Dissertation

National Energy Demand Projections and Analysis of Nepal

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines Doktors der technischen Wissenschaften unter der Leitung von

Univ. Prof. Dr.- Ing. Christian Bauer

E302

Institut für Energietechnik und Thermodynamik

eingereicht an der Technischen Universität Wien

Fakultät für Maschinenwesen und Betriebswissenschaften

von

Nawraj Bhattarai, M.Sc.

e1129963

1200 Wien, Brigittenauer Lände 6648

Wien, im März 2015

Acknowledgement

I am sincerely grateful to Univ. Prof. Dr.-Ing. Christian Bauer for supervising this dissertation as well as providing all kinds of support needed during my study in Vienna, Austria. Without his proper guidance, support and encouragement; this study could not have been materialized. Similarly I am greatly thankful to Ass. Prof. Dr. Eduard Doujak for his continuous supports and encouragements during the study. Likewise, I am greatly pleased to Univ. Prof. Dr.-Ing. Wolfgang Gawlik, Institut für Energiesysteme und Elektrische Antriebe for being the external reviewer of this dissertation. I am also thankful to Prof. Dr. Tri Ratna Bajracharya, Institute of Engineering, Tribhuvan University for providing continuous academic as well as moral supports during the study.

I extend my deep gratitude to Austrian Partnership Programme in Higher Education and Research for Development (appear) for providing me financial support for my study in Austria. Similarly, I would like to express my appreciation to all friends in TU-Wien, Vienna, Austria and in Nepal for their continuous supports and encouragements.

Likewise, special gratitude goes to Tribhuvan University of Nepal, for providing me study leave for this research. Further, special thanks go to Prof. Dr. J.R. Pokharel, Prof. Dr. G.R. Pokharel, Prof. Dr. B.B. Ale, Prof. Dr. J.N. Shrestha, Prof. A.M. Nakarmi, Prof. R. C. Sapkota, Dr. R. Shrestha, Mr. M.C.Luitel, Mr. R.P. Singh, Mr. H. Darlami, Mr. I. Bajracharya, Mr. R.P. Dhital, Mr. S. Sapkota, Mr. N.R. Dhakal, Mr.R.B.Thapa, Mr. M. Ghimire, Mr. P. Aryal, Mr. N. Aryal, Mr. K.Gawali, Ms. M. Manandhar, and Mrs. K. Gautam for providing various kinds of supports during this research. Their kind supports are greatly appreciated.

Finally, I would like to thank and express my deep love to my wife Deewa who supported me in every moment of my life and without her continuous encouragement and support; I would perhaps be impossible for me to complete the study. Similarly, I am greatly thankful to my parents, my son Shaarav, daughter Saanvi, brothers, sisters, and all relatives for their continuous encouragements and supports during my study. At last but not the least, special thanks also goes to sister in law Mrs. T. Pokharel and brother in law Mr. D.R. Dahal for their continuous effort in grammatical corrections of the dissertation.

Kurzfassung

Eine realistische Prognose des Energiebedarfs ist eine Voraussetzung für nachhaltige Nutzung der heimischen Energieressourcen eines Landes. Das Ziel dieser Studie ist es, den langfristigen Energiebedarf Nepals zu analysieren und Prognosen für dessen zukünftigen Verlauf zu erstellen. In dieser Studie wird das Energiebedarfsmodell in Sektoren unterteilt und die verfügbaren Informationen über den Energieverbrauch des Landes einbezogen. Zur Ermittlung des künftigen Energiebedarfs wurden vier jährliche Wachstumsszenarien der Nationalwirtschaft, sowie ein immer wechselndes demographisches Bild herangezogen. Aus diesen Szenarien wurde das Mittelwachstumsszenario ausgesucht um politische Eingriffe bei dem Wohn- und Industriesektor des Landes anzunehmen.

Die Studienergebnisse zeigen, dass bei den projektierten Szenarien im Wohnsektor die Energienachfrage am Meisten ansteigen wird, gefolgt vom Transport-, Gewerbe-, Industrie-, Agrar- und Restsektor. In allen untersuchten Szenarien zeigt sich, dass die Nachfrage nach fester Biomasse abnimmt während die Nachfrage nach Erdölprodukten, Strom, Kohle und Biogas ansteigen wird. Von allen Energieformen wird die Preiserhöhungsrate der Erdölprodukte am höchstens sein, gefolgt von jener des Stroms, des Biogases beziehungsweise der Kohle. Ebenfalls wurde beobachtet, dass die Nachfrage nach fester Biomasse für das höchste Wachstumsszenario rascher absinkt als in den anderen Wachstumsszenarien.

Die projizierten nationalen Energieindikatoren wie zum Beispiel der Pro-Kopf Stromverbrauch, der Pro-Kopf Energieverbrauch, der Teil des regionalen Energieverbrauchs und der strukturelle Teil des immer ansteigenden Kraftstoffkonsums sind wichtige Faktoren zum Planen und Vergleichen der heimischen Energieressourcen eines Landes. Wenn das obengenannte Strategieszenario im Wohnsektor eintritt, würde dies zu einem jährlich signifikant ansteigenden Energiebedarf führen. Die Studie des Industriebereichs hat ergeben, dass durch strategische Maßnahmen eine beträchtliche Menge an Energie eingespart werden kann.

Abstract

A reliable future energy demand projection is a prerequisite condition for sustainable utilization of local energy resources of a country. The purpose of this study is to project and analyze the long term national energy demands of the country - Nepal. In this study, sector wise nation's energy demand model has been developed by incorporating available energy consumptions information of the country. For capturing the future energy demands, this study has considered four annual growth scenarios of national economy along with changing demographic situations of the country. Among the selected growth scenarios, the medium growth scenario has been selected for further policy interventions on the residential and industrial sectors of the country.

The finding from this research provides the evidence that in all of the projected scenarios, residential sector will be the main energy demanding sector, followed by transport, industrial, commercial, agricultural and others respectively. In coming years, the share of national demand of solid biomass will be decreased, while the demanding shares of petroleum products, electricity, coal and biogas will be increased in all of the projected scenarios. Among the fuels, the growth rates of the petroleum products will be the highest, followed by electricity, biogas and coal. It has also been observed that for the highest growth scenario, the demand of solid biomass will be decreased more rapidly in comparison with the other growth scenarios.

The projected national level energy indicators like per capita electricity consumption, per capita total energy consumption, shares of sectoral energy demand and structure of demanding fuels shares will be the useful parameters for comparing and planning of local energy resources of the country. If the mentioned policy scenario on the residential sector will be followed then annually, a significant amount of reliable local electricity demand will be generated within the country. Similarly, in the industrial sector, the study has also figured out that the quantities of energy can be saved through the implementation of the suggested sectoral policy measures of the country.

Acronyms and Abbreviations

AAGR	:	Annual Average Growth Rate
AEPC	:	Alternative Energy Promotion Centre
AIM	:	Asia-Pacific Integrated Energy Model
ATF	:	Aviation Turbine Fuel
BA	:	Business as Usual
CBS	:	Centre Bureau of Statistics
CDR	:	Central Development Region
CH	:	Central Hill
CM	:	Central Mountain
CT	:	Central Terai
EDR	:	Eastern Development Region
EFOM	:	Energy Flow Optimization Model
EH	:	Eastern Hill
EI	:	Energy Intensity
EM	:	Eastern Mountain
ENPEP	:	Energy and Power Evaluation Program
ET	:	Eastern Terai
FSU	:	Former Soviet Union
FSU	:	Former Soviet Union
FWDR	:	Far Western Development Region
FWH	:	Far Western Hill
FWM	:	Far Western Mountain
FWT	:	Far Western Terai
GDP	:	Gross Domestic Product
GHG	:	Green House Gas
HDV	:	Heavy Duty Vehicle
HG	:	High Growth
IAEA	:	International Atomic Energy Agency
IIASA	:	International Institute for Applied Systems Analysis
IVA	:	Industrial Value Added
LDV	:	Light Duty Vehicle
LEAP	:	Long Range Energy Alternative Planning
LG	:	Low Growth

