings (%)**	**Dwelling size (m^2)**	**Heat Loss ($Wh/m^2/°C/h$)**	**Dwelling Air conditioned (%)**	**Specific Air conditioning (kWh/dwelling/year)**
Villa	5.0	250.0	1.083	5.0	872.101
High consumption house	20.0	150.0	1,083	1.0	581.401
Regular house	65.0	100.0	1.733	0.0	290.7
Traditional dwellings	10.0	30.0	2.058	0.0	0.000

Rural dwellings, cooling and heating requirements

Table 5.22 shows information on dwelling sizes, cooling and heating requirements in rural areas. This information was based on calculations and assumptions made by the Working Team.

Table 5.22: Rural dwellings, cooling and heating requirements

Item	Unit	2008
Share of Village house	%	100
Dwelling size for Village house	m^2	70
Area of heat Village house	%	30
Heat loss. Village house	$Wh/m^2/°C/h$	2.91
Dwelling Air Conditioning for the Village house	%	0

5.3.6.4 Share of electric air-conditioning in rural and urban households

All air conditioning in the country is done using electricity. The shares of electric air - conditioning in urban and rural households have been presented above in Tables 5.21 and 5.22.

5.3.6.5 Share of dwellings with hot water facilities

All dwellings in rural and urban areas have hot water facilities. Dwellings with electricity use either geysers, electric cookers, hotplates or electric kettles for water heating while those without electricity use either three-stone or ceramic stoves. Electricity penetration is 37% for the urban and 2% for the rural.

5.3.6.6 Specific useful energy consumption for households

Specific useful energy consumption for water heating, cooking, specific final electricity consumption, specific fossil fuel consumption in rural and urban households are shown in Table 5.23. These figures were obtained by calculations based on assumptions made by the Working Team.

Table 5.23: Specific useful energy consumption for urban and rural households

Item	Unit	Urban Household	Rural Household
Cooking	kWh/dwelling/year	1762	1188
Water heating per capita	kWh/dwelling/year	135	35
Electricity consumption for appliances	kWh/dwelling/year	1248	255
Fossil fuel for lighting	kWh/dwelling/year	140	52

5.3.6.7 Penetration of energy carriers into thermal use

The penetration of energy carriers into thermal uses (space heating, water heating and cooking) in urban and rural areas is shown in Table 5.24 below. It can be seen that there is high usage of traditional fuels for space heating, water heating and cooking in both urban and rural areas as compared to electricity and fossil fuel. The fossil fuel referred to in this section is kerosene. Although there is coal in the country, most households are currently not using it because of lack of appropriate end-use technology, among other reasons.

Table 5.24: Penetration of energy carriers into thermal uses in households

Source	Urban area (%)			Rural area (%)		
	Space Heating	Water Heating	Cooking	Space Heating	Water Heating	Cooking
Electricity	75.68	30.19	15.18	-	0.06	0.03
Fossil Fuel	-	0.08	0.03	-	0.30	0.04
Traditional Fuels	24.32	69.73	84.79	100.00	99.64	99.93

5.3.6.8 Efficiencies of energy carriers in households

Efficiencies of energy carriers for space heating, water heating, cooking, and air conditioning for rural and urban households as enshrined in the National Energy Policy are as follows:

- traditional fuels - 10 to 15%
- electricity – 100%
- fossil fuel - 40%

5.4. Scenario development

5.4.1. Qualitative description of scenarios

Three scenarios were developed in the Study namely: reference growth, accelerated growth and moderated growth scenarios.

5.4.1.1. Reference Growth scenario

This scenario was developed based on the current major Government policies contained in the MGDS, Vision 2020 and NEP. Other major sources for this scenario development were Annual Economic Report 2009 and Population and Housing Census 2008. Under this scenario, the income per capita will reach the level of middle-income countries by 2030. The GDP structure is also expected to change as follows:

- average annual GDP growth will be 7% in the next 20 years,
- share of mining will increase considerably,
- share of service sector will increase,
- share of manufacturing sector will increase with a shift from non-durables to basic materials, and machinery and equipment in the long term, and
- share of agriculture, after some period, will be decreasing gradually.

5.4.1.2. Accelerated growth scenario

This scenario was developed with an assumption that there will be higher attainment of policy goals and targets than in the reference scenario. This will result in accelerated growth of the economy and reduced population growth rate. Under this scenario, the income per capita will reach the level of middle-income countries by 2030. The GDP structure is also expected to change as follows:

- average annual GDP growth will be 10% in the next 20 years,
- share of mining will increase considerably,
- share of service sector will increase,
- share of manufacturing sector will increase with shift from non-durables to machinery and equipment, and
- share of agriculture will gradually decrease.

5.4.1.3. Moderate Growth Scenario

This is a low growth scenario with an assumption that some of the policy goals and targets set in the reference scenario may not be achieved. Under this scenario, the income per capita will at least double by 2030. The following structural changes are assumed:

- average annual GDP growth rate will be 5% in the next 20 years,
- share of mining will slightly increase,
- share of service sector will increase slowly,
- share of manufacturing sector will slightly increase with a shift from non-durables to basic materials, and
- share of agriculture after some period will be gradually decreasing.

5.4.2. Demographic assumptions

This section describes assumptions made on the development of demographic parameters under reference, accelerated and moderate growth scenarios defined above.

5.4.2.1. Reference Growth Scenario

Assumptions made under this scenario include:

- population growth rate will go down following past long-term trend, and
- share of settlements with urban pattern of energy consumption will increase following the trend observed in some countries.

Table 5.25 below presents demographic information used in the MAED for the Reference Scenario.

Table 5.25: Demographic information for Reference Scenario

Item	Unit	2008	2015	2020	2025	2030
Population	Million	13.077	15.334	16.847	18.283	19.696
Population growth rate	% per annum		2.3	1.9	1.7	1.5
Urban population	%	15.3	16.3	20.4	25.0	30.0
Capita/household	Capita	4.607	4.310	4.070	3.770	3.400
Households	Million	0.435	0.580	0.844	1.212	1.738
Rural population	%	84.7	83.7	79.6	75.0	70.0
Capita/ household	capita	4.505	4.520	4.512	4.388	4.200
Households	million	2.458	2.839	2.972	3.125	3.283
Potential labour force	%	50.2	51.5	52.6	53.7	55.0
Participating labour force	%	69.3	69.4	69.6	69.8	70.0
Active labour force	million	4.549	5.474	6.164	6.857	7.583
Share of population in large cities	%	11.9	16.3	20.3	24.3	28.0
Population inside large city	million	1.558	2.499	3.420	4.443	5.515

5.4.2.2. Accelerated Growth Scenario

Table 5.26 below presents demographic information for this scenario. Some of the assumptions made include:

- Population growth rate will go down due to improved life style and will follow past long-term trend, and
- Share of settlements with urban pattern of energy consumption will increase following the trend observed in some countries.

Table 5.26: Demographic information for Accelerated Growth Scenario

Item	Unit	2008	2015	2020	2025	2030
Population	Million	13.077	15.022	16.423	17.78	19.06
Population growth rate	% per annum		2.0	1.8	1.6	1.4
Urban population	%	15.3	16.3	20.4	25.0	30.0
Capita/household	Capita	4.607	4.31	4.07	3.77	3.40
Households	Million	0.435	0.568	0.823	1.179	1.682
Rural population	%	84.7	83.7	79.6	75.0	70.0
Capita/ household	Capita	4.5	4.4	4.2	3.9	3.6
Households	Million	2.458	2.858	3.113	3.419	3.706
Potential labour force	%	50.2	51.5	52.6	53.7	55.0
Participating labour force	%	69.3	69.4	69.6	69.8	70.0
Active labour force	Million	4.549	5.363	6.009	6.668	7.338
Share of population in large cities	%	11.9	11.0	15.0	21.0	28.0
Population inside large city	Million	1.558	1.652	2.463	3.734	5.337

5.4.2.3. Moderate Growth Scenario

Demographic information for this scenario is presented in Table 5.27 below. Some of the assumptions made include:

- population growth rate will go down with slow rate, and
- urbanization rate will increase.

Table 5.27: Demographic information for Moderate Growth Scenario

Item	Unit	2008	2015	2020	2025	2030
Population	million	13.077	15.334	16.929	18.509	19.939
Population growth rate	% per annum		2.3	2.0	1.8	1.5
Urban population	%	15.3	18.0	25.0	30.0	35.0
Capita/household	capita	4.61	4.31	4.07	3.7	3.4
Households	million	0.435	0.640	1.040	1.473	2.053
Rural population	%	84.7	82.0	75.0	70.0	65.0
Capita/ household	capita	4.505	4.520	4.512	4.388	4.200
Households	million	2.458	2.782	2.814	2.953	3.086
Potential labour force	%	50.2	51.5	52.6	53.7	55.0
Participating labour force	%	69.3	69.4	69.6	69.8	70.0
Active labour force	million	4.549	5.474	6.194	6.942	7.677
Share of population in large cities	%	11.9	18.0	22.0	26.0	32.0
Population inside large city	million	1.558	2.760	3.724	4.812	6.381

5.4.3. Assumptions on economic growth and structural change of the economy

This section describes assumptions made on the development of parameters for economic growth and structural changes of the economy under reference, accelerated and moderate growth scenarios.

5.4.3.1. Reference Growth Scenario

Table 5.28 below presents information for GDP and GDP structure for this scenario. Some of the assumptions made include:

- GDP will grow with a high rate following a trend of latest years,
- The following structural changes will be implemented:
  - share of mining will increase considerably in the next few years,
  - share of service sector will increase,
  - share of manufacturing sector will increase with a shift from non-durables to basic materials, and machinery and equipment in the long term,
  - share of agriculture will decrease gradually after some period.
- Income per capita will reach the level of middle-income countries by the end of study horizon (2030).

Table 5.28: Total GDP and GDP Structure by main economic sectors

Item	Unit	2008	2015	2020	2025	2030
GDP	billion US$	3.499	5.618	7.880	11.052	15.5
GDP growth rate	% per annum		7.0	7.0	7.0	7.0
GDP/capita	US$	267.5	366.4	467.7	604.5	787.0
Agriculture	%	32.94	28.82	25.88	22.94	20.0
Construction	%	4.55	4.69	4.79	4.90	5.0
Mining	%	0.87	3.14	4.76	6.38	8.0
Manufacturing	%	7.99	8.63	9.09	9.54	10.0
Service	%	52.17	53.07	53.71	54.36	55.0
Energy	%	1.49	1.65	1.77	1.88	2.0

5.4.3.2. Accelerated Growth Senario

Table 5.29 below presents data for GDP and GDP structure for this scenario. Some of the assumptions made include:

- GDP will grow with an accelerated rate,
- The following structural changes will be implemented:
  - share of mining will increase considerably in the next few years,
  - share of service sector will increase,
  - share of manufacturing sector will increase with a shift from non-durables to machinery and equipment,
  - share of agriculture will decrease gradually after some period.
- Income per capita will reach the level of middle-income countries by the end of study horizon (2030).

Table 5.29: Total GDP and GDP structure by main economic sectors

Item	Unit	2008	2015	2020	2025	2030
GDP	billion US$	3.499	6.396	9.840	15.141	23.296
GDP growth rate	% per annum		9.0	9.0	9.0	9.0
GDP/capita	US$	267.5	417.1	584.1	828.1	1182.8
Agriculture	%	32.94	26.59	22.06	17.53	13.0
Construction	%	4.55	5.01	5.34	5.67	6.0
Mining	%	0.87	3.77	5.85	7.92	10.0
Manufacturing	%	7.99	8.95	9.63	10.32	11.0
Service	%	52.17	53.71	54.8	55.9	57.0
Energy	%	1.49	1.97	2.31	2.66	3.0

5.4.3.3. Moderate Growth Scenario

Table 5.30 below presents data for GDP and GDP structure for this scenario. Some of the assumptions made include:

- GDP will grow with a moderate rate,
- The following structural changes will be implemented:
  - share of mining will increase in the next few years,

- share of service sector will increase slowly,
- share of manufacturing sector will increase slightly with a shift from non-durables to basic materials,
- share of agriculture will decrease gradually after some period.

- Income per capita will at least double.

Table 5.30: Total GDP and GDP structure by main economic sectors

Item	Unit	2008	2015	2020	2025	2030
GDP	billion US$	3.499	4.923	6.283	8.019	10.234
GDP growth rate	% per annum		5.0	5.0	5.0	5.0
GDP/capita	US$	267.5	321.1	373.0	438.6	519.6
Agriculture	%	32.94	30.41	28.61	26.80	25.0
Construction	%	4.55	4.69	4.79	4.90	5.0
Mining	%	0.87	2.5	3.67	4.83	6.0
Manufacturing	%	7.99	8.31	8.54	8.77	9.0
Service	%	52.17	52.75	53.17	53.58	54.0
Energy	%	1.49	1.34	1.22	1.11	1.00

5.4.4. Assumptions on future energy use in industrial sector

This section describes assumptions made with respect to future energy use and development in the industrial sector (Agriculture, Construction, Mining and Manufacturing) under reference, accelerated and moderate growth scenarios.

5.4.4.1. Reference Growth Scenario

Tables 5.31 and 5.32 below present penetration of energy carriers into useful thermal energy for ACM (agriculture, construction and mining) and manufacturing sub-sectors respectively. Main assumptions made under this scenario are as follows:

- animal and human power will be replaced by motorized machines, and
- human and animal power for irrigation will be replaced by diesel and later by electrical motors.

Table 5.31: Penetration of energy carriers into useful thermal energy for ACM (%)

ACM	2008	2015	2020	2025	2030
Traditional fuels	87.8	80.4	68.8	53.4	34.4
Electricity	5.7	10.5	15.3	22.4	31.3
Solar	0.0	1.2	1.5	2.1	2.6
Fossil fuels	6.6	7.8	14.4	22.1	31.8

Table 5.32: Penetration of energy forms in manufacturing (%)

Energy carriers	2008	2015	2020	2025	2030
Electricity	9.9	16.6	18.9	21.2	23.6
Traditional fuels	7.3	5.6	4.8	4.1	3.3
Fossil fuels	82.8	77.7	76.3	74.7	73.0

5.4.4.2. Accelerated Growth Scenario

Tables 5.33 and 5.34 below present penetration of energy carriers into useful thermal energy for ACM and manufacturing sub-sectors respectively. Main assumptions made under this scenario are as follows:

- animal and human power will be replaced by motorized machines, and
- human and animal power for irrigation will be replaced by electrical motors.

Table 5.33: Penetration of energy carriers into useful thermal energy for ACM (%)

ACM	2008	2015	2020	2025	2030
Traditional fuels	87.8	79.4	66.7	50.2	30.4
Electricity	5.7	11.6	17.8	27.1	39.2
Solar	0.0	1.2	1.5	2.0	2.3
Fossil fuels	6.6	7.7	13.9	20.7	28.1

Table 5.34: Penetration of energy forms in manufacturing (%)

Energy carriers	2008	2015	2020	2025	2030
Electricity	9.9	18.3	21.8	25.4	29.1
Traditional fuels	7.3	5.4	4.6	3.8	3.0
Fossil fuels	82.8	76.2	73.6	70.9	67.9

5.4.4.3. Moderate Growth Scenario

Tables 5.35 and 5.36 below present penetration of energy carriers into useful thermal energy for ACM and manufacturing sub-sectors respectively. The main assumption is that there will be partial replacement of animal and human power by motorized machines

.

Table 5.35: Penetration of energy carriers into useful thermal energy for ACM (%)

ACM	2008	2015	2020	2025	2030
Traditional fuels	87.8	81.3	70.3	55.4	36.4
Electricity	5.7	9.6	13.5	19.6	27.2
Solar	0.0	1.3	1.6	2.2	2.7
Fossil fuels	6.6	7.9	14.7	22.9	33.7

Table 5.36: Penetration of energy forms in manufacturing (%)

Energy carriers	2008	2015	2020	2025	2030
Electricity	9.9	17.0	19.5	22.0	24.6
Traditional fuels	7.3	5.6	4.8	4.0	3.3
Fossil fuels	82.8	77.4	75.8	74.0	72.1

5.4.5. Development of parameters for freight transportation

This section presents assumptions made on the development of key parameters for the freight transportation sector with respect to future transportation needs and energy use.

5.4.5.1. Reference Growth Scenario

In the base year, freight transportation is dominated by trucks, having a share of 96% but is anticipated that this share will decrease to 87% in 2020 and 80% in 2030 (see Table 5.37). There will be an increase in freight transportation by diesel train, boats and airplanes.

The energy intensities for each transportation mode will decrease because of increased efficiency. These are shown in Table 5.38 below.

Table 5.37: Modal split of freight transportation (%)

Item	2008	2015	2020	2025	2030
Diesel train	3.1	6.9	9.6	12.3	15.0
Electric train	0.0	0.0	0.455	0.909	2.0
Plane	1.1	2.3	3.2	4.1	5.0
Boat	0.2	0.3	0.4	0.4	0.5
Truck	95.612	90.485	86.369	82.253	77.5

Table 5.38: Energy intensity of freight transportation

Item	Units	2008	2015	2020	2025	2030
Diesel train	litres/100tkm	2.3	2.24	2.19	2.15	2.1
Electric train	kWh/100tkm	0.0	0.0	0.227	0.455	1.0
Plane	litres/100tkm	10.0	9.68	9.46	9.23	9.0
Boat	litres/100tkm	0.3	0.216	0.16	0.1	0.04
Truck	litres/100tkm	12.0	11.62	11.35	11.07	10.8

5.4.5.2. Accelerated Growth Scenario

It is anticipated that the share of diesel train will increase at a faster rate as shown in Table 5.39 below. There will be an increase in freight transportation by diesel train, boats and airplanes.

Like in the reference scenario, the energy intensities for each transportation mode will decrease because of increased efficiency. The intensities are shown in Table 5.40 below.

Table 5.39: Modal split of freight transportation (%)

Item	2008	2015	2020	2025	2030
Diesel train	3.1	10.0	15.0	20.0	25.0
Plane	1.1	3.0	4.0	5.0	6.0
Boat	0.2	0.3	0.4	0.5	0.6
Truck	95.6	86.7	80.6	74.5	68.4

Table 5.40: Energy intensity of freight transportation (l/100tkm)

Item	2008	2015	2020	2025	2030
Diesel train	2.3	2.24	2.19	2.15	2.1
Plane	10.0	9.68	9.46	9.23	9.0
Boat	0.6	0.28	0.20	0.12	0.04
Truck	4.	3.87	3.78	3.69	3.6

5.4.5.3. Moderate Growth Scenario

The share of trucks for freight transportation is anticipated to decrease but at the same rate as in the reference scenario (see Table 5.41).

Likewise, the energy intensities for each transportation mode under this scenario will decrease because of increased efficiency. These are shown in Table 5.42.

Table 5.41: Modal split of freight transportation (%)

Item	2008	2015	2020	2025	2030
Diesel train	3.1	6.9	9.6	12.3	15.0
Plane	1.1	2.3	3.2	4.1	5.0
Boat	0.2	0.3	0.4	0.4	0.5
Truck	95.6	90.5	86.8	83.2	79.5

Table 5.42: Energy intensity of freight transportation (l/100tkm)

Item	2008	2015	2020	2025	2030
Diesel train	2.3	2.24	2.19	2.15	2.1
Plane	10.0	9.68	9.46	9.23	9.0
Boat	0.6	0.28	0.2	0.12	0.04
Truck	4.0	3.87	3.78	3.69	3.6

5.4.6. Development of parameters for passenger transportation

This section presents assumptions made on the development of the key parameters for the passenger transportation sector in inter and intra-city with respect to future transportation needs and energy use.

5.4.6.1. Reference Growth Scenario

Tables 5.43 to 5.47 below present key parameters for passenger transportation. Some of the assumptions made include:

- Number of cars per family will increase considerably,
- People will travel more in both urban and rural areas, and
- Public transportation will decrease in the next few years and then start increasing.