LPG	:	Liquefied Petroleum Gas
MADE	:	Model for Analysis of Energy Demand
MADEE	:	Modele d’Evolution de la Demande d’energie
MARKAL	:	MARKet ALlocation
MESAP	:	Modular Energy System Analysis and Planning
MESSAGE	:	Model for Energy Supply Strategy Alternative and their General Environmental Impact
MG	:	Medium Growth
MIS	:	Macroeconomic Information System
MOEV	:	Ministry of Environment
Mote	:	Million tons of oil equivalents
MWDR	:	Mid Western Development Region
MWH	:	Mid Western Hill
MWM	:	Mid Western Mountain
MWT	:	Mid Western Terai
NCL	:	Nepal Coal Limited
NEA	:	Nepal Electricity Authority
NLSS	:	Nepal Living Standard Survey
NOC	:	Nepal Oil Corporation
NRB	:	Nepal Rastra Bank
NRs	:	Nepali Rupees
OPEC	:	Organization of the Petroleum Exporting Countries
RE	:	Renewable Energy
SSVA	:	Service Sector Value Added
USA	:	United State of America
WASP	:	Wien Automatic System Planning
WB	:	World Bank
WDR	:	Western Development Region
WECS	:	Water and Energy Commission Secretariat
WH	:	Western Hill
WM	:	Western Mountain
WT	:	Western Terai

Nomenclatures

A_b	:	Activity level
b	:	Branch
b′	:	Parent of branch b
b″	:	Grandparent of branch b
D	:	Energy demand
E	:	Fuel economy
EI	:	Energy intensity
i	:	Vehicle type
j	:	Fuel type
k	:	Age of vehicle
P	:	Probability
R	:	Number of soled vehicle
s	:	Scenario
S	:	Survival rate of vehicle
T	:	Characteristics service life of vehicle
t	:	Year
TA	:	Total activity
V	:	Total number of actually plying vehicle
VKT	:	Annual average distance travelled
α,β	:	Failure steepness

Table of Contents

Acknowledgement……………………………………………………………………..ii

Kurzfassung…………………………………………………………………...iii

Abstract………………………………………………………………….......iv

Acronyms and Abbreviations..v

Nomenclatures…………………………………………………………….vii

1. Chapter 1: Introduction……………………………………………..…....1

1.1. Background……………………...………………………….…………1

1.1.1. Energy Security….……………..……………………….…………...3

1.1.2. National Energy Consumption and Policy Overview of Nepal………..4

1.2. Problem Statement…………………………………………..….……..7

1.3. Motivation for the Study………………………………………...….……8

1.4. Objectives of the Study…………….………………………………….....10

1.5. Scope of the Study……………………………………………………….....10

1.6. Structure of the Dissertation…………………………………………..…...11

2. Chapter 2: Energy Situation in Nepal…………………………………......12

2.1. Country Information………………...…………………………………...12

2.2. Energy Consumption Scenario of the Country…..……………………….…13

2.2.1. Energy Consumption in Residential Sector…………….…………..15

2.2.2. Energy Consumption in Industrial Sector……………..……………. .19

2.2.3. Energy Consumption in Transport Sector….……………………….....19

2.2.4. Energy Consumption in Commercial Sector………..………………...20

2.2.5. Energy Consumption in Agriculture Sector…………………………...20

2.2.6. Energy Consumption in Others Sector…………………………………...20

2.3. Energy Planning Models………………………………………………....21

2.3.1. Classification of Energy Models…………………………………...….22

2.3.2. Energy Information Systems…………………………………………...26

2.3.3. Macro Economic Models………………………………………….....26

2.3.4. Energy Demand Models……………………………………….......26

2.3.5. Modular Packages……………………………………………………...27

2.3.6. Selection of Energy Modeling Tools……………………………......28

2.4. Economic Growth of the Country……….……………………………………30

2.5. Population Structure of the Country…………………………………...…….34

2.6. Previous Studies Related to Energy Demand of the Country………………...37

3. Chapter 3: Research Methodology ……………………..……………………....38
3.1. Approach And Scenario Developments...38
3.2. Formulation of the models………………………………………….................39
3.2.1. Model for Residential Sector…………………………….……….…....39
3.2.2. Model for Industrial Sector……………………………………..…....41
3.2.3. Model for Commercial Sector……………………………….……....42
3.2.4. Model for Transport Sector……………………………………….…....44
3.2.5. Model for Agriculture Sector……………………………………….….46
3.2.6. Model for Others Sector……………………………………………......47
3.3. Sources of Data…………………………………………………………….......48
3.4. Key Drivers Projections and Boundaries……………………………….......48
3.4.1. Demographic Developments…………………….……………….......48
3.4.2. Economic Growth Targets………………………….…………….......50
3.4.3. Energy Demand Intensities………………………….……………......53
3.5. Calibration and Validation of Models……………………….………….….53
3.6. Boundary of the Study…………………………………….…………….…...54
4. Chapter 4: Results and Findings…………………………….……………….…....55
4.1. Sectoral Energy Demand Projections…...………………….………….……55
4.1.1. Energy Demand for Residential Sector……………………………….….55
4.1.2. Energy Demand for Industrial Sector……………………...………….60
4.1.3. Energy Demand for Commercial Sector..……………………………......62
4.1.4. Energy Demand for Transport Sector…………………………….…....63
4.1.5. Energy Demand for Agriculture Sector……………………………......65
4.1.6. Energy Demand for Others Sector……………………………….……..65
4.2. National Energy Demand Projections…………………….……….................66
4.3. Policy Scenarios………………………………………………………...............73
4.3.1. LPG Substitution Scenarios in Residential Sector….………….............74
4.3.2. Energy Saving Scenarios in Industrial Sector………….……………….....78
4.4. Discussion on Results and Findings……………………….……………......79
5. Chapter 5: Conclusions and Recommendations……………….……………......84
5.1. Conclusions……………………………………….…………………...84
5.2. Recommendations…………………………………………………….......86
Bibliographies……………………………………………………………………....87
Appendices

Chapter 1
Introduction

1.1 Background

The consumption of energy is a crucial indicator for measuring social and economic growth of a society. To meet the growth, the global primary energy demand had been increased from 83.95 million GWh in 1980 to 141.1 million GWh in 2009. It has been further projected to 212.9 million GWh in 2035 under a policy scenario [1], [2], [3]. The total global primary energy supply in 2009 was 146.7 million GWh in which the contribution of fossil, renewable and nuclear fuels were 78%, 17% and 5% respectively. Among the renewable energy, the contributing share of biomass was 7.5%, followed by hydro electricity 6.2%, and the share from solar, wind, modern biomass, geothermal, and ocean energy was only 3.3% [4]. Although the contribution of fossil fuel is major in the world’s primary energy supply, but the global proven conventional reserves of oil and natural gas would be exhausted in coming 41 to 45 and 54 to 62 years, except coal which will be available for more than 100 years [5],[6]. It has been estimated that the amount of uranium in the world is insufficient for massive long-term deployment for nuclear power generation [5]. Energy is related to development; therefore, its sustainable consumption will be needed for meeting the future demand [7]. Sustainable development is defined as the development which meets the needs of the present without compromising the ability of future generations [8]. Thus, the current global energy supply scenario and its continuity seem unsustainable in future. For sustainable development, It is necessary to address its three dimensions of the development approaches which are economic development, social development, and environmental improvement in the process of development [9]. Globally, the wide sprayed energy hungers especially in Asia and Africa have been created the global sustainability problem, although the world has made little progress for implementing programs and policies towards improve the lives of the poor [10]. There is a big challenge for planning future energy supply to match the global demand. In global perspective, the energy system-supply, transformation, delivery and uses are the dominant contributor to climate change, representing around sixty percent of total greenhouse gas emissions [11]. The main primary source of world’s energy demand has been fulfilled by fossil fuel which itself is not sustainable and one reason for climate change. It was estimated that about 1.5 billion people did not have access to electricity in the year 2008 which was more than one-fifth of the world's population. Among them, about 85 percent were living in rural area mainly in Sub-Saharan Africa and South Asia [1]. To address the problem of access to electricity, the clear message for low income countries are, that they need to expand access to modern energy services considerably in order to meet the needs of the several billion people who experience serve energy poverty in terms of inadequate and unreliable access to energy services and reliance on traditional biomass. The access to modern energy services need to supply in such a way that it will be economically viable, affordable, efficient, and release the least amount of GHG [12]. From one side, there has been an alarming pictured of fossil energy supply to cope the future global energy demand, on the other side there has also been growing an international concern about the issue of modern energy accessibility to the poor. In connection to this, the United Nations had declared 2012 to be the "International Year of Sustainable Energy for All" and targeted for the year 2030 are universal access to modern energy, double energy efficiency improvement, and double renewable share in final energy [13].

One of the best options of the energy for all initiative is to increase the utilization of renewable energy sources in energy supply. The renewable energy technologies are energy-providing technologies that utilize the energy sources in such a way that they do not deplete the earth's natural resources and are environmental friendly. The use of renewable energy ensures sustainable development of a country by lowering oil import, diversify energy uses, increase local jobs, as well as reduce GHG emissions [14]. Renewable energy in 2010 supplied an estimated 16.7% of global final energy consumption. Of the total, an estimated 8.2% came from modern renewable energy—counting hydropower, wind, solar, geothermal, bio-fuels, and modern biomass. Traditional biomass, which is used primarily for cooking and heating in rural areas of developing countries, and that could be considered renewable, accounted for approximately 8.5% of total final energy. Hydropower supplied about 3.3% of global final energy consumption, and hydro capacity is growing steadily in recent years. All other modern renewable provided approximately 4.9% of the final energy consumption in the year 2010, and have been experienced rapid growth in many developed and developing countries. [15].

1.1.1 Energy Security

It is an uninterrupted provision of vital energy services and is a critical concern for sustainable energy planning process of a country. For industrialized countries, the key energy security challenges are dependence on imported fossil fuels and reliability of infrastructures. The many emerging economic countries have additional vulnerabilities, such as insufficient power generation capacity, high energy intensity, and rapid demand growth. In many low-income countries, multiple vulnerabilities of energy systems overlap, making them especially insecure [4]. Although, the fossil energy has been major commodity in most of the nations, but the production of fossil fuels is highly concentrated in few regions, like more than 60% of coal reserves are located in United State of America (USA), China, and Former Soviet Union (FSU) [5]. Over 75% of natural gas reserves are held by Organization of the Petroleum Exporting Countries (OPEC) and 80% of the global gas markets are supplied by the top ten exporters [2]. The heavy concentration of energy sources creates a dependency for importers and also raises the risk of energy supply disruptions [16]. Due to the universally distribution of renewable energy resources and increasing uses of them permit countries to substitute away from the use of fossil fuels such that existing reserves of fossil fuels will be depleted less rapidly in the future [17]. In addition to this, renewable energy sources contribute to diversify the portfolio of supply options and reduce an economy's vulnerability to price volatility represents opportunities to enhance energy security at the global, the national as well as the local levels [18],[19].

The impacts of higher oil prices on low income countries and the poor oil importing developing countries are significantly high [20]. Examples of the uses of RE in India, Nepal and parts of Africa indicates that it can stimulate local economic and social development [21]. It has been figured out that the certain minimum amount of energy is required to assure an acceptable standard of living for human being. It has been suggested that about 42 GJ (i.e, 11.7 MWh) per capita per year energy is required, after which raising energy consumption yields marginal improvements for the quality of life [22]. Thus, there are the emerging issues of sustainable development and energy security while planning national energy system. In this connection, two paths are suggested for supplying the energy services [23]:

1. The hard path or unsustainable path continues with heavy reliance on unsustainable fossil fuel or nuclear power. This leads to serious pollution problems and disposal of radioactive waste problems.
2. The soft or sustainable path relies on energy efficiency and renewable resources to meet the energy requirements.

By proper addressing the potential of available renewable resources including hydropower, Nepal can meet the growing demand with enhancing energy security through sustainable manner. The utilization of clean energy resources for long term energy planning process not only stands for sustainable development of the country but also helps to low carbon pathway to address global partnership common agenda for environmental protection.

1.1.2 National Energy Consumption and Policy Overview of Nepal

The total energy consumption of the country was about 111.3 TWh in 2009, out of which 87% were derived from traditional resources (mostly from fuel wood, agricultural residue and animal dung), 12% from commercial sources (electricity, petroleum products, and coal) and less than 1% from the alternative sources (biogas, micro hydro power, solar etc.). Out of the 111.3 TWh energy consumption, the share of residential sector was highest (89.1%) followed by transport (5.2%), industrial (3.3%), commercial (1.3%), agricultural (0.9%) and others (0.2%) sectors respectively [24].

Hydropower is the only commercial indigenous source of energy in Nepal. It's theoretical and economic potential are about 83 GW and 42 GW respectively [24]. The other studies have also shown different resource estimation of total generation capacity of the country like 200 GW and 53.9 GW respectively [25] [26]. Although there are 42 GW economically feasible hydropower resources in the country, however, less than 2% has been exploited at present [27]. All the petroleum products consumed in Nepal have been imported. Nepal Oil Corporation (NOC) is the only one state owned organization responsible to import and distribute of the products across the country. Before 1993, Nepal Coal Limited (NCL) was the sole responsible agency to import the coal in the country. After 1993, NCL became inactive and private enterprises taking part for import and distribution of it. The majority of energy supply fuels have been derived from traditional resources in the country. The traditional resources include fuel wood, dung and agricultural residues. Among the traditional resources fuel wood is the major contributor for national energy supply mix. The fuel wood consumption in the year 2010 was 86.9 TWh, whereas the sustainable supply was only about 75.8 TWh. The unsustainable consumption of the fuel wood has been indicated that there is over exploitation of the forest resources across the country [24], [28], [29].

Nepal Electricity Authority (NEA) was established in the year 1985 with the objectives to generate, transmit and distribute adequate, reliable and affordable power supply option across the country. One of the major responsibilities of the NEA is to recommend long and short- term plans and policies regarding national power sector development of the nation [30]. Although, the country has large potential of hydropower resource and the NEA has the mandate for formulation and recommendation of the policies regarding the sectoral development of the country, but the scheduled power cuts (so- called load-shedding), become a part of power supply in the country since last years. Especially during dry-season country's dependence on hydropower become obvious, forcing the NEA to cut power in Kathmandu up to 16 hours per day (as in April 2011) [24]. However, Nepal is lagging for the development of hydropower but the European country, Norway has already demonstrated that the hydropower resources as, "the white coal", for its industrialization process [31].

In Nepal, the periodic national planning process of the country had been started in the year 1956 however; the fifth plan (1975-1980) policy statement of the government was the first specific energy sector policy statement of the country. In the plan, the government emphasized the need to reduce heavy dependence on traditional source of biomass and imported fossil fuels, along with the rise of renewable energy sources including hydropower to meet the growing energy demand of the country [32]. The main aims of electricity development in the sixth plan (1980-1985) were to produce enough electricity power to meet the growing demands of the country, to extensively widen the domestic use of electricity with a view to stop future depletion of the forest, and to supply the required power for electrifying the transport system as a substitute of petroleum products [33].

The first comprehensive alternative energy development policy for developing Renewable Energy Technology (RET) was adopted during the eighth national development plan (1992-1997). In 1997, an Alternative Energy Promotion Center (AEPC) was formed with the main objective for developing and promoting renewable/alternative energy technologies in the country [34].

The tenth five year plan (2002-2007) aimed to develop hydroelectricity as exportable items of the country through low cost harnessing [35]. Further, the three year interim plan (2008-2010) also intended to develop the hydropower potential of the country as an expert commodity along with expanding its development to the rural areas and providing quality services with low investment [36]. Similarly, in the following three year plan (2011-2013), the objectives were set to access modern energy services in the country through generation, transmission and distribution of hydropower in the country. The policy document also aimed to develop the sector as the exportable commodity of the country [37]. Recently planned, the three years approach paper (2014-2016) has also expected to increase public access of reliable and good quality electricity services by encouraging production of hydropower resources across the country [38].

The target has been taken for long term (up to 2027) generation of 4 GW of hydro electricity to meet the domestic demand of the country according to the national water plan 2005. In the plan, it has been targeted that about 75 % of the population will be accessed through national grid, next 20 % through non grid (small and micro hydro) and remaining 5 % of population through alternative sources [39]. In connection to this, for domestic consumption and export by 2030, a medium term hydropower developments plan to develop 25 GW of hydropower capacity has also been formulated [40]. Additional to the plans and policies, following are some main rule and regulations for guiding the energy sector development including hydropower resources of the country:

- Hydropower Development Policies 1992 and 2001
- Water Resources Strategy 2002 and National Water Plan 2005
- National Electricity Crisis Resolution Action Plan 2008
- Local Self-Government Act,1999
- Rural Energy Policy 2006
- Forest Sector policies and Forest Act, 1992
- National Transport Policy 2001
- Task force for Hydropower Development 2008
- Rural Energy Policy 2006
- Subsidy Delivery Mechanism 2006.