Table 5.43: Distance travelled in intercity and intracity

Item	Unit	2008	2015	2020	2025	2030
Distance travelled in intercity	km/person/year	287.177	323.075	348.717	374.358	400.000
Distance travelled in intra city	km/person/day	9.329	9.542	9.695	9.847	10.000
Total passenger-km(intercity)	10^9 passenger km	3.755	4.954	5.875	6.844	7.878

Table 5.44: Factors for intercity passenger transportation by car

Item		2008	2015	2020	2025	2030
Car ownership	person/car	302.712	235.031	186.687	138.344	90.0
Car-kilometers	km/car/year	3000.0	3954.545	4636.364	5318.182	6000.0

Table 5.45: Modal split of cars intercity passenger transportation (%)

Item	2008	2015	2020	2025	2030
Diesel car	60	45	48	52	55
Gasoline car	40	55	52	48	45

*Table 5.46: Modal split of public intercity passenger transportation **(%)***

Item	2008	2015	2020	2025	2030
Air plane	0.374	5.027	8.352	11.676	15.0
Moto-bike	2.775	2.210	1.807	1.403	1.0
Big bus	45.191	41.630	39.834	36.540	34.0
Medium bus	43.288	40.333	38.222	36.111	34.0
Small bus	7.135	8.047	8.698	9.349	10.0
Train diesel	0.916	1.261	1.507	1.754	2.0
Train electric	0.0	0.0	0.0	1.545	2.0
Boat	0.321	1.491	1.580	1.622	2.0

Table 5.47: Modal split of intracity passenger transportation (%)

Item	2008	2015	2020	2025	2030
Diesel car	6.515	10.169	12.779	15.39	18.0
Gasoline car	9.772	13.663	16.442	19.221	22.0
Big bus	0.000	1.591	2.727	3.864	5.0
Small bus g	0.992	1.313	1.542	1.771	2.0
Small bus d	64.129	51.043	41.695	32.348	23.0
Moto-bike	18.323	21.402	23.601	25.801	28.0

5.4.6.2. Accelerated Growth Scenario

Tables 5.48 to 5.52 below present key parameters for passenger transportation under accelerated growth scenario. Some of the assumptions made include:

- number of cars per family will increase considerably,
- people will travel more in both urban and rural areas, and
- public transportation will decrease in the next few years and then start increasing.

Table 5.48: Distance travelled in intercity and intracity

Item	Unit	2008	2015	2020	2025	2030
Distance travelled in intercity	km/person/year	287.177	323.075	348.717	374.358	400.0
Distance travelled in intra city	km/person/day	9.329	9.542	9.695	9.847	10.0
Total passenger-km(Intercity)	10^9 passenger km	3.755	4.954	5.875	6.844	7.878

Table 5.49: Factors for intercity passenger transportation by car

Item		2008	2015	2020	2025	2030
Car ownership	person/car	302.712	235.031	186.687	138.344	90.0
Car-kilometers	km/car/year	3000.0	3954.545	4636.364	5318.182	6000.0

Table 5.50: Modal split intercity passenger transportation – cars (%)

Item	2008	2015	2020	2025	2030
Diesel car	60	45	40	38	38
Gasoline car	40	55	58	60	60
Alcohol car	0	0	2	2	2

Table 5.51: Modal split of public intercity passenger transportation (%)

Item	2008	2015	2020	2025	2030
Air plane	0.374	5.027	8.352	11.676	15.0
Motor bike	2.775	2.210	1.807	1.403	1.0
Big bus	45.191	41.948	39.632	37.316	35.0
Medium bus	43.288	40.015	38.454	35.338	33.0
Small bus	7.135	8.047	8.698	9.349	10.0
Train diesel	0.916	1.261	1.507	1.754	2.0
Train Electric	0.0	0.0	0.0	1.545	2.0
Boat	0.321	1.491	1.550	1.619	2.0

Table 5.52: Modal split of intra city passenger transportation (%)

Item	2008	2015	2020	2025	2030
Diesel car	6.515	10.169	12.779	15.39	18.0
Gasoline car	9.772	13.663	16.442	19.221	22.0
Alcohol car	0.0	1.591	2.727	3.864	5.0
Big bus	0.992	1.313	1.542	1.771	2.0
Small bus gasoline	64.129	51.043	41.695	32.348	23.0
Small bus diesel	18.323	21.402	23.601	25.801	28.0
Motorbike	0.269	0.82	1.213	1.607	2.0

5.4.6.3. Moderate Growth Scenario

Tables 5.53 to 5.56 present key parameters for passenger transportation under moderate growth scenario. Some of the assumptions made include:

- number of cars per family will increase,
- people will travel more in both urban and rural areas, and
- public transportation will remain the main mode of passenger transportation.

Table 5.53: Distance travelled in intercity and intracity

Item	**Unit**	**2008**	**2015**	**2020**	**2025**	**2030**
Distance travelled in intercity	km/person/year	287.177	323.075	348.717	374.358	400.0
Distance travelled in intra city	km/person/day	9.329	9.542	9.695	9.847	10.0
Total passenger-km(Intercity)	10^9 passenger km	**3.755**	**4.954**	**5.875**	**6.844**	**7.878**

Table 5.54: Factors for intercity passenger transportation

Item		**2008**	**2015**	**2020**	**2025**	**2030**
Car ownership	person/car	302.712	235.031	186.687	138.344	90.0
Car-kilometers	km/car/year	3000.0	3954.545	4636.364	5318.182	6000.0

Table 5.55: Modal split of intercity passenger transportation - cars (%)

Item	**2008**	**2015**	**2020**	**2025**	**2030**
Diesel car	60	45	40	40	40
Gasoline car	40	55	59	59	59
Alcohol car	-	-	1	1	1

Table 5.56: Modal split of public intercity passenger transportation (%)

Item	**2008**	**2015**	**2020**	**2025**	**2030**
Air plane	0.374	5.027	8.352	11.676	15.0
Moto-bike	2.775	2.210	1.807	1.403	1.0
Big bus	45.191	41.948	39.632	37.316	35.0
Medium bus	43.288	40.015	38.454	35.338	33.0
Small bus	7.135	8.047	8.698	9.349	10.0
Train diesel	0.916	1.261	1.507	1.754	2.0
Train electric	0.0	0.0	0.0	1.545	2.0
Boat	**0.321**	**1.491**	**1.550**	**1.619**	**2.0**

Table *5.57: Modal split of intra city passenger transportation (%)*

Item	**2008**	**2015**	**2020**	**2025**	**2030**
Diesel car	6.515	10.169	12.779	15.390	18.0
Gasoline car	9.772	13.663	16.442	19.221	22.0
Car alcohol	0.0	1.591	2.727	3.864	5.0
Big bus	0.992	1.313	1.542	1.771	2.0
Small bus gasoline	64.129	51.043	41.695	32.348	23.0
Small bus diesel	18.323	21.402	23.601	25.801	28.0
Moto-bike	**0.269**	**0.820**	**1.213**	**1.607**	**2.0**

5.4.7. Development of parameters on dwelling pattern and energy use in household sector

This section presents assumptions made on the development of key parameters on the future dwelling pattern and energy use in the household sector.

5.4.7.1. Reference Growth Scenario

Tables 5.58 to 5.64 present key parameters on dwelling patterns and energy use in household sector. Some of the assumptions are as follows:

- number of people in one household will decrease following country development and the trend observed in other countries,
- one third of country population will have an access to electricity,
- number of electrical appliances per household will grow, and
- process of cooking will gradually move from household to service sector in later years.

Table 5.58: Penetration of energy forms into space heating - Rural Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	100.0	90.0	86.0	80.0	70.0
Modern biomass	-	6.0	7.0	8.0	10.0
Electricity	0.0	7.0	9.0	13.0	20.0
Fossil fuels	-	3	5	7	10

Table 5.59: Penetration of energy forms into space heating - Urban Household ***(%)***

Item	2008	2015	2020	2025	2030
Traditional fuels	24.316	18.17	13.78	9.39	5.0
Electricity	75.684	77.057	78.038	79.019	80.0
Fossil fuels	**0.0**	**4.8**	**8.2**	**11.6**	**15.0**

Table 5.60: Penetration of energy forms into water heating - Rural Household(%)

Item	2008	2015	2020	2025	2030
Traditional fuels	99.643	83.847	72.565	61.282	50.0
Electricity	0.06	12.768	21.845	30.923	40.0
Fossil fuel	0.3	1.4	2.5	3.52	5.0

Table 5.61*: Penetration of energy forms into water heating - Urban Household (%)*

Item	2008	2015	2020	2025	2030
Traditional fuels	69.732	50.0	37.0	24.0	7.0
Electricity	30.192	44.449	54.633	64.816	75.0
Solar	0.0	4.0	5.0	7.0	10.0
Fossil fuels	0.1	0.6	1.7	1.8	5.0

Table *5.62: Penetration of energy forms into cooking - Rural Household (%)*

Item	2008	2015	2020	2025	2030
Traditional fuels	99.928	80.86	67.24	53.62	40.0
Modern biomass	0.0	6.0	8.045	10.091	9.0
Electricity	0.032	12.749	21.833	30.916	40.0
Solar	0.0	0.0	1.0	2.0	3.0
Fossil fuels	0.0	0.4	1.9	3.4	8.0

Table *5.63: Penetration of energy forms into cooking - Urban Household (%)*

Item	2008	2015	2020	2025	2030
Traditional fuels	84.79	59.403	41.268	23.134	5.0
	0.0	1.0	1.682	2.364	3.0
Electricity	15.182	34.215	47.81	61.405	75.0
Soft solar	0.0	0.0	0.0	1.0	2.0
Fossil fuels	0.03	5.4	9.2	12.1	15.0

5.4.7.2. Accelerated Growth Scenario

Tables 5.64 to 5.69 present key parameters on dwelling patterns and energy use in household sector under accelerated growth scenario. Some of the assumptions are as follows:

- number of people per household will decrease following country development and the trend observed in other countries,
- electrification is one of the highest priorities with more than one third of the population having access to electricity,
- number of electrical appliances per household will increase,
- cooking will gradually move from household to service sector in later years,
- there will be considerable improvement in health care and life expectancy, and
- the women’s involvement in formal labour force will increase.

Table 5.64: Penetration of energy forms into space heating - Rural Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	100.0	90.0	86.0	80.0	70.0
Electricity	0.0	7.0	9.0	13.0	20.0
Fossil fuels	0.0	3.0	5.0	7.0	10.0

Table 5.65: Penetration of energy forms into space heating - Urban Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	24.316	18.17	13.78	9.39	5.0
Electricity	75.684	77.057	78.038	79.019	80.0
Fossil fuels	0.0	4.8	8.2	11.6	15.0

Table 5.66: Penetration of energy forms into water heating - Rural Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	99.643	83.847	72.565	61.282	50.0
Modern biomass	0.000	2.000	3.136	4.273	5.0
Electricity	0.060	12.768	21.845	30.923	40.0
Fossil fuels	0.3	1.4	2.5	3.52	5.0

*Table 5.67: Penetration of energy forms into water heating - Urban Household **(%)***

Item	2008	2015	2020	2025	2030
Traditional fuels	69.732	50.0	37.0	24.0	7.0
Modern biomass	0.0	1.0	1.682	2.364	3.0
Electricity	30.192	44.449	54.633	64.816	75.0
Soft solar	0.0	4.0	5.0	7.0	10.0
Fossil fuels	0.1	0.6	1.7	1.8	5.0

Table 5.68: Penetration of energy forms into cooking - Rural Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	99.928	80.860	67.240	53.620	40.0
Modern biomass	0.0	6.0	8.045	10.091	9.0
Electricity	0.032	12.749	21.833	30.916	40.0
Soft solar	0.0	0.0	1.0	2.0	3.0
Fossil fuels	0.0	0.4	1.9	3.4	8.0

Table 5.69: Penetration of energy forms into cooking - Urban Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	84.790	59.403	41.268	23.134	5.0
Modern biomass	0.0	1.0	1.682	2.364	3.0
Electricity	15.182	34.215	47.810	61.405	75.000
Soft solar	0.0	0.0	0.0	1.0	2.0
Fossil fuels	0.03	5.4	9.2	12.1	15.0

5.4.7.3. Moderate Growth Scenario

Tables 5.70 to 5.75 present key parameters on dwelling patterns and energy use in household sector under moderate growth scenario. Some of the assumptions are as follows:

- number of people per household will decrease slowly,
- one quarter of the population will have an access to electricity,
- number of electrical appliances per household will grow slowly, and
- the women’s involvement in formal labor force will increase.

Table 5.70: Penetration of energy forms into space heating - Rural Heating (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	100	90	86	80	70
Electricity	0.0	7.0	9.0	13.0	20.0
Fossil fuels	0.0	3.0	5.0	7.0	10.0

Table 5.71: Penetration of energy forms into space heating - Urban Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	24.316	18.17	13.780	9.39	5.0
Electricity	75.684	77.057	78.038	79.019	80.0
Fossil fuels	0.0	4.8	8.2	11.6	15.0

Table 5.72: Penetration of energy forms into water heating - Rural Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	99.643	83.847	72.565	61.282	50.0
Modern biomass	0.0	2.0	3.136	4.273	5.0
Electricity	0.06	12.768	21.845	30.923	40.0
Fossil fuels	0.3	1.4	2.5	3.52	5.0

Table 5.73: Penetration of energy forms into water heating – Urban Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	69.732	50.000	37.000	24.000	7.0
Modern biomass	0.0	1.0	1.682	2.364	3.0
Electricity	30.192	44.449	54.633	64.816	75.0
Solar	0.0	4.0	5.0	7.0	10.0
Fossil fuels	0.1	0.6	1.7	1.8	5.0

Table 5.74: Penetration of energy forms into cooking - Rural Households (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	99.928	80.860	67.240	53.620	40.0
Modern biomass	0.000	6.000	8.045	10.091	9.0
Electricity	0.032	12.749	21.833	30.916	40.0
Soft solar	0.0	0.0	1.0	2.0	3.0
Fossil fuels	0.0	0.4	1.9	3.4	8.0

Table 5.75: Penetration of energy forms into cooking - Urban Household (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	84.79	59.403	41.268	23.134	5.0
Modern biomass	0.0	1.0	1.682	2.364	3.0
Electricity	15.182	34.215	47.81	61.405	75.0
Soft solar	0.0	0.0	0.0	1.0	2.0
Fossil fuels	0.03	5.4	9.2	12.1	15.0

5.4.8. Assumptions on the service sector development

This section presents assumptions on future energy use and the development of the service sector.

5.4.8.1. Reference Growth Scenario

Tables 5.76 to 5.78 present key data on service sector development and future energy use.

- share of service sector contribution to GDP will increase,
- cooking will gradually move from household to service sector in later years, and
- the share of Service sector buildings equipped with air-conditioning will increase.

Table 5.76: Basic data for useful energy demand in Service Sector

Item	Unit	2008	2015	2020	2025	2030
Labour force in Service Sector	%	15.0	29.318	39.545	49.773	60.0
Floor area per employee	m^2/capita	8.0	8.0	8.0	8.0	8.0
Labour force in Service Sector	Million	0.682	1.605	2.437	3.413	4.55
Floor area of Service Sector	million m^2	5.459	12.839	19.499	27.303	36.398

Table 5.77: Penetration of energy forms into Space heating (%)

Item	2008	2015	2020	2025	2030
Electricity	100	100	100	100	100

Table 5.78: Penetration of energy forms into other thermal uses (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	49.497	38.521	30.681	22.84	15.0
Electricity	40.217	46.511	51.008	55.504	60.0
Solar thermal	5.156	6.697	7.798	8.899	10.0
Soft solar	0.0	3.182	5.455	7.727	10.0
Fossil fuels	5.13	5.09	5.06	5.03	5.0

5.4.8.2. Accelerated Growth Scenario

Tables 5.79 to 5.80 present key data on service sector development and future energy use under accelerated growth scenario. The following were the main assumptions:

- share of service sector contribution to GDP will increase,
- cooking will gradually move from household to service sector in later years, and
- there will be high use of air conditioners both in service and household sectors.

Table 5.79: Basic data for useful energy demand in Service Sector

Item	Unit	2008	2015	2020	2025	2030
Labour force in Service Sector	%	15.0	29.318	39.545	49.773	60.0
Floor area per employee	m^2/capita	8.0	8.0	8.0	8.0	8.0
Labour force in Service Sector	Million	0.682	1.605	2.437	3.413	4.55
Floor area of Service Sector	million m^2	5.459	12.839	19.499	27.303	36.398

Table 5.80: Penetration of energy forms into Space heating (%)

Item	2008	2015	2020	2025	2030
Electricity	100	100	100	100	100

Table 5.81: Penetration of energy forms into other thermal uses (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	49.497	38.521	30.681	22.84	15.0
Electricity	40.217	46.511	51.008	55.504	60.0
Solar thermal	5.156	6.697	7.798	8.899	10.0
Soft solar	0.0	1.0	3.0	6.7	10.0
Fossil fuels	5.13	7.27	7.51	6.06	5.0

5.4.8.3. Moderate Growth Scenario

Tables 5.82 to 5.84 present key data on service sector development and future energy use under moderate growth scenario. Assumptions made are as follows:

- share of service sector contribution to GDP will increase slowly, and
- more service sector buildings will be equipped with air-conditioning.

Table 5.82: Basic data for useful energy demand in Service Sector

Item	Unit	2008	2015	2020	2025	2030
Labour force in Service Sector	%	15.0	29.318	39.545	49.773	60.0
Floor area per employee	m^2/capita	8.0	8.0	8.0	8.0	8.0
Labour force in Service Sector	Million	0.682	1.605	2.437	3.413	4.55
Floor area of Service Sector	million m^2	5.459	12.839	19.499	27.303	36.398

Table 5.83: Penetration of energy forms into Space Heating (%)

Item	2008	2015	2020	2025	2030
Electricity	100	100	100	100	100

Table 5.84: Penetration of energy forms into other thermal uses (%)

Item	2008	2015	2020	2025	2030
Traditional fuels	49.497	38.521	30.681	22.84	15.0
Electricity	40.217	46.511	51.008	55.504	60.0
Solar thermal	5.156	6.697	7.798	8.899	10.0
Soft solar	0.0	1.0	3.0	6.7	10.0
Fossil fuels	5.13	7.27	7.51	6.06	5.0

5.5. Energy demand projections

5.5.1. The ranges of total energy demand projections

This sub-section discusses total energy demand projections for the analysed scenarios. The projections are summarized in Figure 5.3 below, and explained in the preceding sub-sections:

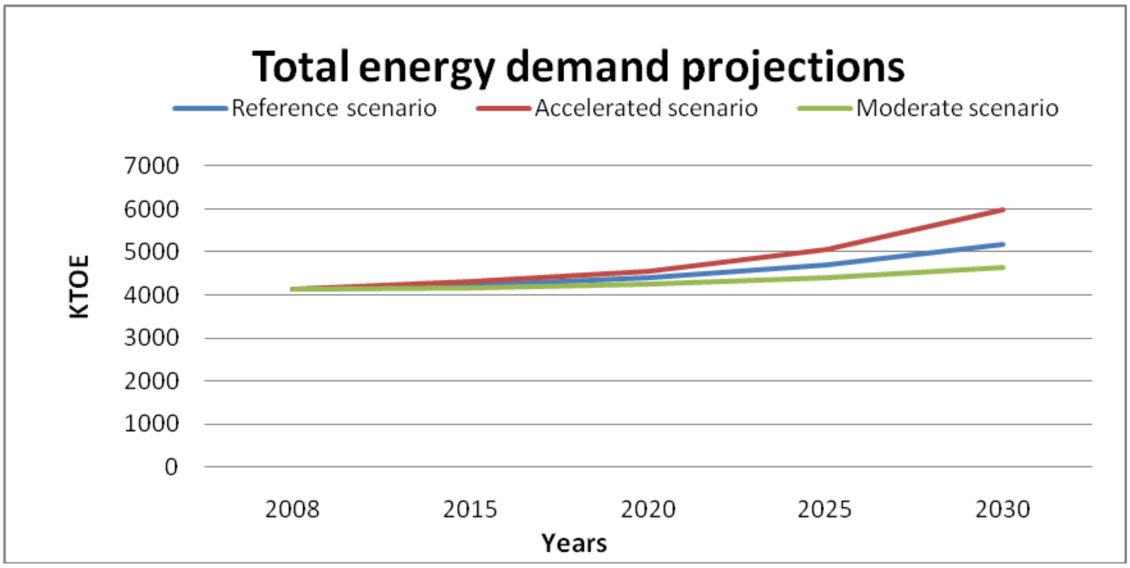
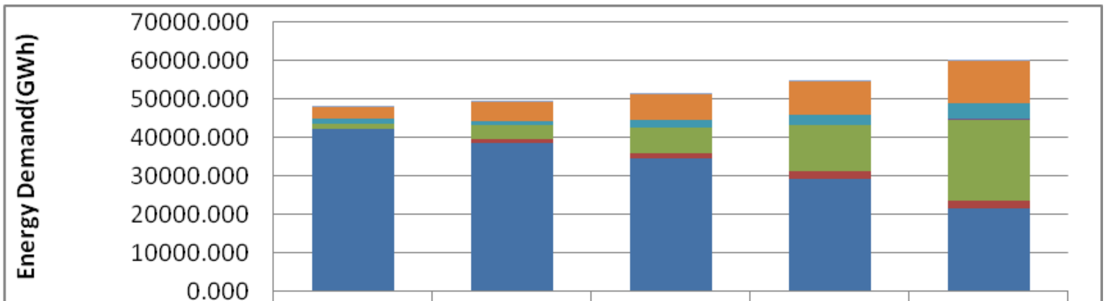


Figure 5.3: Total energy demand projections

5.5.2. Detailed analysis of reference scenario

Figure 5.4 below shows total final energy demand by energy form. Total energy demand will grow from about 48,000GWh to 60,000GWh by 2030. Electricity, motor fuels (gasoline and diesel), fossil fuels (coal and kerosene), solar thermal and soft solar will increase by 17, 4, 3, 5 and 13 times respectively. Usage of modern biomass grows from 0 to 2225 GWh in the same period. Consumption of traditional fuels will decrease by half in 20308 from the base year consumption of 42,333GWh. Figures 5.5 to 5.7 below show shares of energy demand by energy form.