For addressing the sustainable development issue of the country, the climate change policy 2011 has already been introduced in the country. There are concrete objectives in the policy to promote and use of clean and renewable energy resources of the country to meet the long term energy demand by adopting a low carbon development path [41]. Although there are various rules, regulations and periodic plans for governing the energy sector of the country but the achievements are limited and are not encouraging [32-37].

1.2 Problem Statement

The national energy consumption demand of the country has been increased and will be also increased in future along with changing structure of demanding fuels. Thus, the reliable demand projections of the fuels are a crucial pre- requisite requirement for supply side planning of the country.

Due to continuous rise in consumption of imported fossil fuels has not only created economical burden of the country, but also raise the issues of energy security and sustainable development of the nation. Thus, it is necessary to know qualitative and quantitative amount of demanding fuels such that the necessary reliable supply measures can be planned.

For meeting the energy demand of the growing population and changing socio-economic condition of the country, per capita energy consumption of the people will be a particular concerned for national development.

There is an urgent need to find out sector wise energy demand of the country in terms of demanding fuels, and also need to examine the additional demand of the clean local hydropower resource by substituting the imported liquefied petroleum gas (LPG) in residential sector and the possible amount of energy saving in industrial sector to facilitate the further secure energy system planning of the country.

It is needed to change the present energy consumption mix dominated by traditional and imported fuels to a more desirable energy mix having higher share of local clean renewable energy resources. For this purpose, first the prediction of actual demand of the demanding fuels are necessary and afterwards, the essential policy measures can be formulated to path the future national energy supply system of the country.

In connection to this, a proper combination of sectoral energy demand models of the country must be formulated for determining the national energy demand of the country. For this purpose, in this study, Long Range Energy Alternative Planning (LEAP) framework has been selected for residential, industrial, commercial, agriculture and road transport sectors whereas econometric modeling approach to the aviation transport and others sector energy demand models respectively. Further, the residential and industrial sectors models are again expanded to analyze the LPG substitution by electrical fuel in residential sector and energy saving opportunities in industrial sector of the country through the proper policy interventions in these sectors.

1.3 Motivation of the Study

The total energy consumption of the country was 81.1 TWh in 1996 and reached to 111.3 TWh in 2009.There was not only rise in total national consumption demand of the country but also changes of contributing fuels for meeting the demand. Then, it is important to know about the possible future structure of demanding fuels. The reliable future demand projections of the fuels are a crucial pre- requisite requirement for supply side planning of the country. Hence, one of the motivation factors of this study is to find the answer about the total energy demand of the country along with demanding fuels and per capita energy consumption by the end of the projection year 2030.

The residential sector's share on national energy consumption demand has been dominated. In the year 2009, the demanding shares of residential, transport, industrial, commercial, agriculture and others sectors were 89.1%, 5.2 %, 3.3 %, 1.3%, 0.9% and 0.2% respectively. Thus, the future contributing scenarios of those energy demanding sectors will be needed for their efficient supply side planning process.

In 1996, 6.1 TWh of petroleum products was consumed in the country. The consumption was increased by 1.5 fold and reached to 9.2 TWh in the year 2009. Within the petroleum products, the liquid petroleum product (i.e., oil products) consumption was increased by 1.3 fold and reached to 7.6 TWh in 2009 ,while the LPG consumption (i.e., gases fuel) was grown from 0.3 TWh in 1996 to 1.6 TWh by increasing 5.3 fold during the period. The total petroleum product contribution on national energy system was 7.4% in 1996 and increased to 8.24% in 2009. It is noticeable that country had spent only 19% of national exports' earning in 2001 whiles in the year 2013 the amount money spent has been raised to 142.2% of the earning just for importing the products [42], [43], [44]. The price of crude oil which is the raw material for all petroleum products has been increased in international market. In 2001, the price was $23.12 per barrel, while it soared to $105.87 per barrel in the year 2013 [45]. Hence, the current consumptions of the products on the country have already been made the national energy mix unsustainable and further growth of their demands will be more vulnerable for national economy. A study has also pointed out that the impacts of higher oil prices on low income countries and the poor oil importing developing countries are significantly affected by oil price [20]. In one side, the formulated plans and policies of the country emphasize to utilization of local clean hydropower resource of the country to meet the growing demand, but in existing scenario of national energy supply mix, the consumptions of imported fossil fuels have been increased annually in all of the energy demanding sectors of the country. The growing consumption demand of fossil fuel like LPG in residential sector has been created alarming situation for the sectoral energy security. The consumption of LPG in residential sector alone is more than half of total LPG consumption of the country. Thus, to address the country's adopted policies and plans, it is necessary to examine the additional demand of clean local hydropower resource by substituting the imported fossil fuel (i.e., LPG) in the sector. It is noticeable matter that; despite the huge potential of hydropower resources in the country, the share of electricity in the national energy system is less than 2% [24].

A study on the selected industries of the country has shown that there is a potential of energy saving in industries [46]. Thus, it is necessary to figure out the amount of energy that can be saved through intervention of an appropriate policy scenario in the sector.

There is a crucial need to change the present energy consumption mix dominated by traditional and imported fossil fuel to a more desirable energy mix with higher share of electricity derived from clean local hydropower resources. For this reason, first the reliable future consumption demands of the fuels are necessary then through policy interventions, the substitution of required fuels will be planned for making national energy system more efficient and secure in days to come.

By proper addressing the potential of renewable energy resources including hydropower resource, Nepal can meet the growing energy demand of the country. The utilization of clean energy resources for long term energy planning process of the country not only stands for its sustainable development but, also helps to grasp low carbon pathway for environmental protection. To demonstrate the future energy demand and supply options in quantitative and qualitative terms, it is necessary to carry out energy planning work by projecting different scenarios for demand and corresponding supplies alternatives.

The design of present study has been initiated based on the mentioned issues, and motivation of this study has been raised for finding the solution of the issues. But, due to the importance of work and available timeframe, this study has been focused only on the national energy demand projections and analysis of the country.

1.4 Objectives of the Study

The main objective of the study is to project and analyze the national energy demand of the country. Apart from the main objective, following are the specific objectives of this study:

1. To study existing energy consumption pattern of the country.
2. To project and analyze sector wise energy demand of the country.
3. To evaluate the change in electricity demand through substitution of LPG fuel in residential sector.
4. To figure out change in energy demand in industrial sector through intervention of energy saving opportunities.
5. To evaluate and compare per capita energy consumption of the country.

1.5 Scope of the Study

Sector wise nation's energy demand model has been developed by incorporating available energy consumption information of the country. The outcomes of the study will be helpful for formulating necessary policy measures for policy makers and concerned stakeholders in the sector. The policy makers can use the information from this study to adopt necessary actions for sustainable utilization of the local energy resources to avoid any negative implications for national energy systems. This study provides the possible structure of national energy demand with contributing demanding fuels. It also provides the necessary information of the energy demand inputs for supply side energy planning of the country. It is highly expected that, these outcomes will support for future energy planning process of the country through proper utilization of available resources in sustainable manner.

1.6 Structure of the Dissertation

Chapter 1 covers the introductory information including background, problem statement, motivation, objective and scope of the study. Chapter 2 deals with energy situation in Nepal related to energy consumption of the country, energy planning tools and related past studies. The chapter further deals with revision of energy planning tools, national economic growths, and demographic situations of the country. Chapter 3 explains for adopted methodological approach of the research in order to be able to response the research objectives. The chapter furthermore deals with the key selected drivers, their projections, boundary conditions and approaches for calibration and validation of the research outputs. Chapter 4 illustrates figures and describes the results and findings of the projected energy demands under the four anticipated growth scenarios of national economy along with policy scenarios related to LPG substitution in residential sector and energy saving opportunities in industrial sector. Finally, Chapter 5 deals with conclusions and recommendations of the research.

Chapter 2
Energy Situation in Nepal

2.1 Country Information

Nepal is a land - locked developing country lies in South Asia, occupying 0.03% of the total land area of the world and 0.3% land area of the Asian continent. Geographically, it is located between 80°12’ to 88°12’ east longitude and 26°22 to 30°27’ north latitude. The total area of the country is 147,181 km^2 with population of 26.5 million (as per 2011 national census). Figure 2.1 shows the geographical location of the country.

Figure 2.1: Geographical Map of Nepal (Source: www.maps.com.)

It extends 145 to 241 km from north to south and 845 km from east to west. It is surrounded by India from east, west and south whereas, Tibetan Autonomous Region of China in the north as shown in the map. The country consists of three ecological zones along east to west called Mountain, Hill and Terai respectively.