	2008	2015	2020	2025	2030
Solar thermal	11.630	20.734	29.705	40.837	53.70865385
Motor fuels	3068.624	4880.992	6563.815	8537.829	10947.03751
Fossil fuels	1329.565	1154.073	1833.381	2702.979	4214.782714
Soft solar	16.282	69.439	106.381	155.791	215.4024626
Electricity	1220.244	3447.934	6522.472	11789.353	20910.54146
Modern biomass	0.000	1098.993	1586.206	2151.893	2225.003578
Traditional fuels	42333.200	38589.727	34477.185	29169.807	21501.57155

Figure 5.4: *Final Energy Demand by energy form under reference scenario*

Figure 5.5: *Shares of energy demand by energy form in 2008*

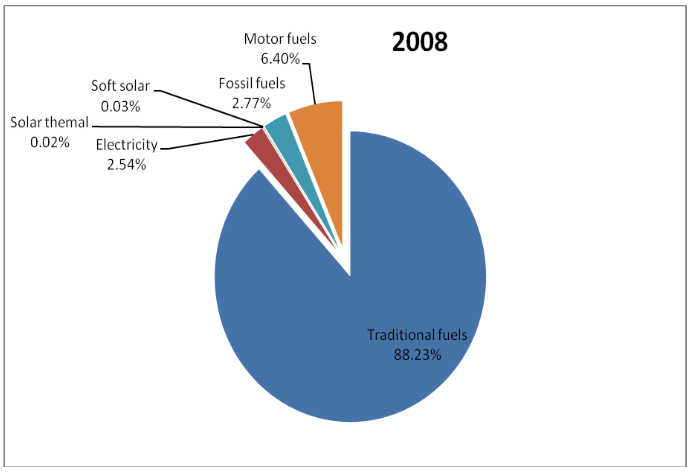


Figure 5.6: *Shares of energy demand by energy form in 2020*

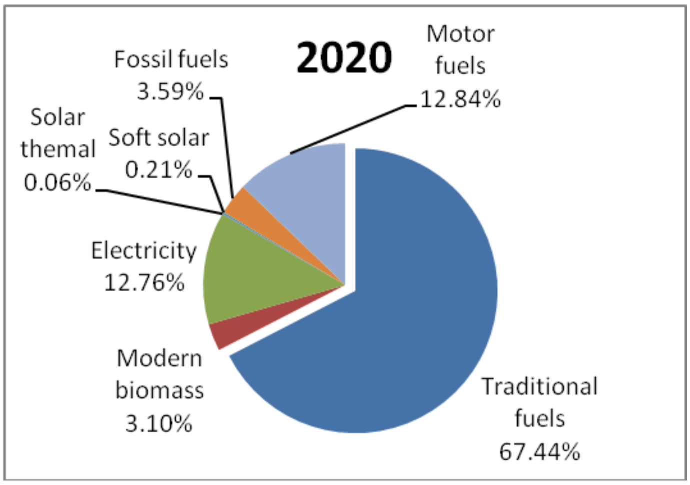


Figure 5.7: *Shares of energy demand by energy form in 2030*

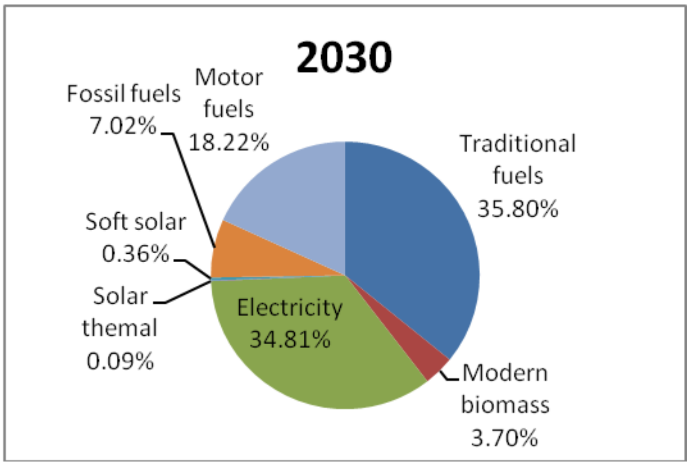


Figure 5.8 below shows the variation of total energy, commercial energy and electricity demand per GDP for the study period. Energy demand per value added decreases by 3 times while commercial energy demand and electricity demand per value added will slightly increase.

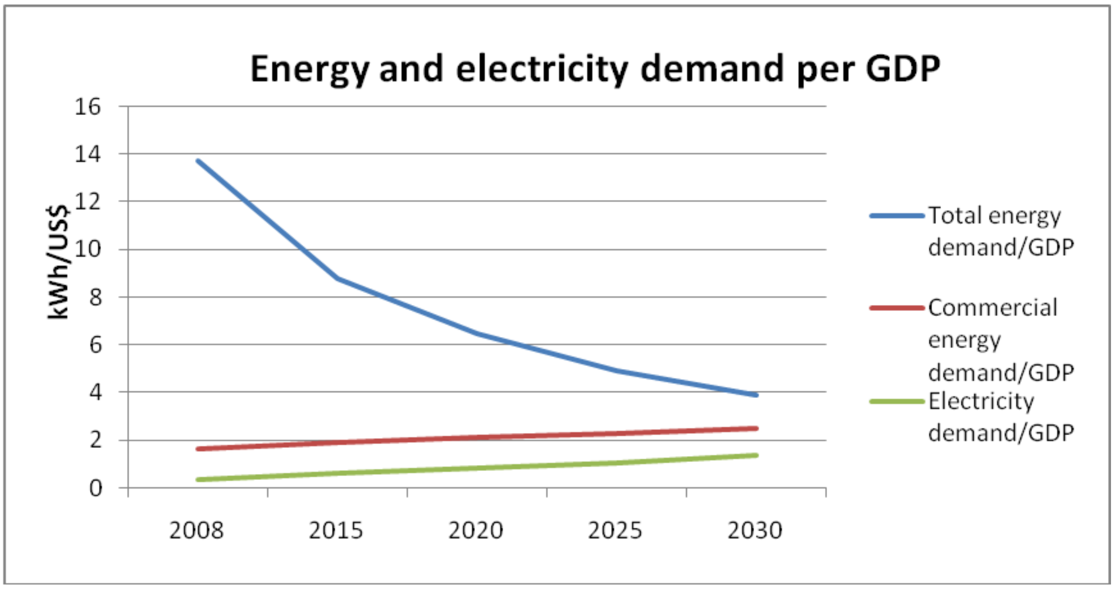


Figure 5.8: Energy and electricity demand per GDP

Figure 5.9 below shows the variation of total energy, commercial and electricity demand per capita for the study period. Total energy demand per capita will decrease by about 17% while electricity demand will increase by almost 900%.

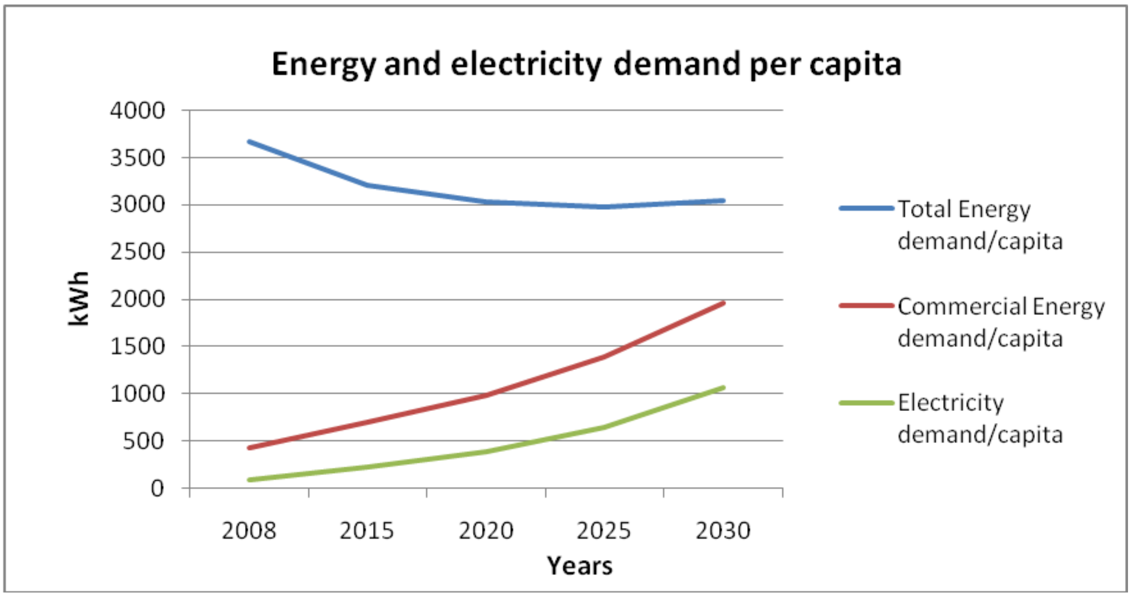


Figure 5.9: Final energy demand per capita

Final energy demand by sector is shown in Figure 5.10 below. There is a general increase in energy demand in all sectors with huge increases in industry and transport sectors. Energy demand in industry and transport will both increase by 3 times by 2030. However, household will still dominate the energy demand.

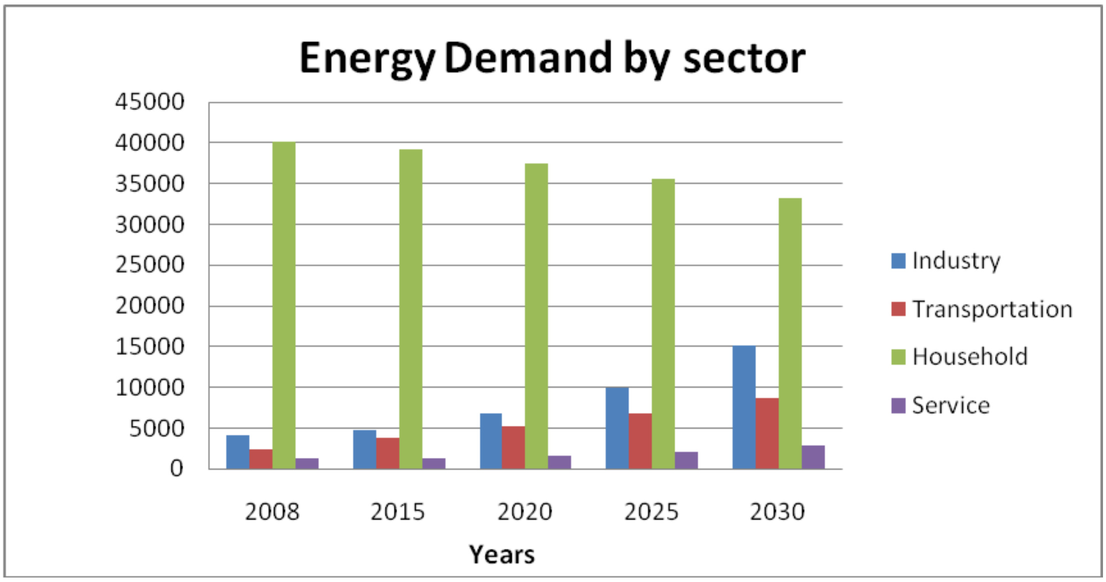


Figure 5.10: Final energy demand by sector

Figure 5.11 below shows final electricity demand by sector. There is a general increase in electricity demand in all sectors with the highest increase in ACM. ACM will increase by more than 60 times with major contribution coming from mining. Demand for electricity in household, manufacturing and service sectors will increase by 23, 11 and 12 times respectively. Figure 5.12 shows the same information with ACM and manufacturing aggregated as industry sector.

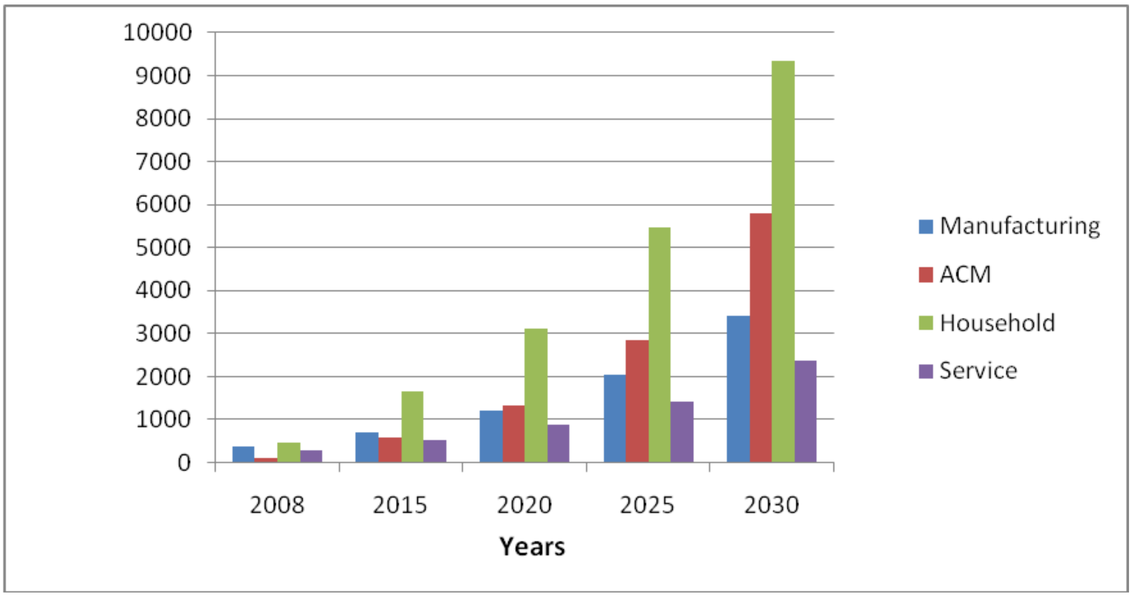


Figure 5.11: Final electricity demand by sector

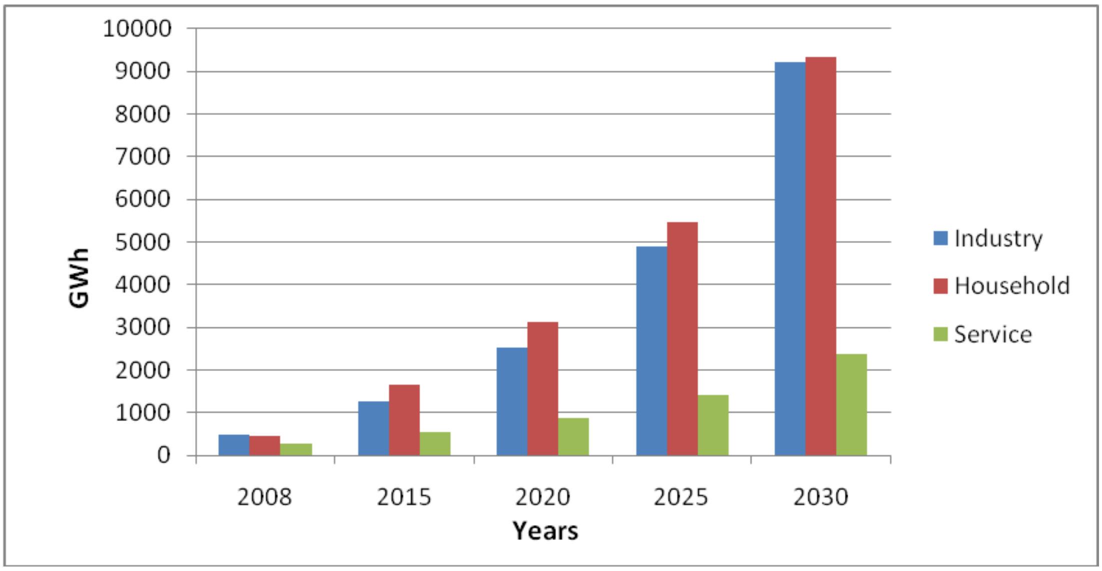
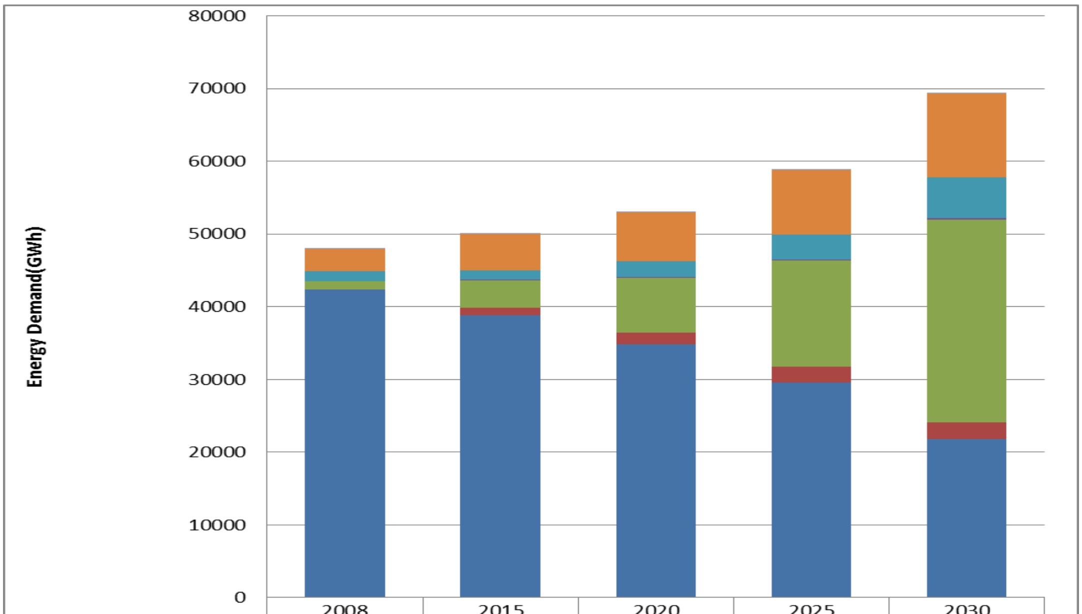


Figure 5.12: Final electricity demand by sector with ACM and manufacturing aggregated.

5.5.3 Detailed analysis of Accelerated Growth Scenario

Figure 5.13 below shows total final energy demand by energy form under accelerated growth scenario. Total energy demand will grow by almost one and a half times from 2008 to 2030. Electricity, motor fuels (gasoline and diesel), fossil fuels (coal and kerosene), solar thermal and soft solar will grow by 23, 4, 4, 7, 14 times respectively. Consumption of modern biomass grows from 0 in 2008 to 2225GWh in 2030. Consumption of traditional fuels decreases by almost half from 42,333 GWh in 2008 to 21,864GWh by 2030. Figures 5.14 to 5.16 show shares of energy demand by energy form.