For an effective administration purpose, the country has been divided into five development regions; which are Eastern, Central, Western, Mid-western and Far-western respectively as shown in Figure 2.2. The development regions are further divided into 14 zones. The 14 zones are again divided into 75 districts. Within the districts, there are 58 municipalities (urban places) and 3915 village development committees (rural places).

The capital city, Kathmandu lies in the Central development region of the country [47], [48].

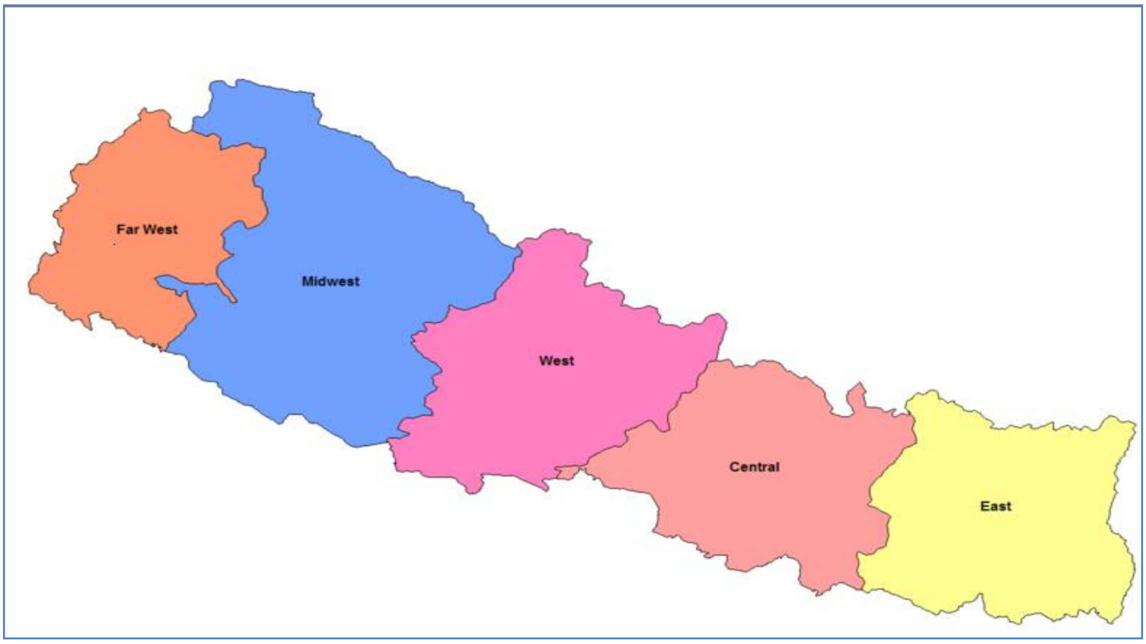


Figure 2.2: Five Development Regions of Nepal (Source: www.wikipedia.org)

2.2 Energy Consumption Scenario of the Country

The total energy consumption of the country was increased annually with average growth rate of 2.5% from 1996 to 2009. The amount of energy consumption in the year 1996 was 81.1TWh and reached 111.3 TWh in the year 2009 [24]. Figure 2.3, shows the historical pattern of energy consumption of the country from the year 1996 to 2009. The contribution of fuel wood is significant to fulfill national energy demand. In 2009, 85.7 TWh energy was supplied by fuel wood which was 77% of the total energy consumption of the year. Similarly, in 1996, 64.2TWh energy was consumed from it which was 79.2% of total energy consumption of the year [24].

During the period, the annual average growth rate (AAGR) of the fuel wood demand was 2.3%. Although, the percentage contribution of its consumption in national energy system has been decreased in recent years, but the quantity of its consumption has been increased annually.

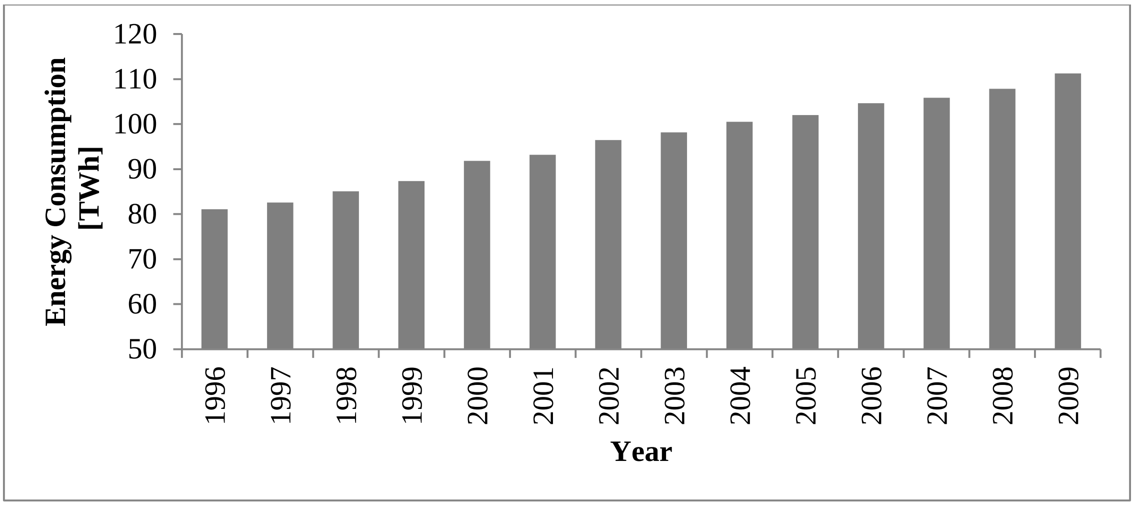


Figure 2.3: Historical Energy Consumption Pattern of Nepal (Source: WECS, 2010)

In the national energy consumption system, the role of traditional biomass (i.e., including fuel wood, animal waste, and agriculture residue) is significant. Figure 2.4 shows the contribution of consuming fuels to meet the national demand of the country in the year 2009. The contribution of renewable (i.e., solar, biogas, and micro hydro) is less than 1% as shown in the figure.

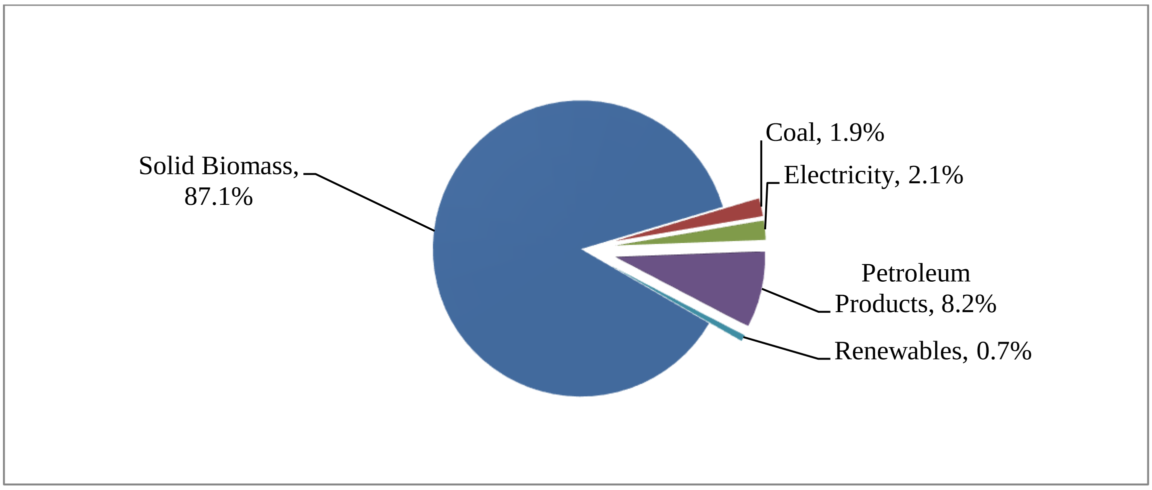


Figure 2.4: National Energy Consumption Pattern of Nepal in 2009

(Source: WECS, 2010)

The total energy consumption of the country in the year 2009 was 111.3 TWh, in which the most of the energy was consumed by residential sector, followed by transport, industrial, commercial, agriculture and others sector as shown in Figure.2.5.

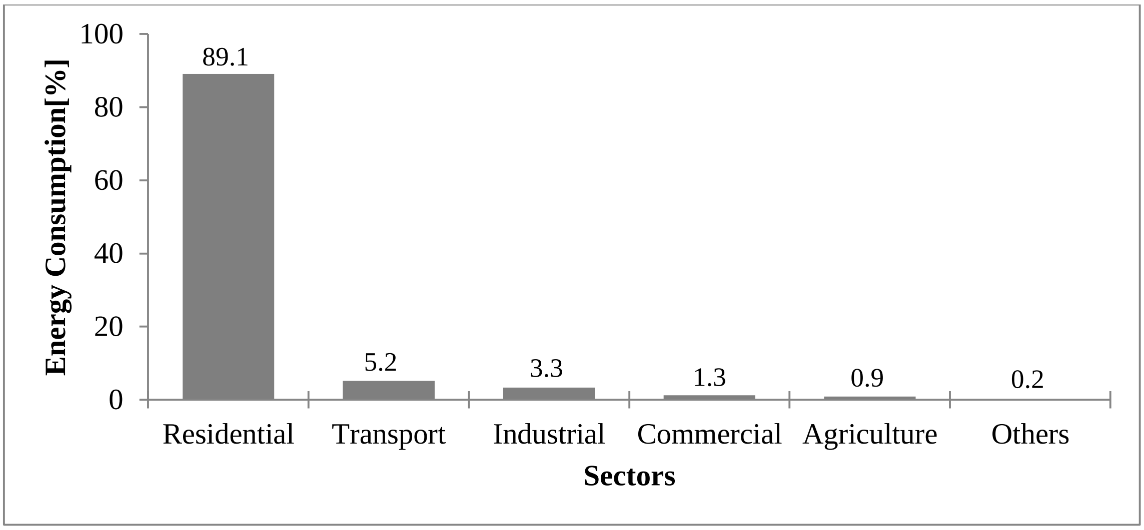


Figure 2.5: Sectoral Energy Consumption Pattern (Source: WECS, 2010)

2.2.1 Energy Consumption in Residential Sector

In 1996, about 91.7% of total energy was used in the residential sector whereas in 2009, the share was reduced to 89.1% [24]. Figure.2.6 shows the historical pattern of the sector's energy consumption since 1996 to 2009.

In the sector, the contribution of solid biomass, petroleum products, electricity, biogas and coal were 96.5%, 1.5%, 1.1%, 0.8%, 0.1%, respectively in the year 2009. The energy is used in the sector for cooking, heating; animal feed preparation, and lighting applications.

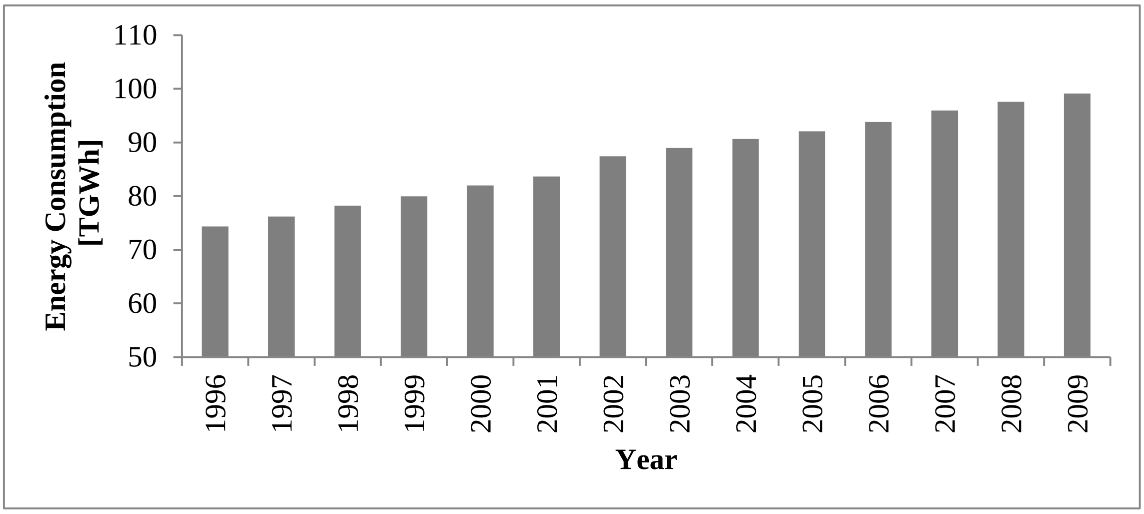


Figure 2.6: Historical Residential Energy Consumption Pattern of Nepal (Source: WECS, 2010)

Figure 2.7 shows, the historical trends of the selected per capita modern residential fuels consumption. It illustrates that, the per capita modern fuels consumption of the sector has been increased in recent years. Among them, biogas and grid electricity are locally available resources, however, liquefied petroleum gas (LPG) has been fully imported.

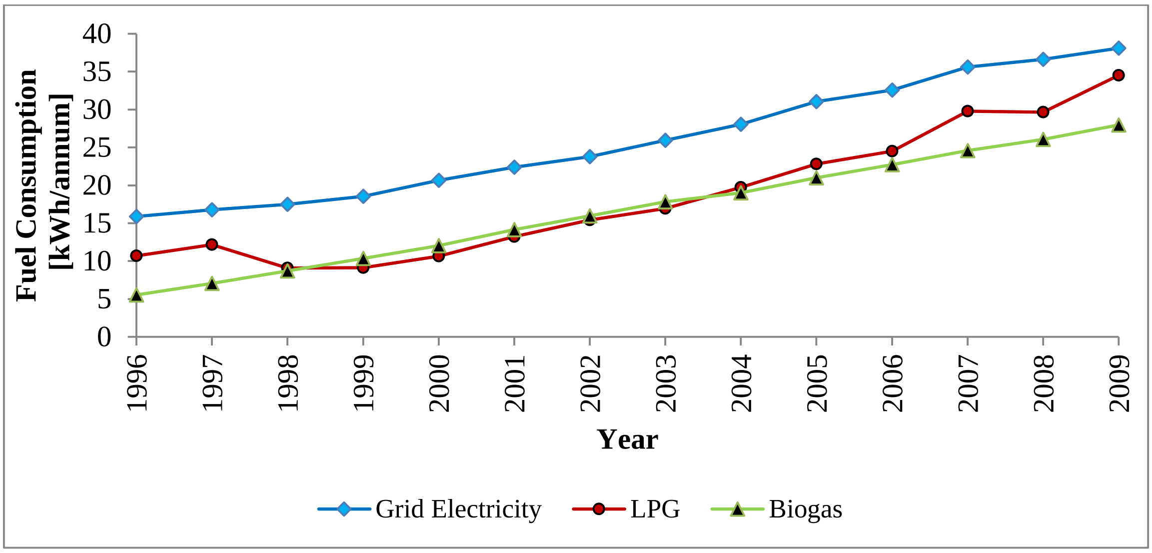


Figure 2.7: Selected Per Capita Fuel Consumption in Residential Sector

(Source: WECS, 2010)

The trend shows that the percentage of the sector's LPG consumption was more than half of the total consumption. In 2009, about 56.2% 0.9 TWh of total imported LPG was used in the sector alone [24]. Figure 2.8 shows the historical total national and residential sector's LPG consumption patterns of the country since the year 1996 to the year 2009.

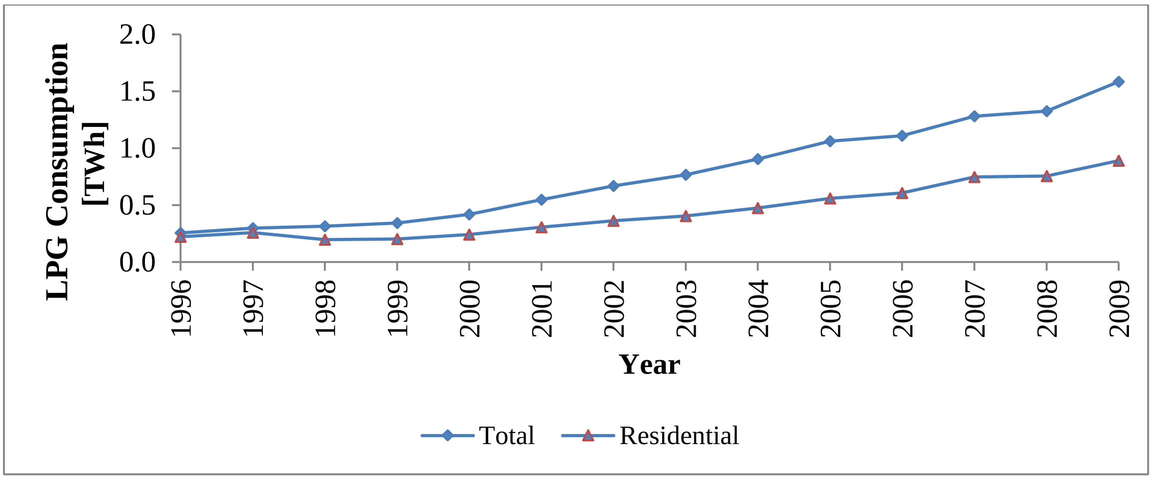


Figure 2.8: Liquefied Petroleum Gas (LPG) Consumption Scenario

(Source: WECS, 2010)

In 1996, about 10.8% of urban households used LPG for cooking purpose. It is noticeable that only 0.2% of rural households used LPG for cooking in 1996, however, this percent leaped to 6.8% in 2011 [49], [50], [51]. Figure 2.9 shows the rising trends of LPG consumptions in urban and rural households of the country.