	2008	2015	2020	2025	2030
Solar thermal	12	23	37	55	79
Motor fuels	3069	4970	6759	8908	11599
Fossil fuels	1330	1313	2210	3437	5555
Soft solar	16	68	105	158	222
Electricity	1220	3760	7559	14620	27932
Modern biomass	0	1099	1586	2152	2225
Traditional fuels	42333	38810	34826	29581	21865

Figure 5.13: Total final energy demand by energy form under accelerated growth scenario

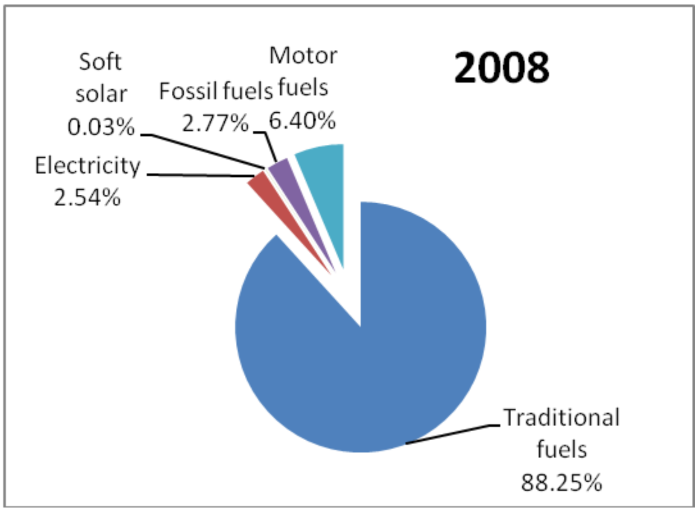


Figure 5.14: Shares of energy demand by energy form in 2020

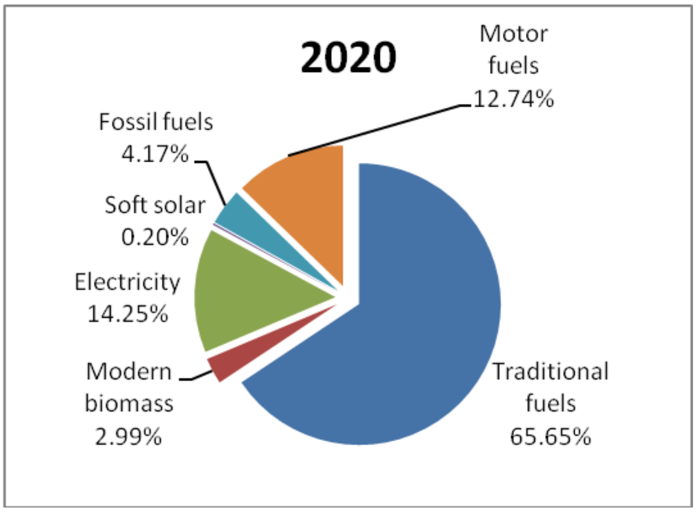


Figure 5.15: Shares of energy demand by energy form in 2020

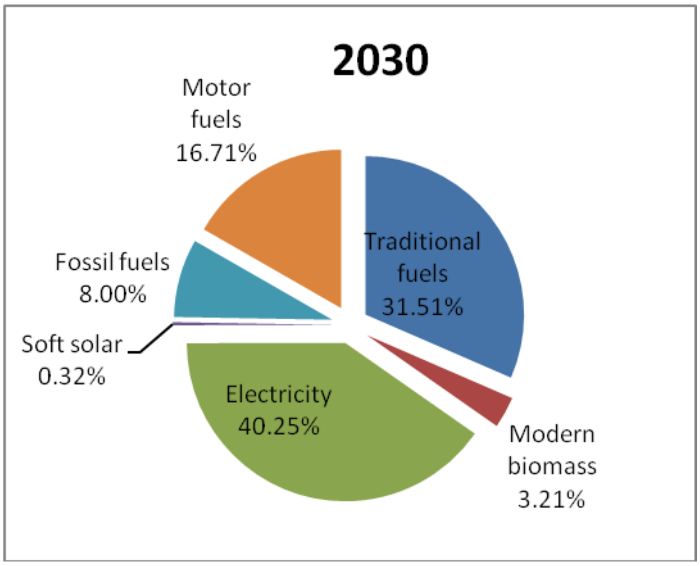


Figure 5.16: Shares of energy demand by energy form in 2020

Figure 5.17 below shows the variation of total energy, commercial energy and electricity demand per capita for the study period (2008 – 2030). Total energy demand per capita decreases from about 3,700 kWh in 2008 to about 3,200 kWh by 2020 then will start increasing to 3,500 kWh by 2030. Electricity demand per capita will increase significantly from about 100kWh in 2008 to 1400 kWh in 2030.

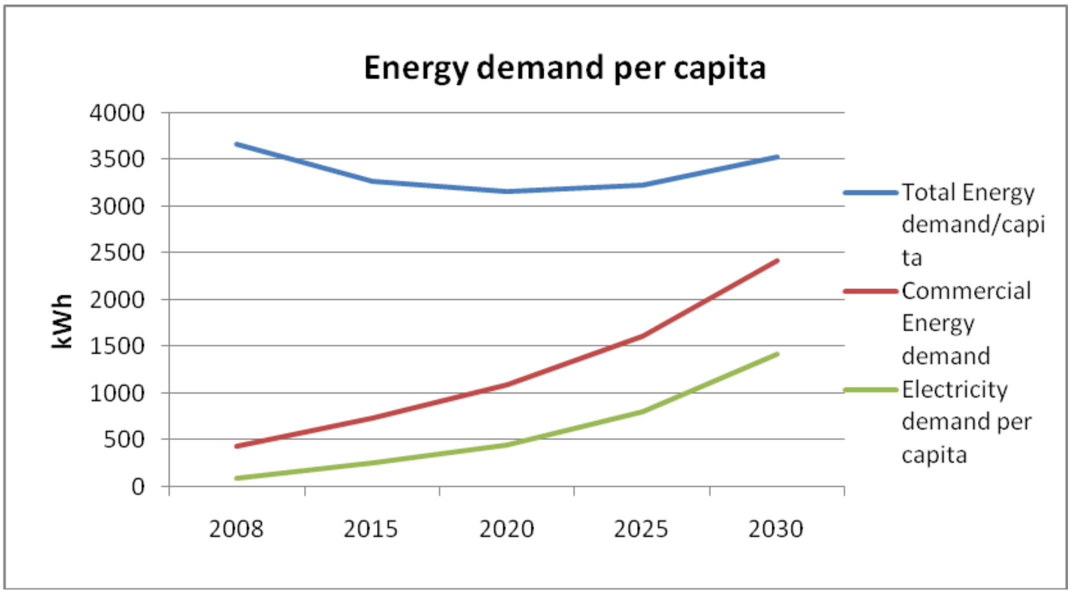


Figure 5.17: Energy demand per capita under accelarated scenario

Figure 5.18 below shows the variation of total energy, commercial energy and electricity demand per GDP for the study period. Total energy demand per value added decreases by about 5 times from 2008 figures to 2030 while commercial energy demand and electricity demand per value added will increase slightly.

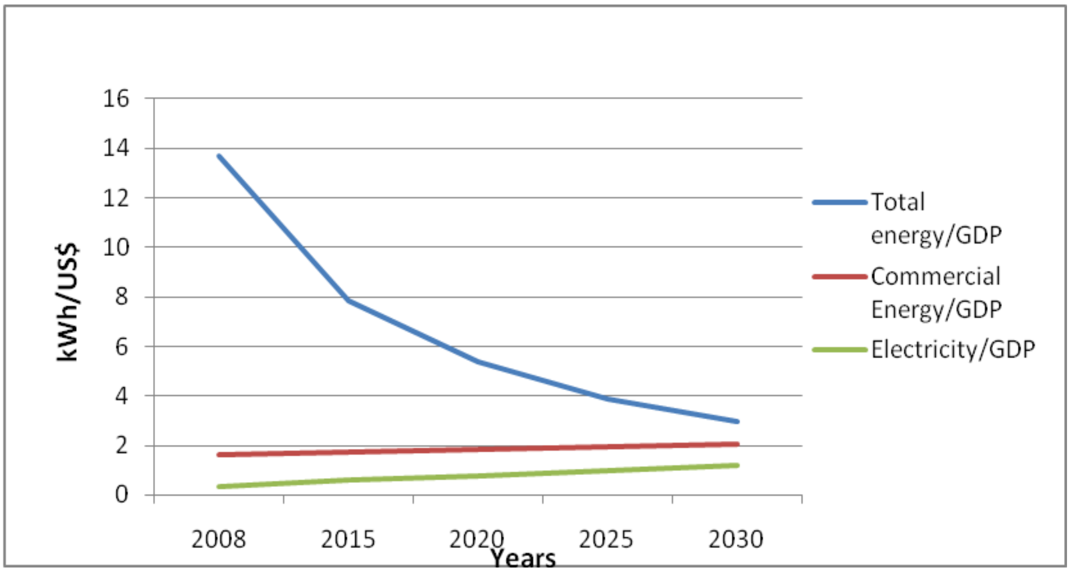


Figure 5.18: Energy and electricity demand per GDP

Figure 5.19 below shows final energy demand by sector. There is a general increase in energy demand in all sectors with huge increases in industry and transport sectors (energy demand in industry and transportation will increase by 6 and 3 times respectively by 2030). Household will still dominate the energy demand.

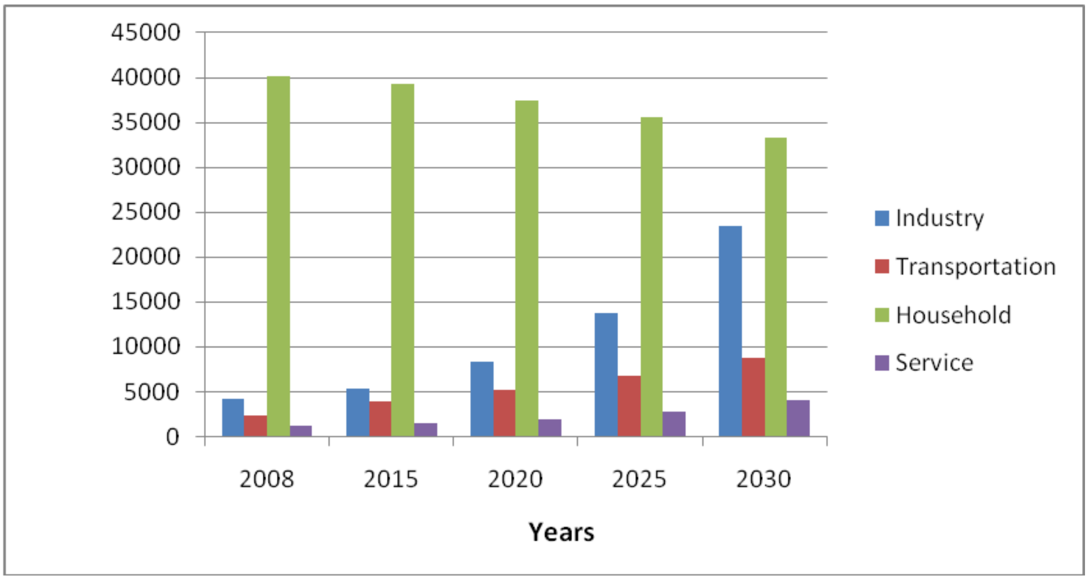


Figure 5.19: Final energy demand by sector

Figure 5.20 below shows final electricity demand by sector. There is general increase in electricity demand in all sectors with the highest increase in ACM. ACM will increase by about 95 times with major contribution coming from mining. Demand for electricity in household, manufacturing and service sectors will increase by 23, 20 and 16 times respectively. Figure 5.21 shows the same information with ACM and manufacturing aggregated as industry sector.

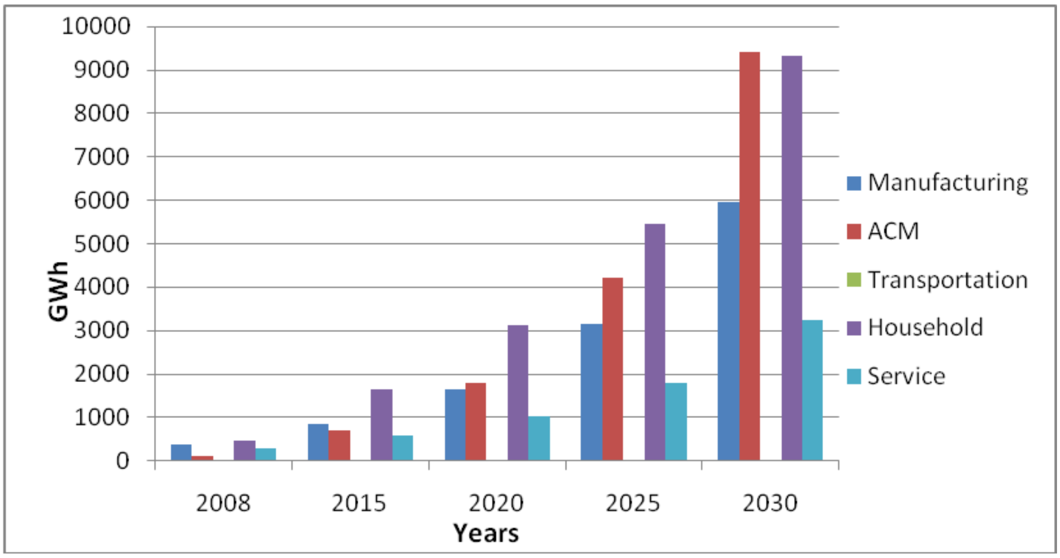


Figure 5.20: Electricity demand by sector

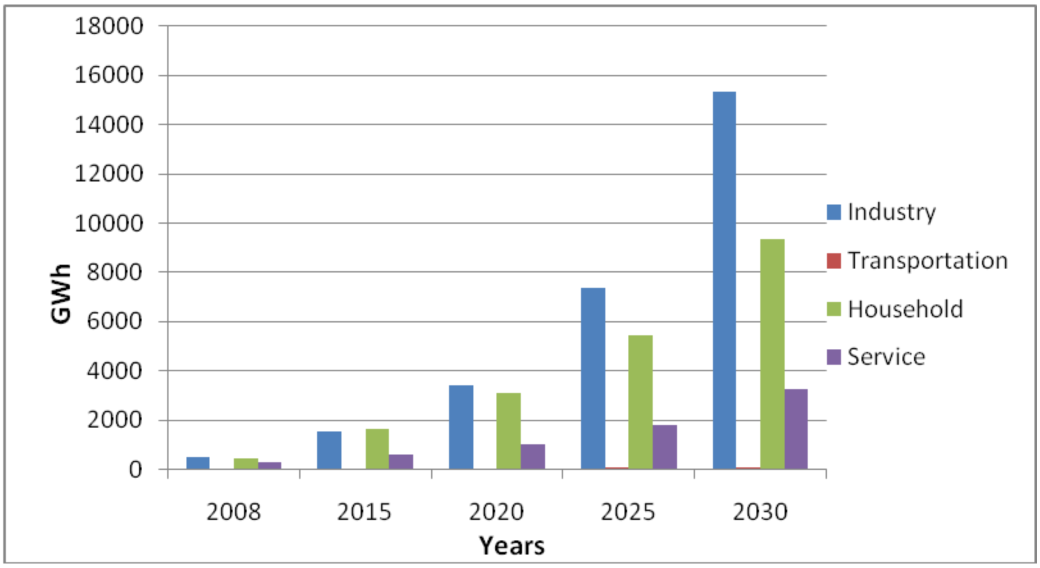
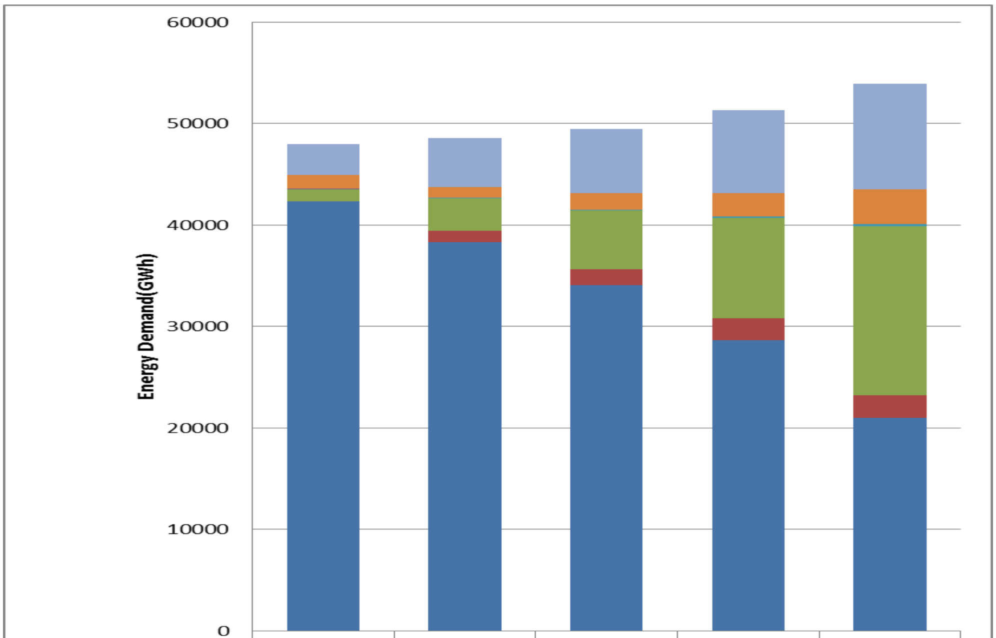


Figure 5.21: Electricity demand by sector with ACM and manufacturing aggregated as industry sector

5.5.4. Detailed analysis of Moderate Growth Scenario

Figure 5.22 below shows total final energy demand by energy form under moderate growth scenario. Total energy demand will grow by one and a half times from 2008 to 2030. Electricity, motor fuels (gasoline and diesel), fossil fuels (coal and kerosene), solar thermal and soft solar will grow by 14, 3, 3, 3 and 13 times respectively. Consumption of modern biomass grows from 0 to 2225 GWh in the same period. Consumption of traditional fuels decreases from 42,333 GWh in 2008 to 21011GWh by 2030. Figures 5.23 to 5.25 show shares of energy demand by energy form.



	2008	2015	2020	2025	2030
Motor fuels	3069	4788	6357	8179	10400
Fossil fuels	1330	1053	1600	2263	3453
Soft solar	16	67	103	151	208
Solar thermal	12	18	24	30	36
Electricity	1220	3188	5743	9871	16616
Modern biomass	0	1099	1586	2152	2225
Traditional fuels	42333	38348	34087	28678	21011

Figure 5.22: Total final energy demand by energy form - moderate scenario

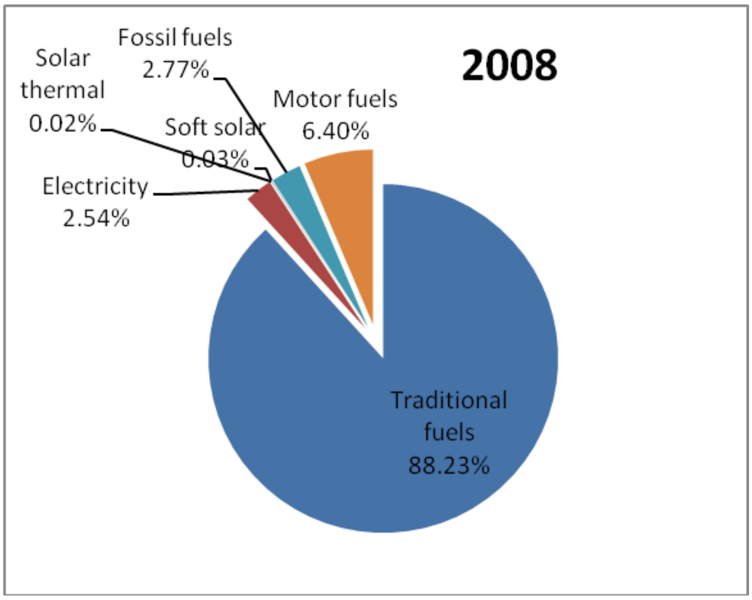


Figure 5.23: Shares of energy demand by energy form in 2008

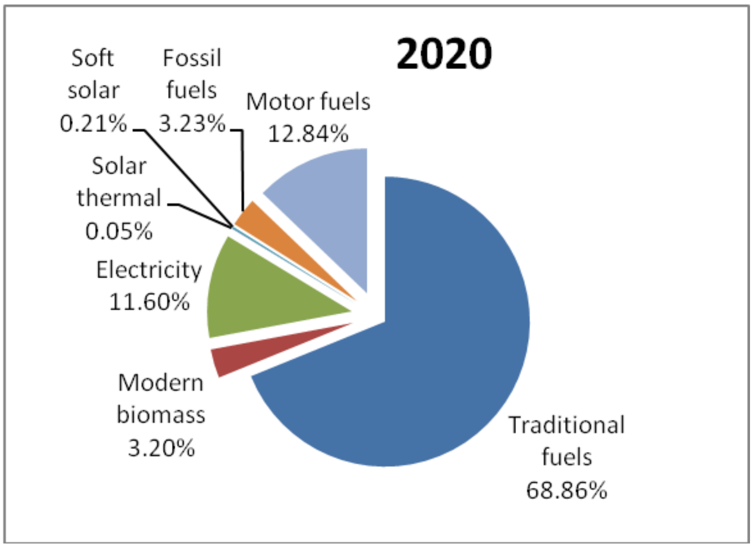


Figure 5.24: Shares of energy demand by energy form in 2020

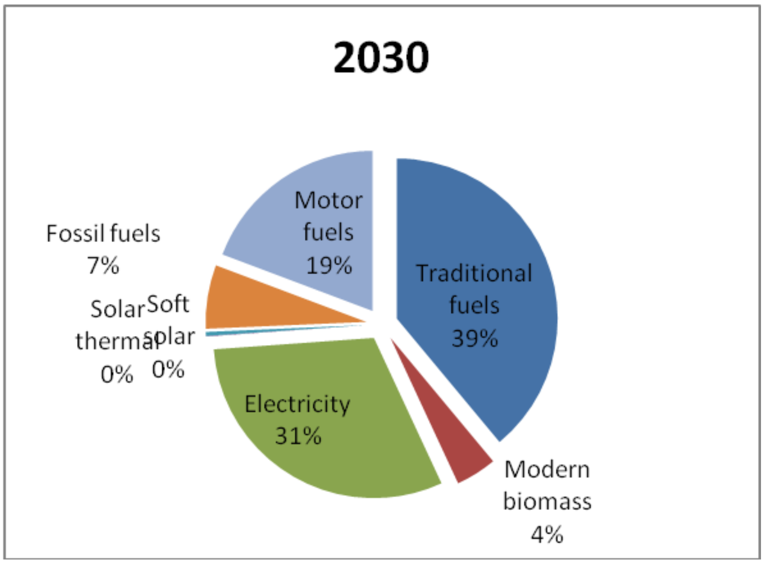


Figure 5.25: Shares of energy demand by energy form in 2030

Figure 5.26 below shows the variation of total energy, commercial energy and electricity demand per capita for the study period (2008 – 2030). Total energy demand per capita decreases from about 3,700 kWh in 2008 to about 2,750 kWh by 2030. Electricity demand per capita will increase from about 100kWh in 2008 to 800 kWh in 2030.

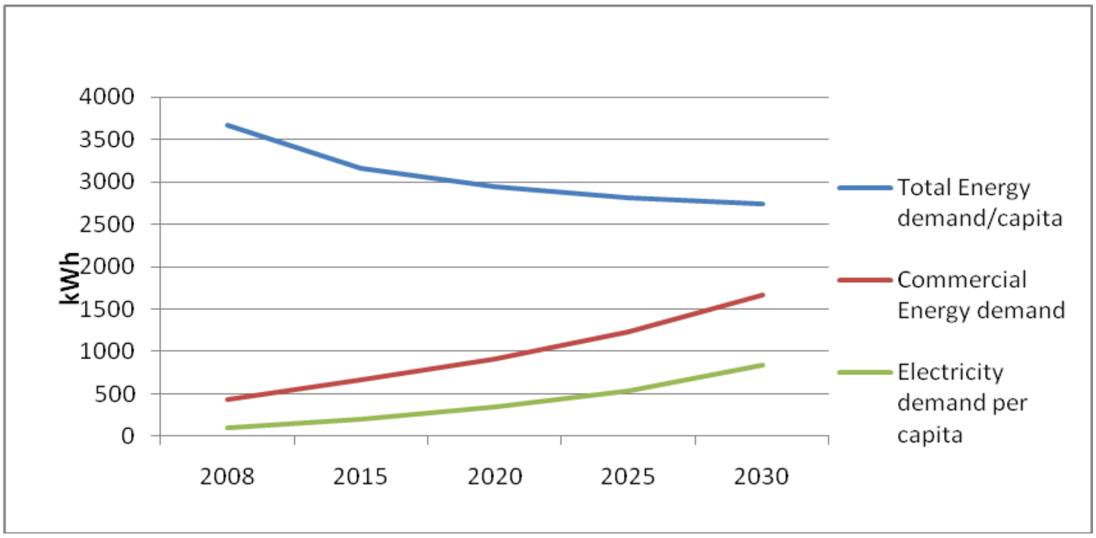
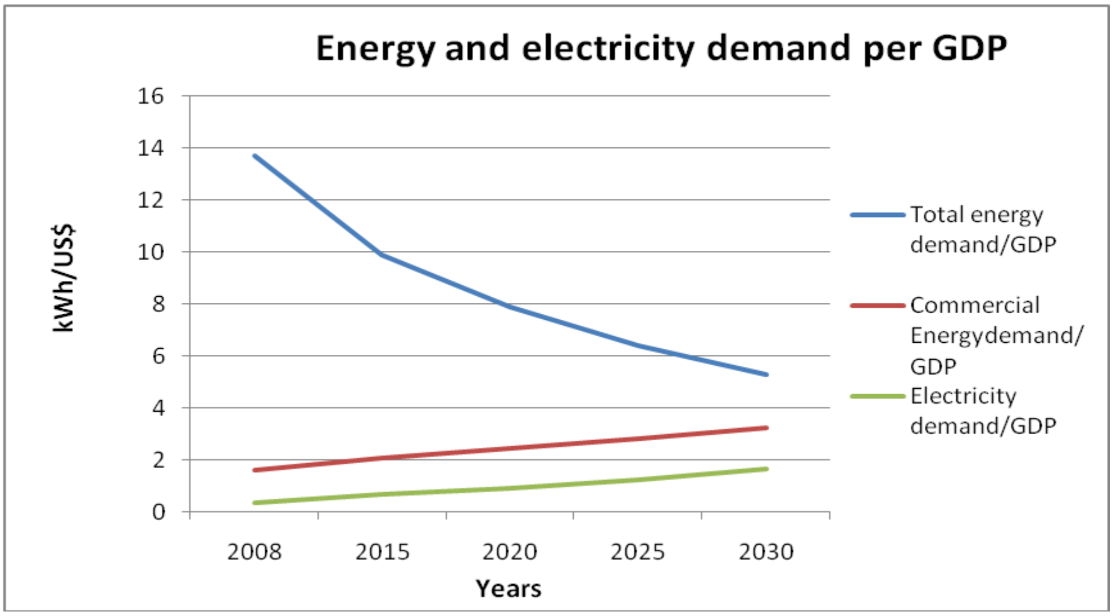


Figure 5.26: Energy demand per capita - moderate scenario

Figure 5.27 below shows the variation of total energy, commercial energy and electricity demand per GDP for the study period. Total energy demand per value added decreases by about 27 times from 2008 figures to 2030 while commercial energy demand and electricity demand per value added will increase by 2 and 20 times respectively.



igure 5.27: Final energy demand per capita per GDP- moderate scenario

Figure 5.28 below shows final energy demand by sector. There is a general increase in energy demand in all sectors but the increases are insignificant as compared to the reference scenario. Final energy demand in industry, transportation and service sectors increases by 2 and 3 times respectively. There is a very slight increase in energy demand for the service sector from 2008 to 2030 figures. Household total energy demand decreases from 40,000 GWh in 2008 to 33,000 GWh by 2030.

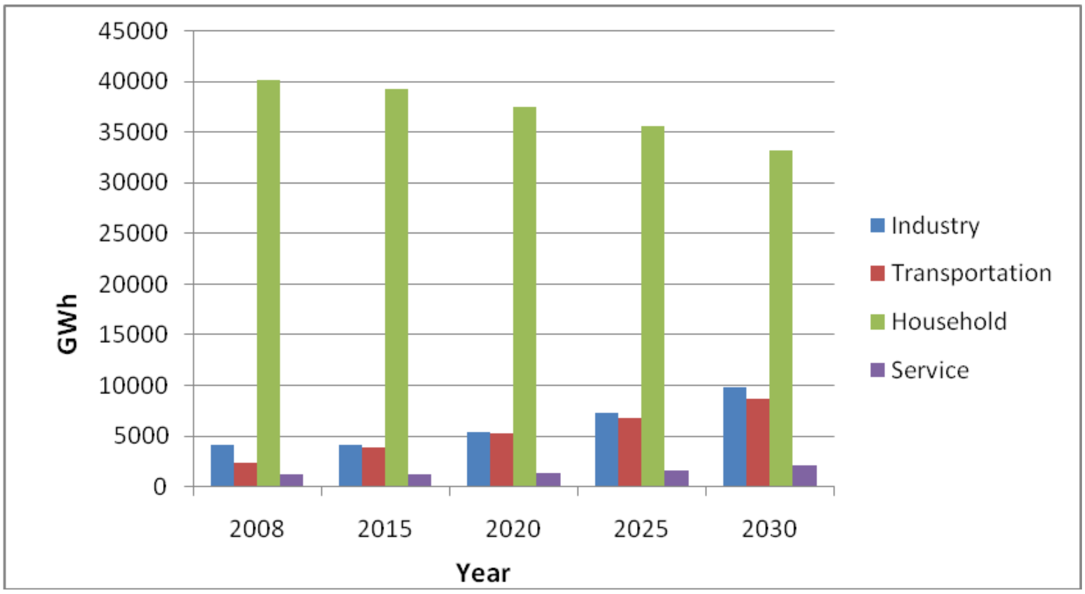


Figure 5.28: Final energy demand by sector - moderate scenario

Figure 5.29 below shows final electricity demand by sector. There is a general increase in electricity demand in all sectors with the highest increase in ACM. ACM will increase by about 35 times with major contribution coming from mining. Demand for electricity in household, manufacturing and service sectors will increase by 23, 7 and 4 times respectively. Figure 5.30 shows the same information with ACM and manufacturing aggregated as industry sector.

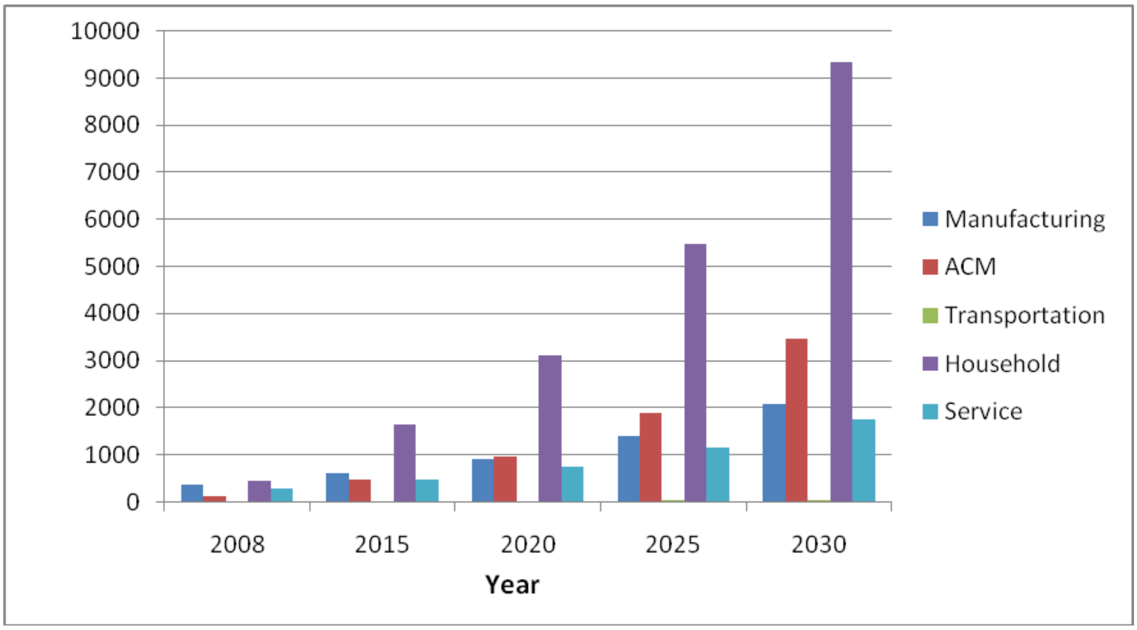


Figure 5.29: Electricity demand by sector – moderate scenario

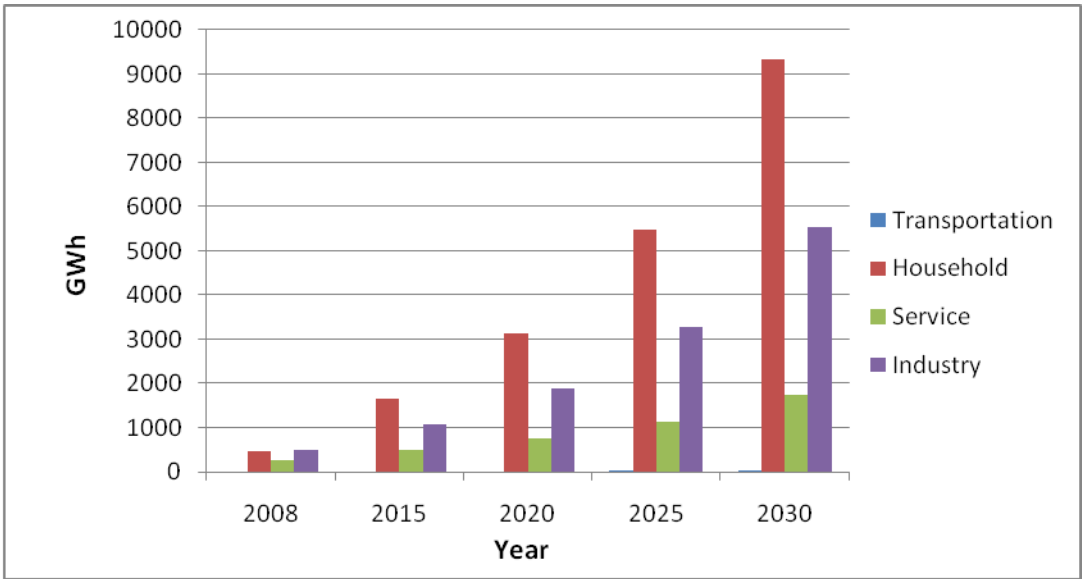


Figure 5.30: Final electricity demand by sector with ACM and manufacturing aggregated.

Chapter 6

PROJECTION OF ELECTRICITY LOAD PATTERNS

6.1. Methodological description – MAED - El model

MAED-el converts the annual electricity demand for each economic sector (considered for demand forecasting in MAED-D) to the hourly electricity demand during the year. This module considers four economic sectors, namely Industry, Transport, Household and Service and up to six clients for each of these sectors for calculation of hourly electricity demand.

Various modulation factors are used to calculate the hourly demand from the annual electricity demand. These factors characterise the changes in the electricity consumption with respect to the average electricity consumption during a year, week or a day. This module converts the total annual electricity demand of a sector to the electricity load of the sector in a given hour, day and week of the year by taking into account the following factors:

- The trend of the average growth rate of the electricity demand during the year.
- The changes in the level of electricity consumption owing to the various seasons of the year (this variation is reflected on a weekly basis in this Module).
- The changes in the level of electricity consumption owing to the type of day being considered(i.e. working days, weekends, special holidays, etc)
- The hourly variation of electricity consumption during a particular type of day.

The trend of average growth rate of electricity demand is already known from the results of MAED - D. The variation of electricity load of a given sector by hour, day and week is characterised by three sets of modulation coefficients that are defined for 24 hours in a day, by type of days in a week, and for each week in a year. The product of all the coefficients, along with the coefficients for the average growth rate of electricity demand, multiplied by the average electricity demand of a particular sector result in the electric load of that sector in a particular hour. Knowing all these coefficients in a particular year allows us to calculate the chronological hourly electricity load for 8760 hours of that year.

Similar calculations are repeated for each sector of the economy(Industry, Transport, Household and service) and the loads for same hour in all sectors are aggregated together to produce the hourly load values of the total load imposed on the power system in a particular year. The graphical representation of these hourly loads in decreasing order produces the well- known hourly load duration curve for the electric power system.

The modulation coefficients used for these calculations are obtained from statistical analysis based on the past operating experience for the power sector under consideration.

6.2 Features of Electricity Load in Malawi

6.2.1 Historical electricity consumption pattern

Table 6.1 shows total electricity consumption, shares of different sectors in total electricity consumption and the corresponding average growth rates for the past 20 years from 1989 to 2008. Electricity consumption grew by two and a half times over the last 20 years at an average annual growth rate of 5.1%, which is almost 1.5 times the corresponding GDP growth rate. It can be seen in Table 6.1, that the sectoral pattern of electricity consumption underwent considerable change due to different growth rates experienced in the various economic sectors. This change is mainly in household and industrial sectors. The share of household sector has been steadily increasing from 17.8% in 1989 to 37.5% in 2008 while the share of industrial sector has been decreasing from 59.7% in 1989 to 40.1% in 2008. The share of service sector has almost remained constant. Sectoral growth rates also underwent significant changes in the various time periods considered as can be seen in Table 6.1.

Table 6.1: Evolution of sectoral electricity consumption

Item	1989	1994	1999	2004	2008
Electricity Consumption(GWh)	476	639	844	964	1219
Shares(%) by sector					
Household	17.8	22.5	29.9	33.8	37.5
Service	22.5	24.6	20.9	22.0	22.4
Industry	59.7	52.9	49.2	44.2	40.1
Average Annual Growth Rates (%)					
Household		11.4	11.9	4.8	8.8
Service		6.4	1.4	2.5	6.5
Industry		8.0	0.8	1.0	3.5
Total Consumption		8.0	4.0	3.0	6.0

The large variations experienced in the sectoral growth rates for the past 20 years were due to changes in electricity demand determining factors such as economic policies, sectoral economic activity levels, urbanisation, pumped irrigation, use of air conditioners and increase in usage of other electric appliances at household level and in commercial establishments. The evolution of these factors will continue to determine growth of electricity and sectoral patterns in the coming years.

6.2.2 Evolution of System Load Factor

Figure 6.1 shows the evolution of system load factor for the past 20 years from 1989 to 2008. The average system load factor for the past 20 years was 65%. The actual annual system load factor has been varying between 60% and 70% except in 2008 when it reached 73%. This very high system load factor in 2008 was because of generation constraints which led to the chopping of the peak demand by load shedding.

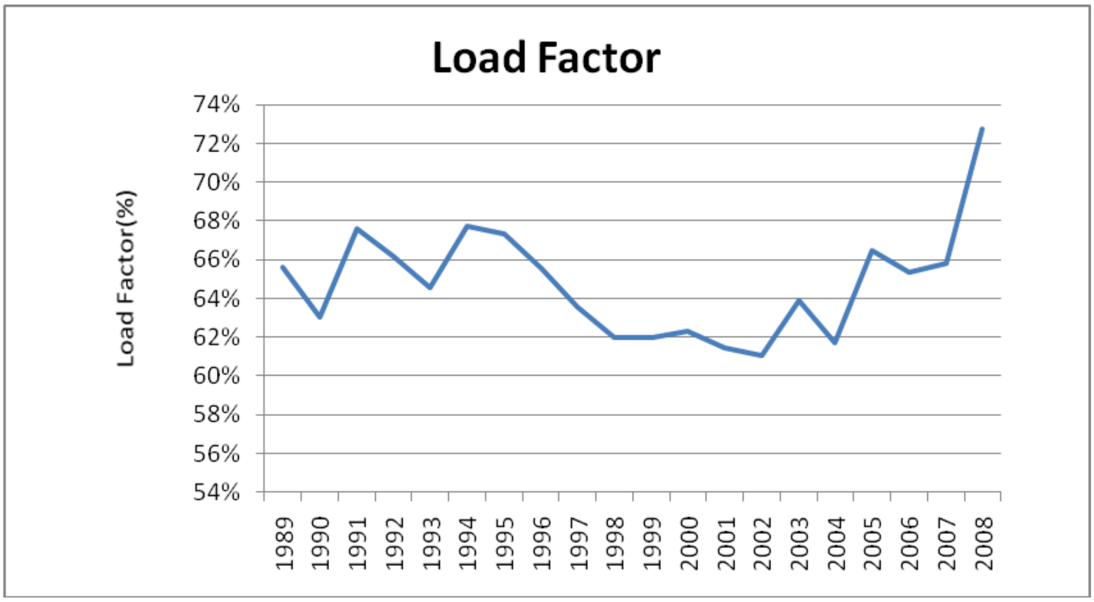


Figure 6.1: Load factor

6.2.3 Maximum Demand

Table 6.2 shows the growth of system demand and the corresponding annual growth rates for five year periods in the past 20 years. It can be seen that the system demand has been growing at a decreasing rate. This is partly due to the fact that demand is being curtailed due to generation constraints.