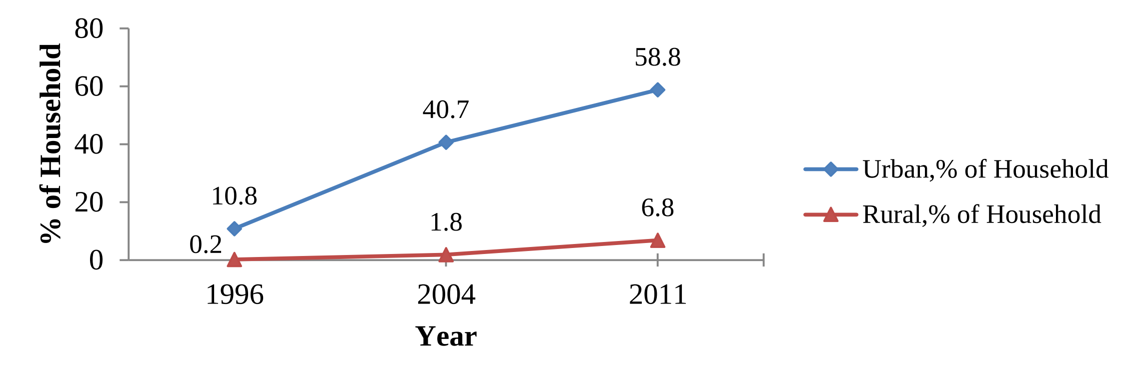


Figure 2.9: Shares of Households Using LPG for Cooking Application (Source: CBS 1996, 2004, 2011)

The outcomes of Nepal Living Standards Surveys (NLSS) have been illustrated that the sources of households' income have been changed. In 1996, the main source of households' income was from farm income, but in 2011, the main source of income changed into non-farm activities as well. In the year 2011, about 28% of households' income came from agriculture, 37% from non-farm enterprises, and remaining from other activities like remittances, and own housing consumptions. There is a noticeable difference between urban and rural farm incomes. Among the development regions, the central region is the least dependent on agriculture sector while the far-west is the most dependent on the sector. It has been found that about 47% households' income in urban areas came from non-farm enterprises in 2011. Figure.2.10 shows the changing pattern of sources of households' incomes in the country. [49], [50], [51].

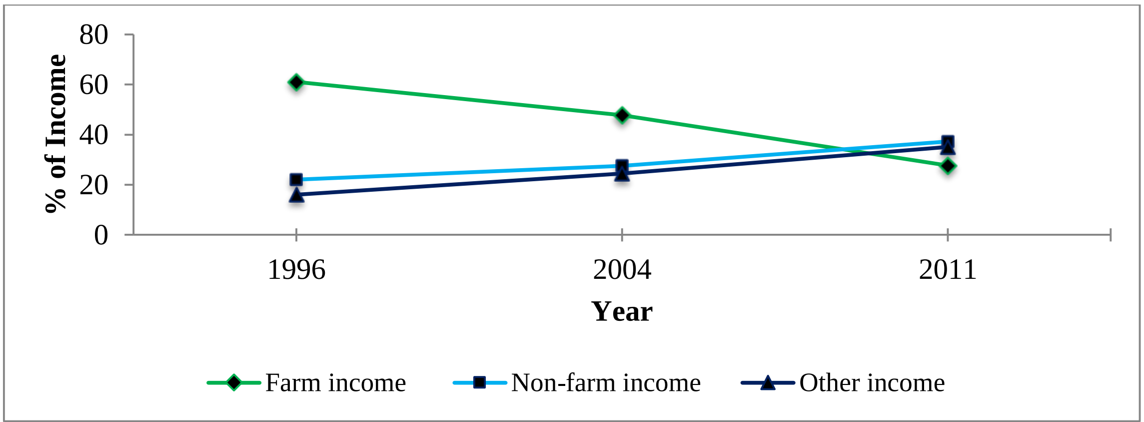


Figure 2.10: Sources of Household Income (Source: CBS 1996, 2004, 2011)

The income of both urban and rural people has been increased, however, the income of their quintile levels has been observed different as shown in Figure 2.11. One considerable observation from the figure is that, the urban and rural income ratio has been reduced from 2.7 in 2004 to 2.1 in 2011[49], [50], [51]. The figure indicates that in recent years the rural people of the country have also become more capable in spending money in modern commercial energy services.

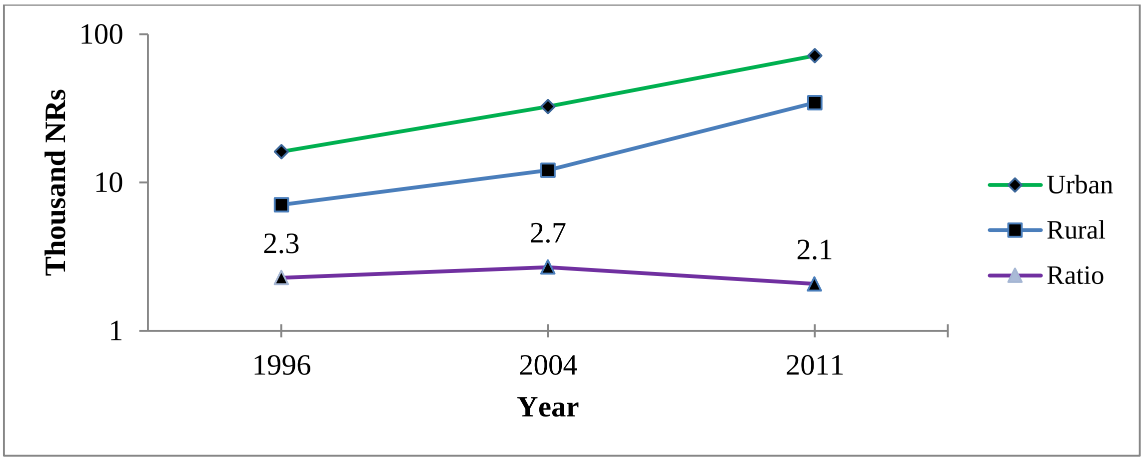


Figure 2.11: Mean Income of Urban and Rural People (Source: CBS 1996, 2004, 2011)

Historical observation shows that the income of all classes of the country has been increased as shown in Figure 2.12.The average income of the people has been increased from the year 1996 to the year 2011. In connection to the growth of household income, the demands of modern fuels have been increased not only in the urban households but also in the rural households of the country.