Table 6.2: Annual system demand

Item	***Annual System Demand***				
Year	**1989**	**1994**	**1999**	**2004**	**2008**
System Demand(MW)	101	139	188	227	242
Average Annual Growth Rate		8%	6%	3%	2%

6.2. Reconstruction of electricity load patterns for the base year

Half-hourly data for the base year was collected from the electricity utility company, ESCOM. The half-hourly data was averaged to hourly data.

Seasons were defined as follows:

- Pre-winter - Warm – wet season (November to April)
- Winter - Cool – dry season (May to August)
- Post-winter- Hot –dry season (September to October)

Load profiles for representative days in the three seasons were captured by averaging data for all the days in the particular season. These average values were normalised. The normalised values were for working days, Saturdays and Sundays in all the seasons. These values (coefficients) defined the seasonal, daily and hourly patterns for the sectors. These coefficients were used as input into MAED-El.

6.2.1. Definition of major clients within sectors

Hourly load profile data obtained from ESCOM was categorised in form of economic sectors of industrial, service and household only with no electricity consumption in the transport sector. Load profile data for sub-sectors was not available and therefore no clients have been defined within the three economic sectors considered in this Module.

6.2.2. Shares of electricity demand by major clients within sectors

The shares of electricity demand for the three economic sectors are shown in Figure 6.2. These shares are for 2008, the base year. There is no electricity consumption in the transport sector because Malawi does not have electric trains and cars at the moment.

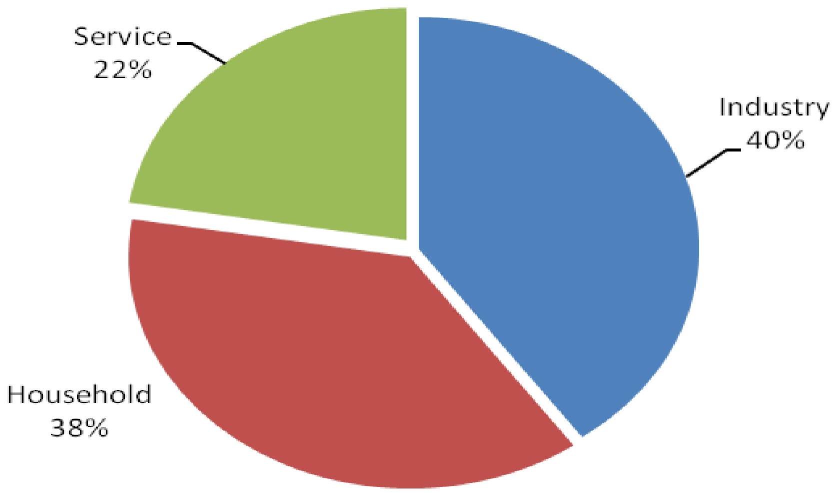


Figure 6.2: Shares of electricity consumption by sector in the base year

6.2.3. Transmission/distribution losses

According to ESCOM's sales and generation statistics reports, total system losses for the base year are 21% of energy sent out to transmission grid. Of these, 7% are transmission losses while 14% are distribution losses (both technical and commercial losses)

6.2.4. Peak load

Peak load for the base year obtained from the reconstructed load duration curve is 233 MW while the actual peak load for 2008 was 242 MW.

6.2.5. Load modulating coefficients (by week and by day).

In the MAED methodology, the load curves for various clients in different end-use sectors are constructed using electricity consumption by each client and load modulation coefficients. The load modulation coefficients for various sectors include the following: (a) seasonal coefficients representing the seasonal variation in electricity consumption; (b) daily coefficients accounting for relative weights of each day within the week and (c) hourly coefficients describing the hourly load variation behaviour of the sector.

In the following section, weekly and daily load modulating coefficients for the three economic sectors of industrial, service and household are presented graphically. The coefficients were obtained from half-hourly load profile data which was obtained from ESCOM. Profiles for feeders supplying industrial, household and commercial establishments were used as represented profiles for the three sectors. The feeders used were single feeders such that they may not be representative of all the clients within the economic sectors but were still considered reasonable in absence of detailed load profiles.

Figures 6.3(a), 6.4(a) and 6.5(a) show seasonal variation in electricity consumption for Industry, Service and Household sectors, respectively while Figures 6.3(b), 6.4(b) and 6.5(b) show relative weights of each day within the week. It can be seen from the Figures that there is not significant seasonal variations in all the sectors, except during weekends. This variation comes from the working pattern of the sugar industry which is one of the major consumers of electricity. During winter, the sugar industry crushes the sugarcane using its own electricity which is generated from bagasse. This reduces electricity demand from the national grid. The demand for electricity of the sugar industry picks up in post-winter when they begin to irrigate the sugarcane fields. On a weekly basis, the load pattern is almost the same. Demand levels are not significantly different. However, Sundays have got the lowest demand levels followed by Saturdays and peaks up during working days. The difference between Saturday and Sunday is due to some industries and service sector companies that work half day on Saturday and close down on Sunday.

NORMALISED LOAD

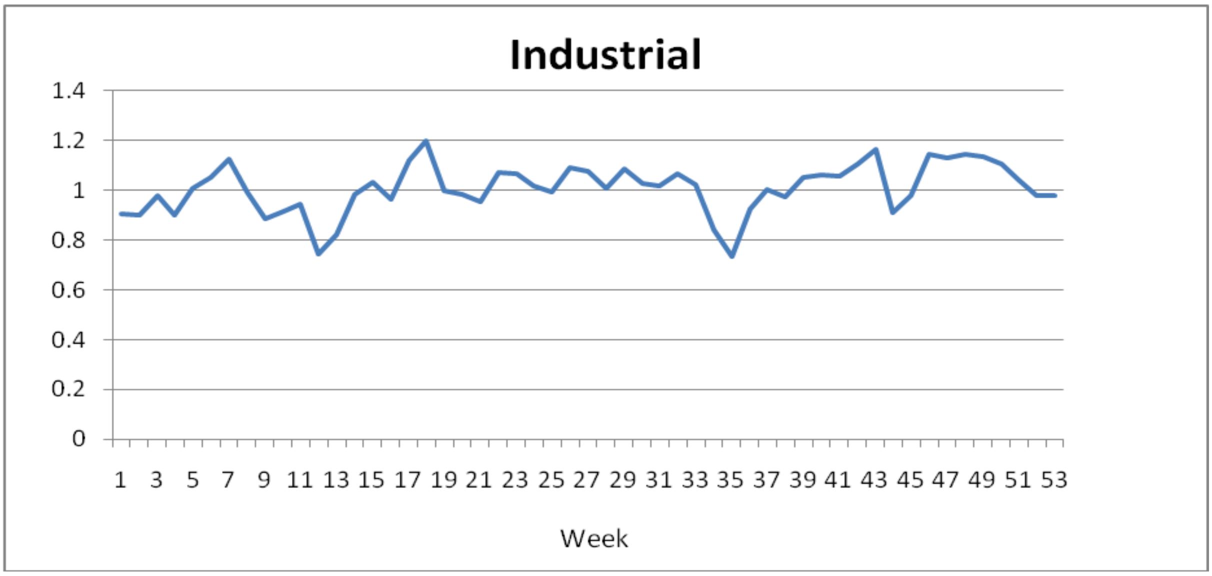


Figure 6.3(a): Seasonal Variation of Industrial Loads

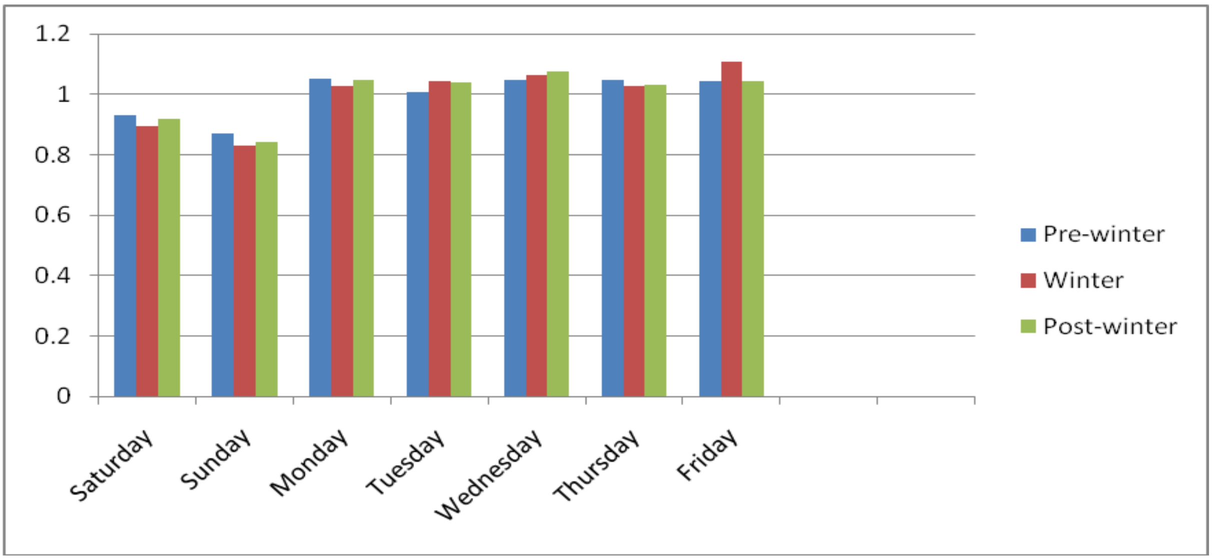


Figure 6.3(b): Relative Weights of Week Days for Industrial Loads

NORMALISED LOAD

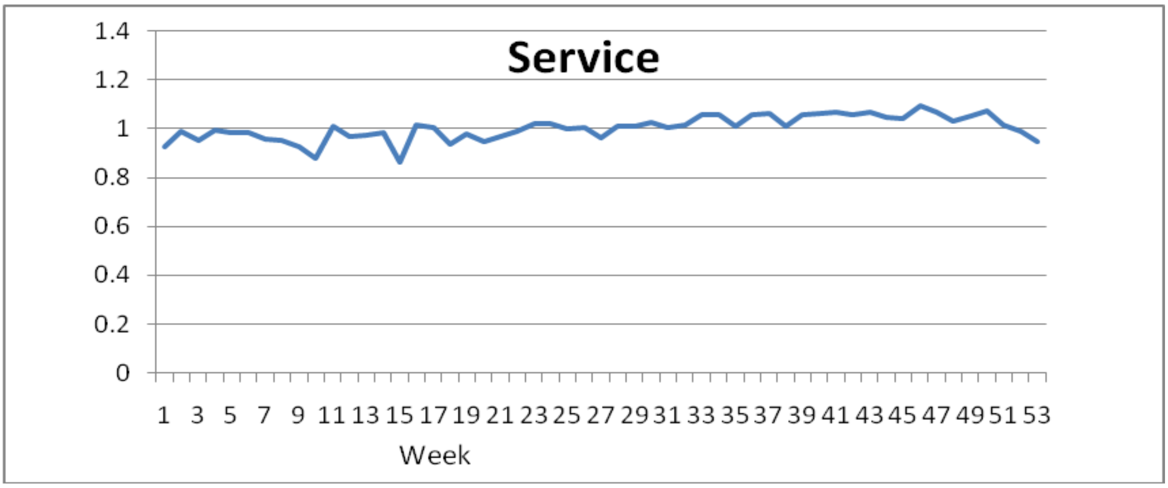


Figure 6.4(a): Seasonal Variation of Service Sector Loads

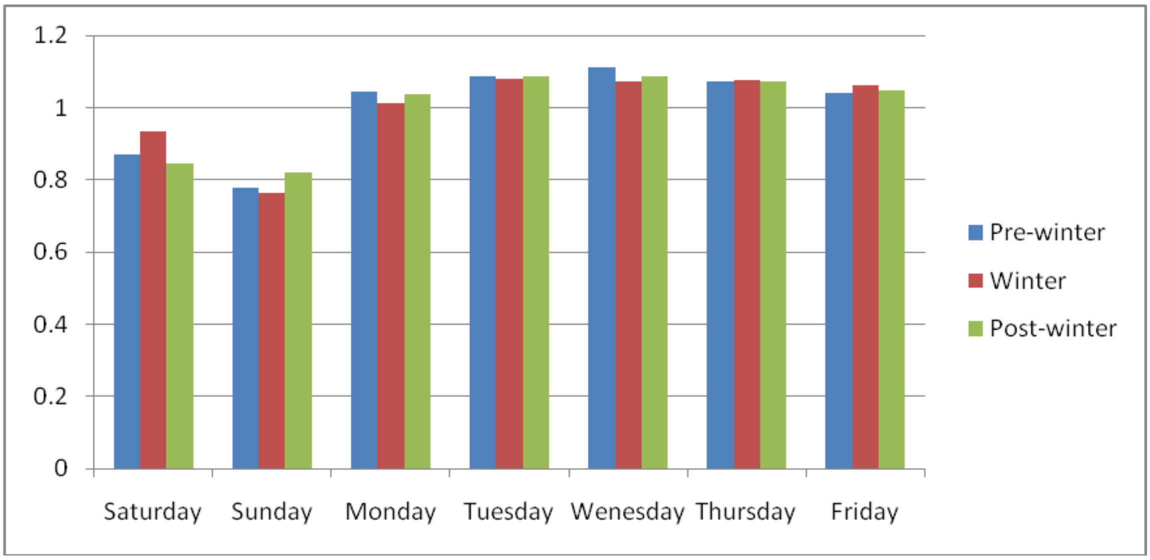


Figure 6.4(b): Relative Weights of Week Days for Service Sector Loads

NORMALISED LOAD

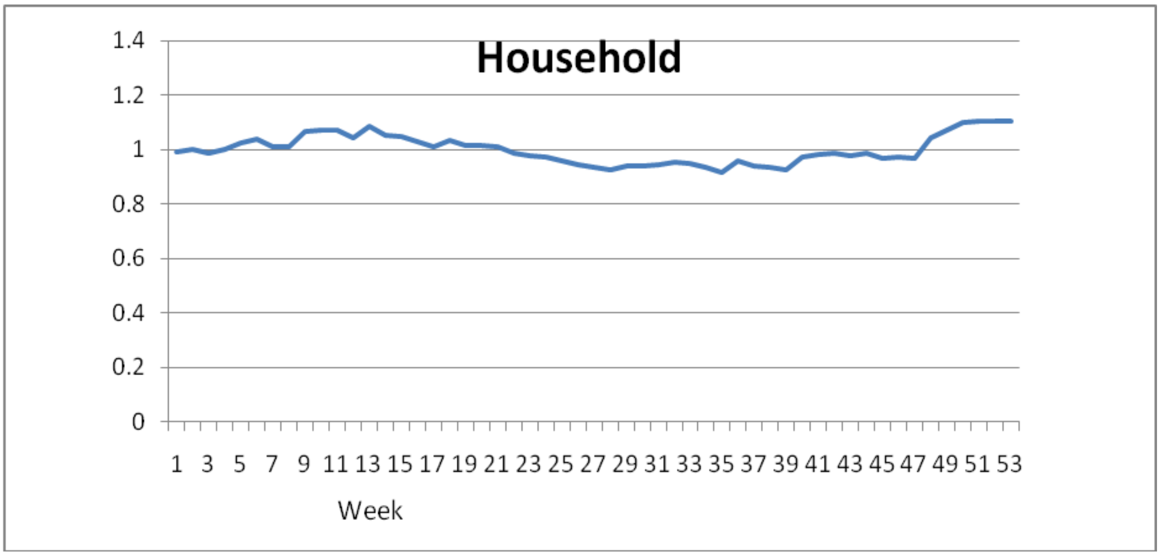


Figure 6.5(a): Seasonal Variation of Household Loads

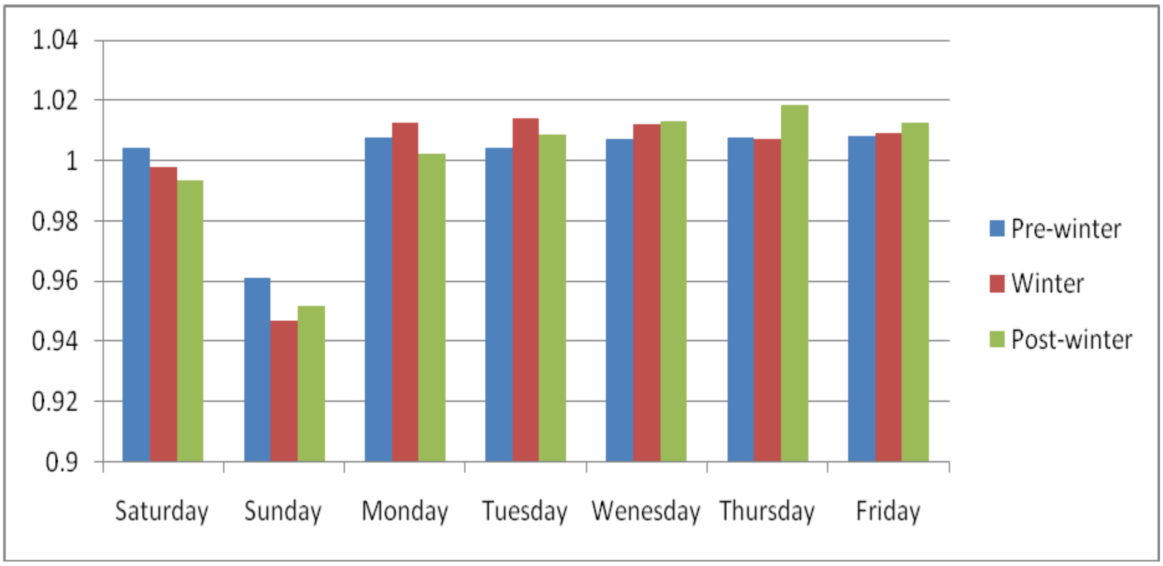


Figure 6.5(b): Relative Weights of Week Days for Service Household Loads

.

6.2.6. Hourly load coefficients by day for the sectors

Hourly coefficients for clients within the sectors of industry, service and household sectors were calculated for three representative days: Saturday, Sunday and a working day (which is an average of the five working days in a week). These coefficients define hourly load variations in a day.

Industrial Profile:

Figures 6.6(a), 6.6(b) and 6.6(c) show hourly load variations within the day for industrial loads for Saturday, Sunday and Working day respectively. Profiles depict very high load factors for industrial loads. For Saturday, there is a sustained peak in the morning hours from 0600 hours to 1300 hours owing to industries that work for a half-day on a single shift. Some peaks are observed at various other times in the afternoon and evening due to non-standard timings of some small-scale industries. Other industries operate three shifts such as water pumping industries. Demand is lower than on a working day but a bit higher especially in the morning hours than on a Sunday. However, there is no significant variation within the day in the three seasons.

Industries that operate on Sunday are three shift industries and therefore the profile for Sunday is flatter (see Figure 6.6(b). There is no significant variation within the day in the three seasons. Demand level is the lowest because most industries are closed on Sundays.

The consumption pattern is fairly constant within the working days i.e. Monday to Friday. There are two significant peaks, one in the morning and the other in the afternoon hours. These show that most industries operate during the day from 0600 hours to 1800 hours within the working days.

NORMALISED DAILY LOAD CURVES (INDUSTRY).

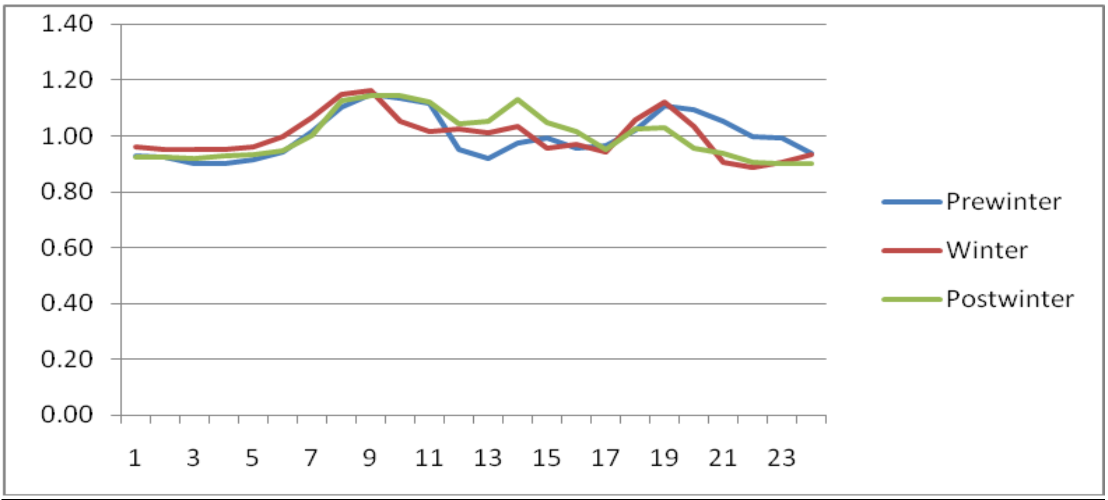


Figure 6.6(a): Industrial Hourly Load coefficients for Saturday

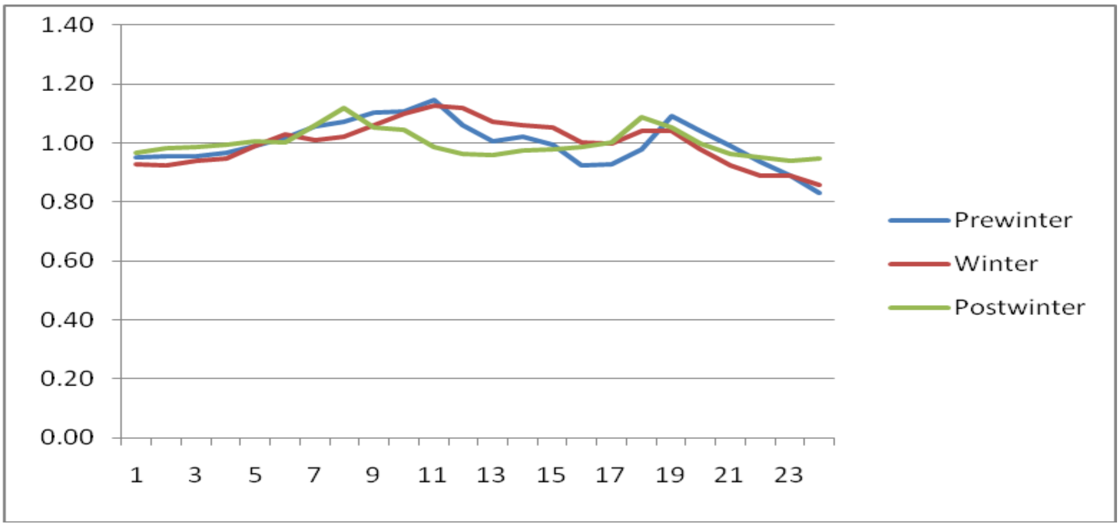


Figure 6.6(b): Industrial Hourly Load co-efficients for Sunday

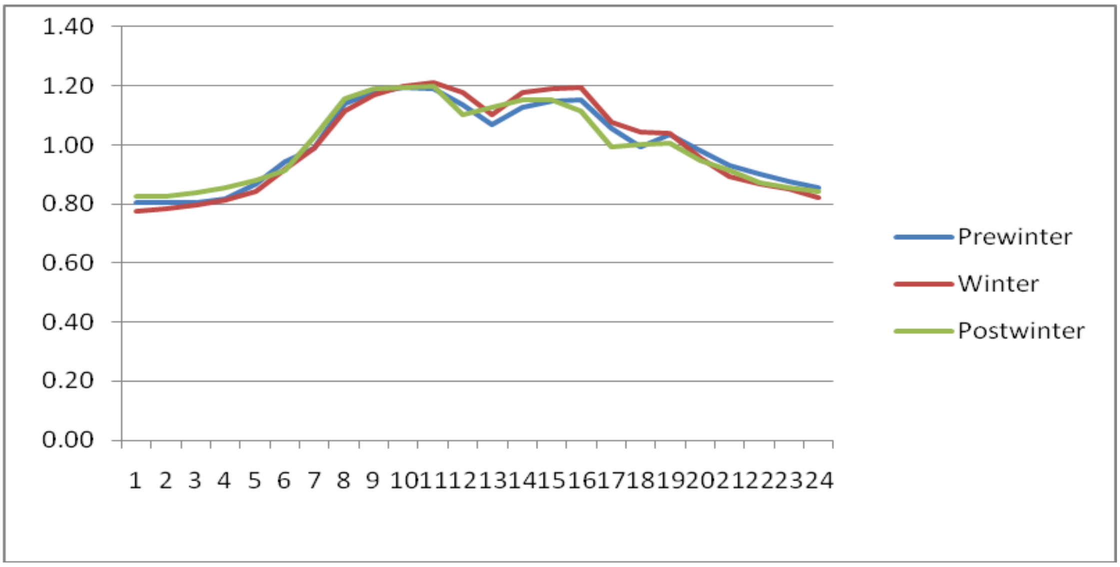


Figure 7.6(c): Industry Hourly Load co-efficients for a working day

Household Profile

Figures 6.7(a), 6.7(b) and 6.7(c) show normalised daily load curves for households.. There is a similar pattern of electricity use in households for all the seasons. However, there is a significant drop and delay on Saturday and Sunday mornings as compared to working days. The shapes depict domestic lifestyles and behaviour in Malawi. Two peaks are observed one in the morning and the other in the evening with the latter more pronounced and sharp. This shows low load factor.

NORMALISED DAILY LOAD CURVES (HOUSEHOLD)

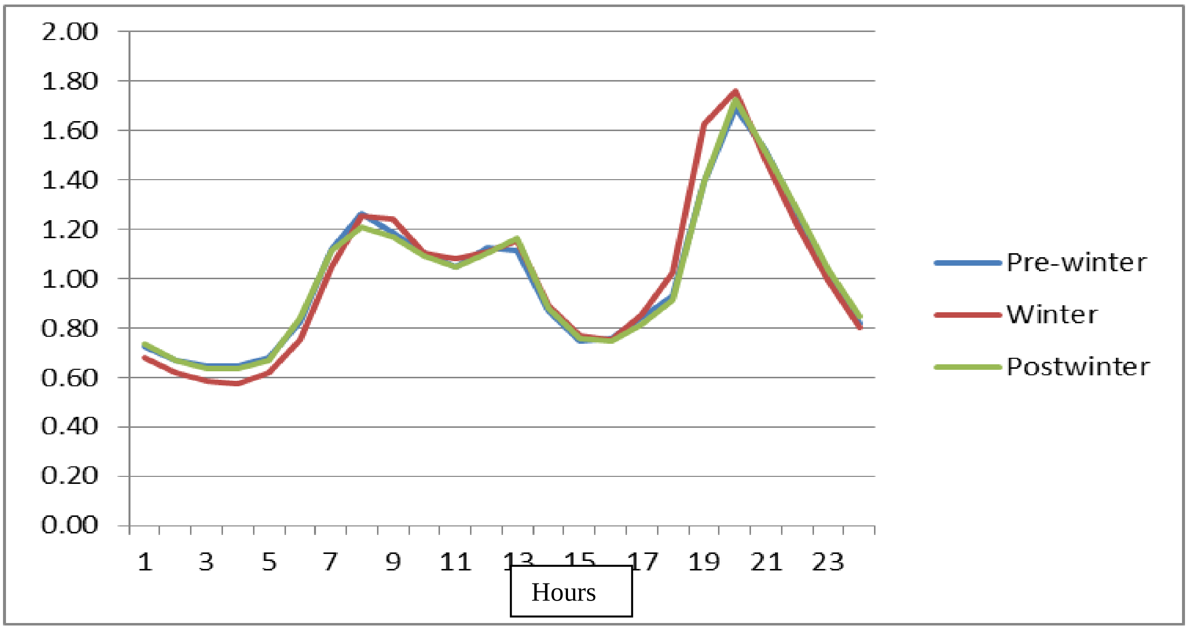


Figure 6.7(a): Domestic Hourly Load co-efficients for Saturday

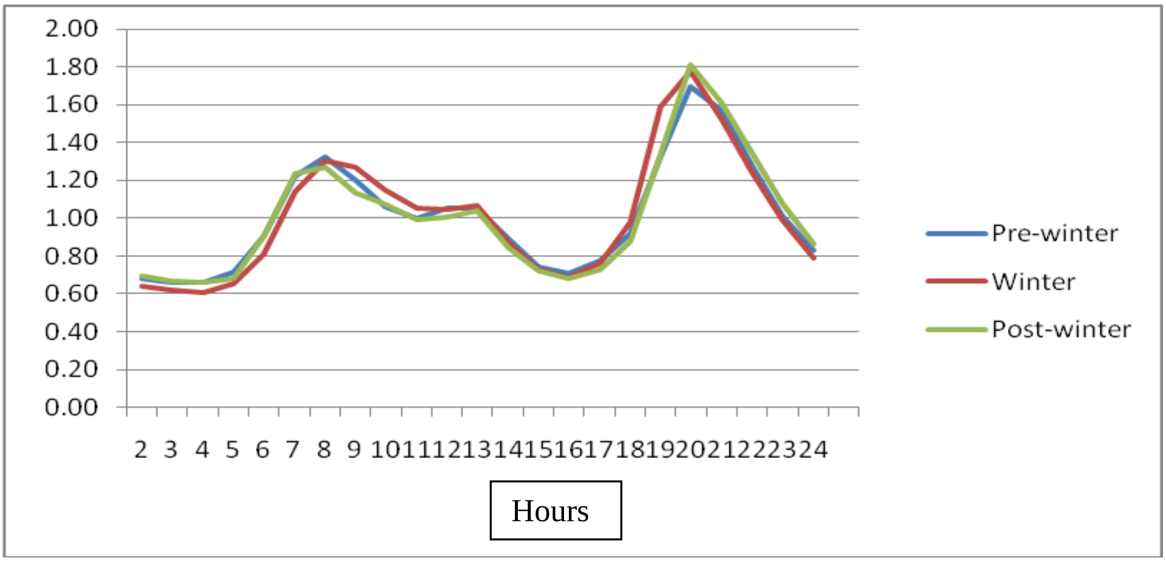


Figure 6.7(b): Domestic Hourly co-efficients for Sunday

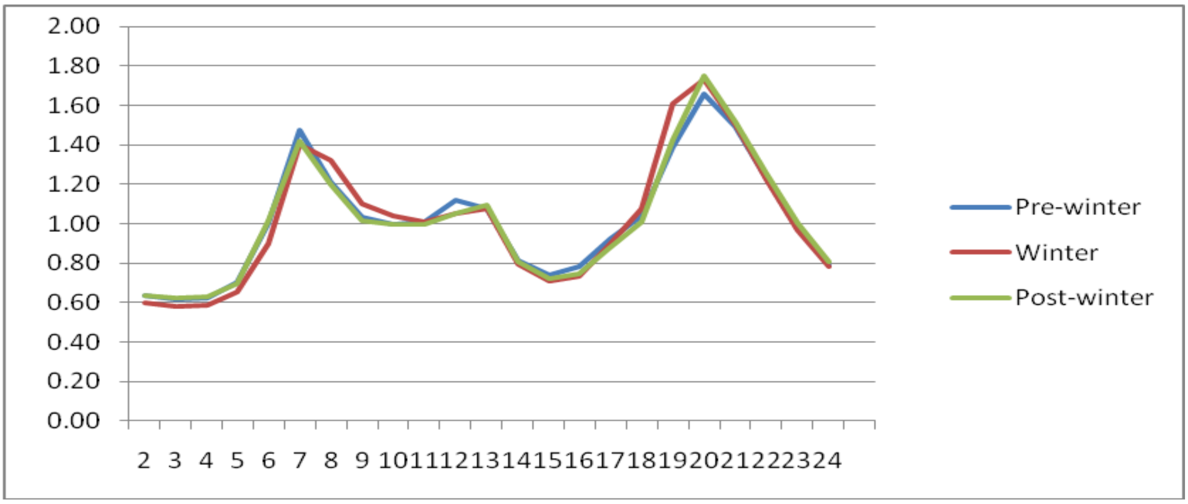


Figure 6.7(c): Domestic hourly co-efficients for a working day

Service

Figures 6.8(a), 6.8(b) and 6.8(c) show normalised daily load curves for the Service Sector.There are no significant differences in profile shapes for the service sector and the profiles show significant consumption during the day time (0600 hours to 1800 hours). The load factor is also significantly high.

NORMALISED DAILY LOAD CURVES (SEREVICE)

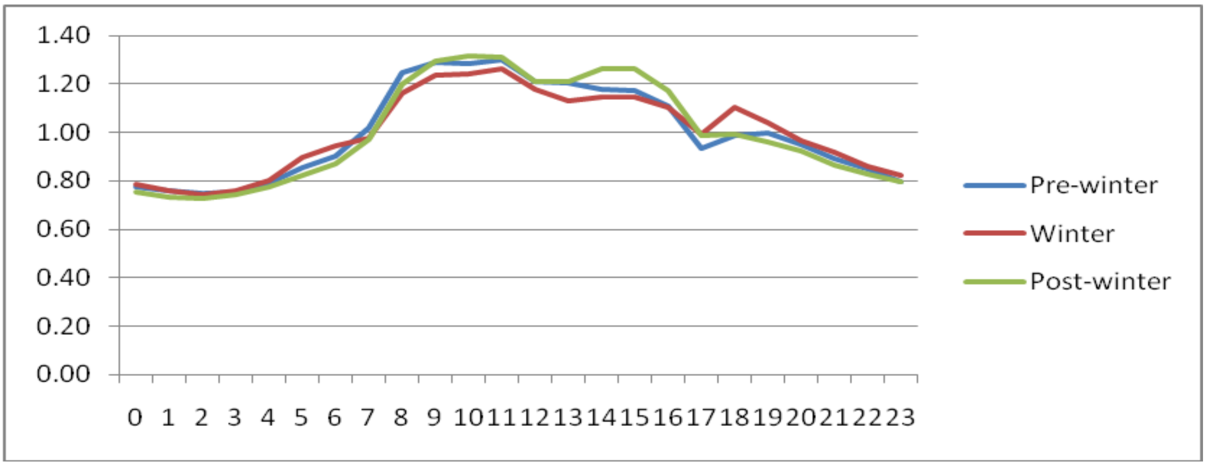


Figure 6.8(a): Hourly Load co-efficients for Saturday

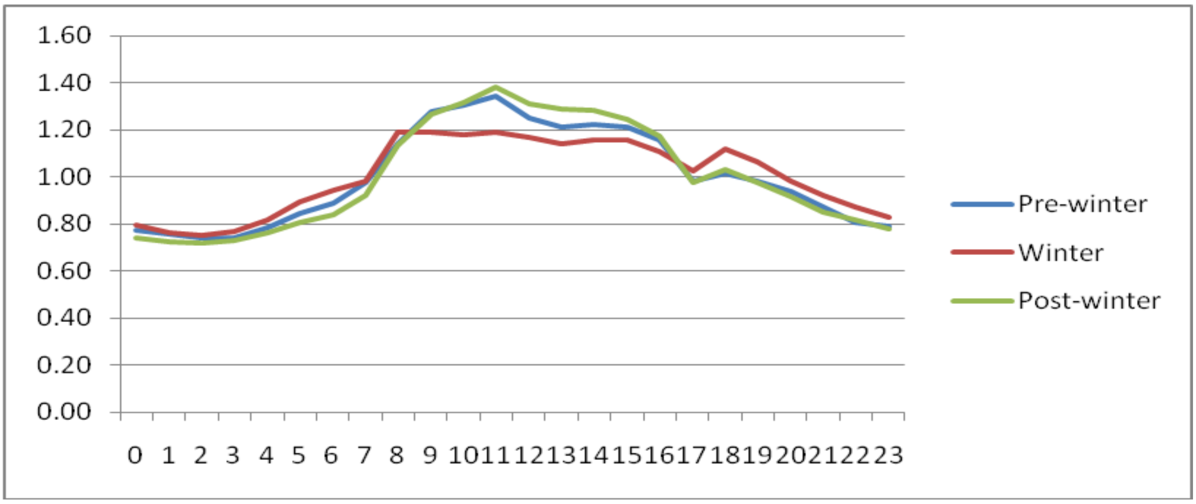


Figure 6.8(b): Hourly Load co-efficients for Sunday

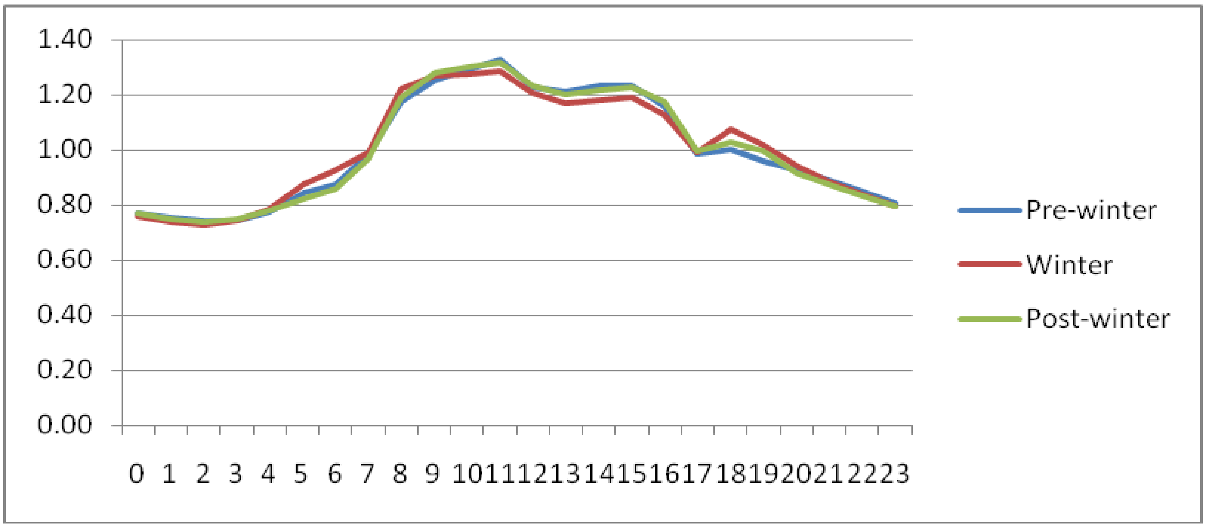


Figure 6.8(c): Hourly load co-efficients for a working day

6.3. Projection of electricity load patterns

6.3.1. Assumptions on the development of the electricity load patterns

The weekly, daily and hourly load modulating coefficients in all the three economic sectors considered in this study have been assumed to remain the same throughout the study period. The same coefficients have also been used in Reference, Accelerated and Moderate scenarios. However, it is recognised that some factors may influence the consumption patterns in future. For example, changes in weather patterns due to global warming and climate change may have impact on seasonal variations of electricity consumption by altering air-conditioning requirements (cooling and heating) in households and in commercial establishments. Prolonged drought conditions may also have an impact on irrigation requirements in Agriculture sector. Such changes cannot be accurately predicted in the long term as such they have not been incorporated.

The only change which has been made in the scenarios that will influence future load profiles is the contribution of various sectors in the future years. For example, load factors of various clients in the economic sectors are different. Households have lower load factors compared to Industry and Service sectors. Even within household sector, rural electrification loads have lower load factors than households in the middle and high-income range. This means that if household loads are growing at a faster rate than the other sectors, the system peak will tend to increase as compared to the scenario where industrial loads are growing faster.

System losses have been assumed to reduce from 21% in 2008 to 17.8% in 2020 and 15% in 2030. The same targets have been adopted in all the scenarios.

The other initiative which is being carried out by ESCOM to promote efficiency in the utilisation of electricity is DSM. This is done through the use of time-of-use tariffs to encourage industries to shift consumption from peak periods to off-peak periods, and through the promotion of energy efficient lighting devices. This initiative is expected to change the load consumption pattern in the future. However, this scenario has not been studied since its long-term impact is still uncertain.

6.3.2. Projections of the electricity load patterns

Table 6.3 shows shares of different sectors in total consumption. In the Reference Scenario, both the shares of Industry and Household grow, the latter growing from 38% in the base year to 45% in the final year while the former grows from 40% in the base year to 44% in the final year. The share of Industry in the Accelerated Scenario grows from 40% in the base year to 55% in the final year while that of Household decreases from 38% to 33%. In the Moderate Scenario, the share of Household increases from 38% in the base year to 56% in the final year while that of Industry decreases from 40% to 33%.

Table 6.3: Consumption shares by Client (%)

Scenario	Client	2008	2015	2020	2025	2030
Reference Scenario	Industry	40	37	39	42	44
	Household	38	48	48	46	45
	Service	22	15	13	12	11
Accelerated Scenario	Industry	40	41	45	50	55
	Household	38	44	41	38	33
	Service	22	15	14	12	12
Moderate Scenario	Industry	40	33	33	33	33
	Household	38	52	54	56	56
	Service	22	15	13	11	11

Using the load modulating coefficients as discussed in section 6.3.1, assumptions made on system losses, and sectoral shares as shown in Table 6.3, the projected system peak demand for all the scenarios is shown in Table 6.4 below.

Table 6.4: Projected Peak demand (MW)

YEAR	MODERATE SCENARIO	REFERENCE SCENARIO	ACCELERATED SCENARIO
2008	233	233	233
2015	700	740	789
2020	1257	1374	1532
2025	2141	2425	2847
2030	3622	4274	5352

In the Reference Scenario, the system peak demand increases from 233MW to 4274 MW in 2030 at an average growth rate of 14% per annum. For Accelerated Scenario, system peak demand increases from 233MW in 2008 to 5352MW in 2030 at an average growth rate of 15% per annum while in the Moderate Scenario, peak demand increases from 233MW in the base year to 3622MW in 2030 at an average growth rate of 13% per annum.

The system load factor decreases from 67.5% in the base year to 60.94%, 64.65% and 57.47% in Reference, Accelerated and Moderate scenarios respectively.

6.3.3 Composition of the National Load Curve.

Figure 6.9 shows a national load curve for a peak day in 2008(the base year) while figure 6.10 shows a projected national load curve for 2025. The load curve for 2025 has been plotted using assumptions made on load modulating factors and evolution of sectoral shares as presented in sections 6.3.1 and 6.3.2. The curves have been split into components corresponding to different sectoral demands as assumed in this study. The load curves show that the load pattern in Malawi has two peaks, one in the morning from 7am to around 12pm and the other, which is more pronounced, is in the evening from 5pm to around 9pm. It can been seen from the Figure 6.9 that the total system load curve follows the pattern of the household load curve because the household is the major consumer and has wide variations in its consumption pattern.

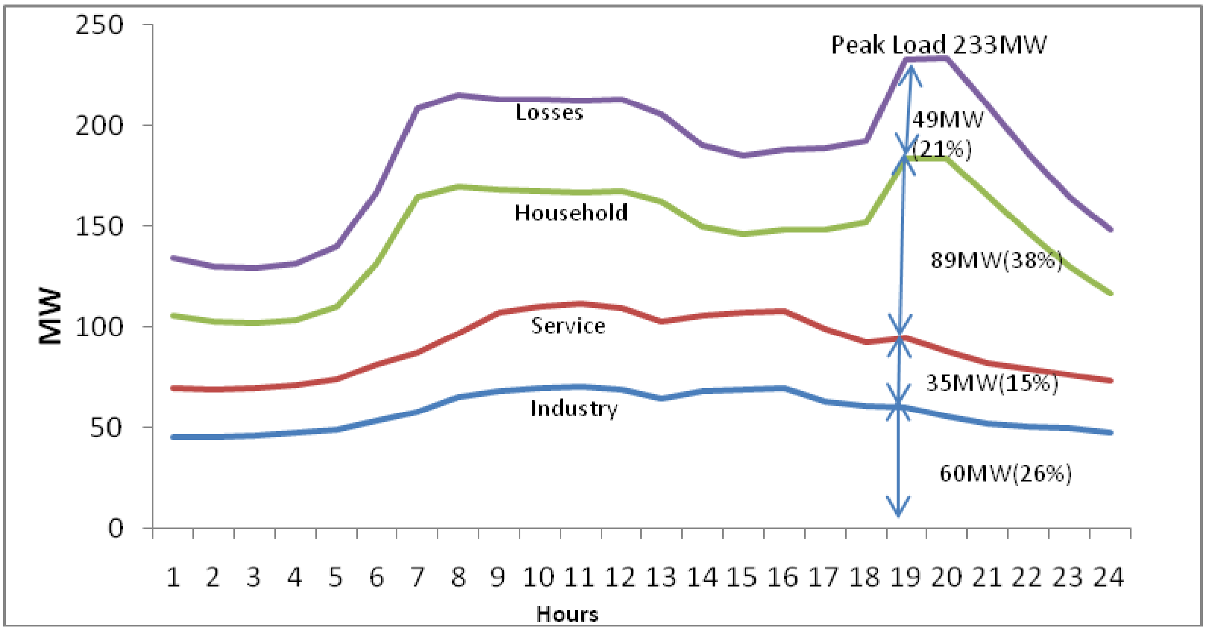


Figure 6.9: Sectoral Composition of The National Load Curve for 2008

The weekly, daily and hourly load modulating coefficients in all the three economic sectors considered in this study have been assumed to remain the same throughout the study period (see section 6.3.1). This means that the load pattern, as depicted in Figure 6.10, is the same as that of the base year. However, the load curve is expected to undergo some changes in the future due to changes in sectoral composition of energy demand. It can be seen from the load curves that the share of household load increases from 38% in the base year to 45% in 2025. This will lead to a declining load factor. The expected increase in air conditioning, mining and rural electrification loads will also have an effect on future load curves.

It is therefore necessary to do further analysis of sectoral as well as sub-sectoral load patterns to estimate power distribution of the different sectors for future years.

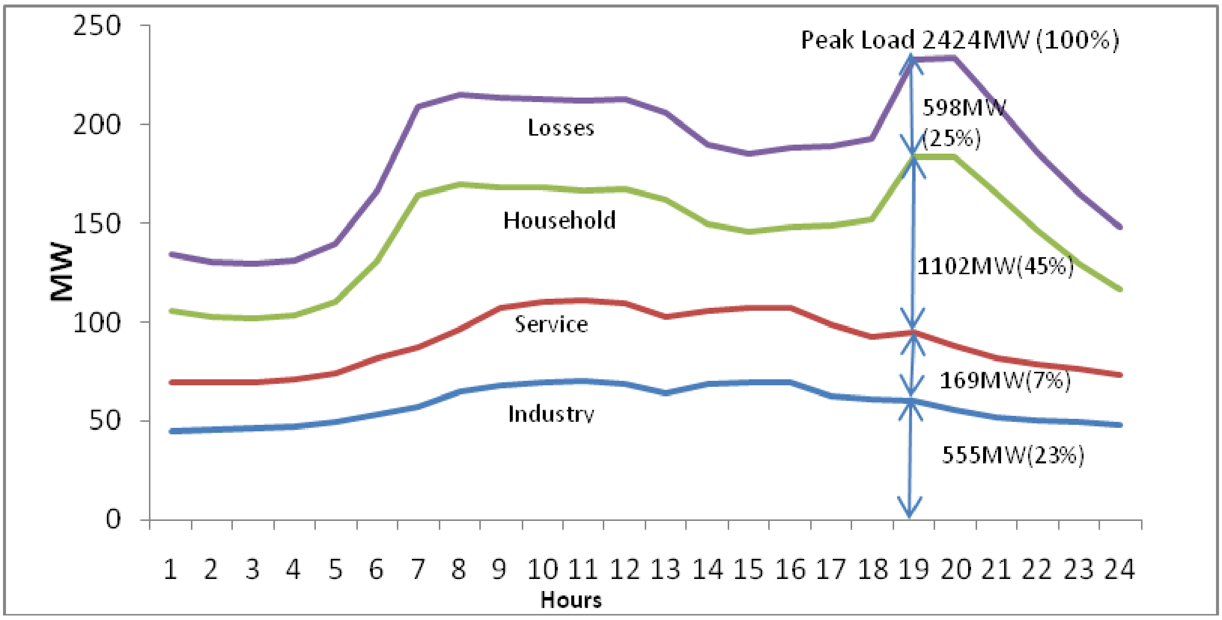


Figure 6.10: Sectoral Composition of the National Load Curve for 2025

Chapter 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

The Energy Demand Assessment for Malawi was conducted by a Working Team constituted by the Ministry of Natural Resources, Energy and Environment through the Department of Energy Affairs (see Appendix A). The Working Team was comprised of experts drawn from various institutions in the country. The International Atomic Energy Agency (IAEA) offered technical assistance to the Working Team. Funding for the study was provided by the United Nations Development Programme and the Malawi Government through the Ministry of Natural Resources, Energy and Environment.

The study analysed the entire energy system in Malawi in 2008 (the base year) and its progression in future years up to 2030, and is the first of its kind in the country. Two IAEA models were used in the study, namely MAED-D and MAED –El to assess the entire energy demand system and electricity demand respectively. It is hoped that the Working Team will continue using the models to update the energy demand for the country. The results of the study will be useful for energy planning in the country by both Government and various stakeholders.

The calculations in this study have shown that the electricity peak demand is expected to grow by 13%, 14% and 15% in the Moderate, Reference and Accelerated scenarios respectively. The analysis has also shown that the shares of the various end-use categories have a significant impact on the system load pattern i.e. load factor.

7.1. Major tasks accomplished

The Working Team collected all the necessary data for inputting into the models, run the models out of which results were generated. The results were analysed, and a Country Report on Energy Demand Assessment for Malawi was prepared. To accomplish this work, three (3) training sessions facilitated by IAEA Mission Experts were conducted. Additionally, the Working Team met several times to work on the model and the report. In order to have a peer review of the work, a national stakeholders' workshop was conducted. The drafted report was subjected to IAEA review process through a fellowship programme in Vienna, Austria which was attended by some of the Working Team members. This report, therefore, has taken into consideration comments from the workshop and IAEA experts.

7.2 Main problems encountered and recommendations

In conducting this study, the Working Team met two major challenges. The first challenge was related to data availability. The model required data in a specific format which in some cases was not in a way some institutions store their data. In some cases, data was not available which meant that the Team had to collect the required data during the limited time of the study period.

The second major challenge was time availability for the Working Team who were combining energy demand assessment work with their day to day responsibilities in their respective institutions. This meant that, at times, it was difficult to meet deadlines for some tasks as required by the study programme.

It is recommended that the data collection process should be institutionalised within the National Statistical Office which has the mandate of collecting data in the country. In addition to this, a data collection template should be developed by the Ministry of Natural Resources, Energy and Environment through the Department of Energy Affairs (DoE) and provided to relevant institutions which can assist in data collection.

There is need to have officers within DoE who would be working continuously on this work. The study should be reviewed every two years to consider new developments in the energy sector.

It is recommended that a further study should be conducted on sectoral and sub-sectoral electricity demand to gain more understanding on the consumption pattern. For instance, there is need to study electricity consumption in service, household, manufacturing, agriculture and mining sectors and sub-sectors.

It is also recommended that detailed profile data for various end-use categories should be collected. This data could help improve the projection of system peak demand and load patterns. It is further recommended that in the next update, a scenario of energy efficiency should be studied. This could help in understanding the savings that could be made in investment costs while delivering the same energy requirements.

7.3 Main policy recommendations from the study

This study has shown that energy demand is growing faster than the supply. It is therefore, recommended that the following measures should be undertaken to contain the demand:

- Efficient use of energy and electricity should be promoted through fiscal and regulatory measures. This should include promotion of the use of energy efficient bulbs and appliances in both major consumers and the general public. The Government should ban importation, manufacturing and use of inefficient appliances. In addition to this, labelling of appliances should be mandatory and monitored by Malawi Energy Regulatory Authority (MERA) and Malawi Bureau of Standards (MBS). MERA should also promote time-of-use tariffs. Smart grid infrastructure should be developed and installed to manage electricity demand. Power utilities should implement measures to reduce technical and non-technical electricity losses.

- The study has shown that in the foreseeable future, biomass energy will continue to dominate the energy mix of the country which is not acceptable. The use of biomass has adverse environmental impacts. It is therefore recommended that the country should promote use of modern energy sources such as liquefied petroleum gas (LPG), electricity, biofuels etc.

- Concerted efforts should be made to explore and develop additional local energy resources such as coal, hydropower and renewable energy. Exploration of hydro carbons should be undertaken urgently to reduce dependency on imported petroleum products. Efforts to plan for the development of nuclear power generation should start as soon as possible.

- The Government should promote both local and foreign private investment in the energy sector to ensure efficiency and effectiveness in energy supply. Potential areas for investment include hydropower generation, coal-fired power generation, wind power, solar, geothermal, biofuels, biomass-based power generation etc.

References

1. International Atomic Energy Agency Reports, 2009. *Draft Burkina Faso Energy Demand Assessment*
2. International Atomic Energy Agency Reports, 2009. *Draft Kenya Energy Demand Assessment*
3. Malawi Government, 2009. *Annual Economic Report*, Lilongwe, Malawi
4. Malawi Government, 1996. *Environmental Policy*, Lilongwe, Malawi
5. Malawi Government, *Forestry Policy*, 1997, Lilongwe, Malawi
6. Malawi Government, *Malawi Biomass Energy Strategy*, 2009, Lilongwe, Malawi
7. Malawi Government, *Malawi Growth and Development Strategy*, 2005, Lilongwe, Malawi
8. Malawi Government, *National Energy Policy*, 2003, Lilongwe, Malawi
9. Malawi Government, *Population and Housing Census 2008 Main Report*, 2009, Zomba, Malawi

Appendix A

LIST OF OFFICERS THAT PARTICIPATED IN THE STUDY

This Appendix contains a list of offices from various institutions that participated in the MAED and MAED-El study.

- Mr. L.B. Mhango - Department of Energy Affairs; Project Counterpart.
- Mr. J. Kalowekamo - Department of Energy Affairs
- Mr. W. Silema - Department of Energy Affairs
- Mr. E. Dikiya - Department of Energy Affairs
- Mr. J. Namalima - Ministry of Natural Resources, Energy and Environment
- Mr. Y. Chawanje - Ministry of Natural Resources, Energy and Environment
- Dr. D. Kabambe - Ministry of Development Planning and Cooperation
- Mr. A. Sambani - Ministry of Transport and Public Works
- Mr. W. Chigamba – Department of Mines
- Mr. N. Banda – Geological Surveys Department
- Mr. A Mphonda – National Statistical Office
- Mr. W. Kasakula – Malawi Energy Regulatory Authority
- Mrs. H. Chiwaula – Malawi Energy Regulatory Authority
- Mr. M. Mulimakwenda – Electricity Supply Corporation of Malawi Limited
- Mr. L. Hauli – Electricity Supply Corporation of Malawi Limited
- Mr. K. Gondwe – Mzuzu University
- Mr. C. Kachimanga – Livingstonia University
- Mr. G. Salima - University of Malawi, The Malawi Polytechnic
- Mr. R. Saopa- Centre for Community Development and Empowerment, and
- Mr. H. Nangwale - Petroleum Importers Limited

Appendix B

CONVERSION TABLE

Conversion factors:			name:	= MJ_CFG													
	to -->	example: 1MJ		9.48E-01	CFG												
from	CFG	MJ	TCE	cub m	btu	TOE	boe	kWh	Kwyr	kcal	TJ	Gcal	MTOE	Mbtu	GWh	GWyr	PJ
CFG	1	1.055	3.6E-05	0.028317	1000	2.52E-05	0.000185	0.293056	3.35E-05	251.9824	1.06E-06	0.000252	2.52E-11	0.001	2.93E-07	3.35E-11	1.06E-09
MJ	0.947867	1	3.41E-05	0.026841	947.8673	2.39E-05	0.000175	0.277778	3.17E-05	238.8459	0.000001	0.000239	2.39E-11	0.000948	2.78E-07	3.17E-11	1E-09
TCE	27779.72	29307.6	1	786.6339	27779716	0.7	5.131	8141	0.929338	7000000	0.029308	7	7E-07	27.77972	0.008141	9.29E-07	2.93E-05
cubm	35.31467	37.25697	0.001271	1	35314.67	0.00089	0.006523	10.34916	0.001181	8898.675	3.73E-05	0.008899	8.9E-10	0.035315	1.03E-05	1.18E-09	3.73E-08
btu	0.001	0.001055	3.6E-08	2.83E-05	1	2.52E-08	1.85E-07	0.000293	3.35E-08	0.251982	1.06E-09	2.52E-07	2.52E-14	0.000001	2.93E-10	3.35E-14	1.06E-12
TOE	39685.31	41868	1.428571	1123.763	39685308	1	7.33	11630	1.327626	10000000	0.041868	10	0.000001	39.68531	0.01163	1.33E-06	4.19E-05
boe	5414.094	5711.869	0.194894	153.3101	5414094	0.136426	1	1586.63	0.181122	1364256	0.005712	1.364256	1.36E-07	5.414094	0.001587	1.81E-07	5.71E-06
kWh	3.412322	3.6	0.000123	0.096626	3412.322	8.6E-05	0.00063	1	0.000114	859.8452	3.6E-06	0.00086	8.6E-11	0.003412	0.000001	1.14E-10	3.6E-09
kwyr	29891.94	31536	1.076035	846.4456	29891943	0.753224	5.521135	8760	1	7532244	0.031536	7.532244	7.53E-07	29.89194	0.00876	0.000001	3.15E-05
kcal	0.003969	0.004187	1.43E-07	0.000112	3.968531	1E-07	7.33E-07	0.001163	1.33E-07	1	4.19E-09	0.000001	1E-13	3.97E-06	1.16E-09	1.33E-13	4.19E-12
TJ	947867.3	1000000	34.12084	26840.61	9.48E+08	23.88459	175.074	277777.8	31.70979	2.39E+08	1	238.8459	2.39E-05	947.8673	0.277778	3.17E-05	0.001
Gcal	3968.531	4186.8	0.142857	112.3763	3968531	0.1	0.733	1163	0.132763	1000000	0.004187	1	1E-07	3.968531	0.001163	1.33E-07	4.19E-06
MTOE	3.97E+10	4.19E+10	1428571	1.12E+09	3.97E+13	1000000	7330000	1.16E+10	1327626	1E+13	41868	10000000	1	39685308	11630	1.327626	41.868
Mbtu	1000	1055	0.035997	28.31685	1000000	0.025198	0.184703	293.0556	0.033454	251982.4	0.001055	0.251982	2.52E-08	1	0.000293	3.35E-08	1.06E-06
GWh	3412322	3600000	122.835	96626.21	3.41E+09	85.98452	630.2666	1000000	114.1553	8.6E+08	3.6	859.8452	8.6E-05	3412.322	1	0.000114	0.0036
GWyr	2.99E+10	3.15E+10	1076035	8.46E+08	2.99E+13	753224.4	5521135	8.76E+09	1000000	7.53E+12	31536	7532244	0.753224	29891943	8760	1	31.536
PJ	9.48E+08	1E+09	34120.84	26840613	9.48E+11	23884.59	175074	2.78E+08	31709.79	2.39E+11	1000	238845.9	0.023885	947867.3	277.7778	0.03171	1

Appendix C

CALCULATION OF TOTAL PASSENGER –KM FOR INTERCITY AND INTRACITY

a) Intercity passenger activity:

Total intercity passenger activity = Total population * Average annual distance travelled by each person

Average annual distance travelled by each person

= Total intercity passenger activity ÷ Total population

= $3.76 * 10^9$ passenger-km (*Table 5.16*) ÷ $13.08 * 10^6$

= 287.46km/person/year

Average daily distance travelled by each person

= 287.461km/person/365 days

= 0.79km/person/day

b) Intracity passenger activity:

Total urban passenger activity = Urban population * Average distance travelled every day by each person in urban area * 365 days.

Average distance travelled every day by each person in urban area

= Total urban passenger activity ÷Urban population ÷ 365 days

= $5.3 * 10^9$ passenger-km (*Table 5.17*) ÷ $1.56 * 10^6$ persons ÷ 365 days

= 9.32 km/persons/day