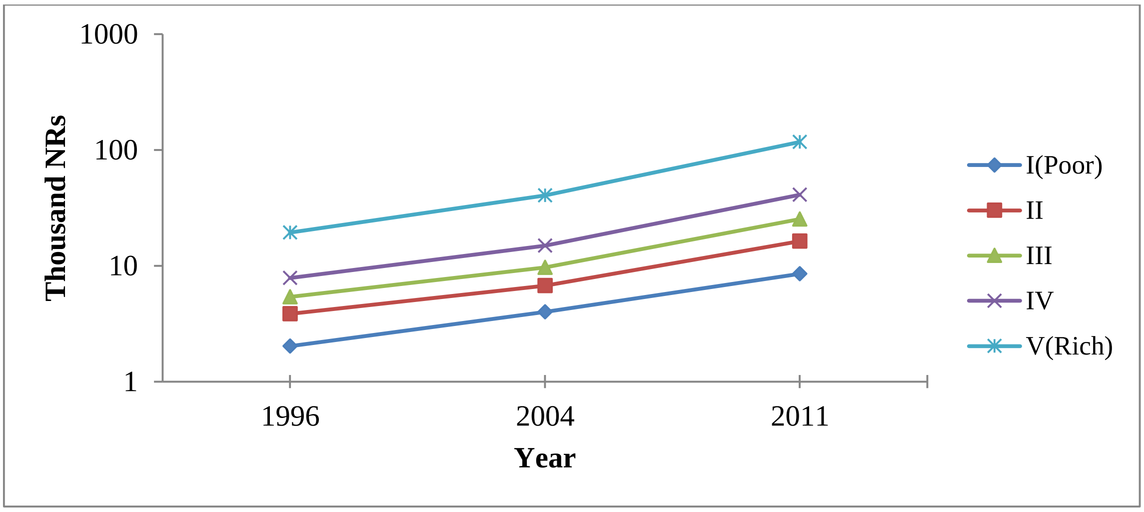


Figure 2.12: Relation between Mean Income and Income Classes (Source: CBS 1996, 2004, 2011)

2.2.2 Energy Consumption in Industrial Sector

The industrial sector's energy consumption was about 3.3% of total national energy consumption of the country in 2009. In 1996, about 34.2% of the total sectoral energy consumption demand was supplied from coal followed by 21.2% from electricity, 19.6% from petroleum products, 16.5% from biomass and 8.5% from fuel wood. But in the year 2009, the energy consumption data shows that about 57.9% of the sector energy consumption was supplied from coal, followed by 23.2 % from electricity, 3.5% from petroleum products, 10.0 % from biomass and 5.4 % from fuel wood [24]. During the period, the contribution of coal, and electricity had been increased while the contribution of other fuels had been decreased. The coal has been used for heating in boiler and kiln. Hence, the consumption of coal in the sector is major. The wood and other biomass fuels have been used in the sector for ignition of fire as well as for heating purposes.

There are five end uses in the sector which are process heat, motive power, boiler, lighting and others. Boiler end use application has used most of the energy (37%) that is why coal is heavily consumed in the sector. Other end uses for energy consumption are motive power (31%), process heat (30%) and lighting (2%) respectively [24]. In this sector, many traditional and small scale industries were closed due to unstable political situation and being unable to compete with international market [23], [52]. As a result, the contribution of this sector to national economy has been decreased.

2.2.3 Energy Consumption in Transport Sector

Transport sector includes mainly road and air transport in Nepal. The energy consumption in this sector deals with fuels used by vehicles and planes (i.e., air transport devices) for passenger and freight transport. The total energy consumption on the sector in 2009 was about 5.8 TWh which was raised from 2.4 TWh in the year 1996. During the period, about 6.9 % of AAGR of the energy demand was observed in the sector. In the year 2009, about 9.2 TWh was supplied by petroleum product which was 8.2 % of total energy consumption of the year. The sectoral consumption of petroleum products was about 63.3% in the year 2009. It has been observed that the road transport demand was increased with AAGR of 7.4% while, the air transport demand was increased with AAGR of 4.2% respectively during the period. From 1996 to 2009, average 84.5% of the sector's energy demand was consumed in road transport alone, and remaining in air transport. In the year 2009, the demand was supplied mainly by diesel (67.1%), followed by gasoline (19.8%), ATF (11.9%), LPG (1.1%) and electricity (0.1%) fuels respectively [24], [52].

2.2.4 Energy Consumption in Commercial Sector

The total energy consumption on the sector in 2009 was 1.4 TWh while in 1996, it was only 0.8 TWh. In the year, the structures of consuming fuels were 35.9% from solid biomass, 53.1% from petroleum products and 11% from electrical energy. During the period, about 5.1% AAGR of the energy demand was observed on the sector. In 1996, about 0.3 TWh of fuel wood was consumed in the sector and in 2009 it was increased to 0.5 TWh. The AAGR of fuel wood was 5.7% during the period. Similarly in 1996, about 33.3 GWh of LPG was consumed and was increased to 636.2 GWh in 2009 with AAGR of 30.4%. Similarly, the demand of electricity was increased with AAGR of 7.5% and reached to 155.6 GWh from 62.7 GWh during the period. Among the fuels, kerosene was decreased from 302.8 GWh to 83.3 GWh with -6.4% AAGR during the same period. As in the residential sector, cooking is the major end use in commercial sector consuming about 68.4% of the total sectoral energy consumption followed by lighting (19.3%), water boiling (0.3%), space heating & cooling (5.3%), and electrical services such as water pumping etc. (6.7%) [24], [52].

2.2.5 Energy Consumption in Agriculture Sector

The consumption of energy in agriculture sector was only 0.9% of national energy consumption in 2009. Among the consumption, the shares of electricity and diesel were about 5% and 95% respectively. Electricity, in the sector is mainly used for irrigation purpose whereas diesel has been used for water pumping and farming machineries. The share of petroleum products on the sector was about 10.6% of total national consumption of the year 2009 [24], [52].

2.2.6 Energy Consumption in Others Sector

Others sector is defined as the sector except above mentioned five sectors. In this sector, about 0.2% of the total national energy was consumed in 2009. The demand of this sector has been supplied by electrical fuel. In 1996, about 72.2 GWh electrical energy was used in the sector, and reached to 205.6 GWh in the year 2009 with AAGR of 8.4% during the period [24], [52].

2.3 Energy Planning Models

Kahen (1995) defined energy planning as a matter of assessing the supply and demand for energy and attempting to balance them from present to future [53]. The energy planning is a way of managing the available resources and, is a process oriented activity. According to Van Beeck (2003), a planning process is the process of making choice between available alternatives [54]. Planning for future is basically done through projecting the scenarios based on present and past information. Energy planning is a dynamic and complex approach for considering the policies and strategies of energy systems, therefore, energy models are used for the planning process. For energy planning purpose, energy models were first developed in 1970s as a result of the increasing availability of computer and the growing concern of environmental consciousness [55]. The importance of developing countries in energy planning began after the first oil crisis in 1973, when the high oil prices suddenly caused trade unbalance of many oil-importing countries [54],[56]. Only after the crisis, the sufficient attention was given for rational utilization of energy resources, and felt the importance of long-term energy planning [57]. Literatures show, energy planning is done for different time horizons. Klein et al. (1984) refer to four years or less as short term, from five to nine years as medium term and ten or more than ten years as long term respectively [58].

Different models have came in practice for addressing the energy system planning like MESSAGE, WASP and MARKAL for supply side, whereas MADEE and MADE for demand side. It has been found that about 80% contribution of the total global greenhouse effect was due to energy related activities [59]. Knowing the fact, the scope of environmental planning along with energy and economics rose - up and the importance of the new dimension of planning was realized and afterwards, environmental dimension was also integrated for the planning process. Therefore, the existing energy planning tools are continuously enhanced to address the energy, economic and environment aspects of the energy planning process.

2.3.1 Classification of Energy Models

Energy models are used for projecting future energy demand, supply, or both the demand and supply scenarios. The total numbers of available energy models have been massively grown with the growth of expanding computer capabilities [60].

Table 2.1: Classification of Energy Models by Characteristics (Source: Van Beeck, 2003 & Nguyen, 2005)

Classification	Description
Module Purpose	Energy information, macroeconomic model, energy demand, energy supply, modular packages, integrated modules
The Model Structure	Degree of indigenization, description of non-energy sectors, description of end-uses, description of supply technologies
The Analytical Approach	Top-Down or Bottom-Up
The Underlying Methodology	Input-output, equilibrium, econometric, overlapping, integrated, game theory, optimization, simulation, forecast
The Mathematical Approach	Linear programming, mixed-integer programming, dynamic programming
Geographical Coverage	Global, Regional, National, Local, or Project
Sectoral Coverage	Energy sectors or overall economy
The Time Horizon	Short, Medium, Long Term
Data Requirements	Qualitative, quantitative, monetary, aggregated, disaggregated

Although, the energy models are used for planning purpose, the scope of models varies according to the planning objectives. They differ from each other in the model purpose, the model structure (internal and external assumptions), analytical approach, geographic coverage, sectoral coverage, the time horizon, and data requirement [60],[61],[62],[63].

The Table 2.1 shows the classification of energy models by characteristics suggested by Van Beeck (2003) and Nguyen (2005) [54],[63]. Similarly, Table 2.2 shows the classification of energy models according to Pandey (2002) [64].

Based on the purpose and performance of energy models, Urban et al. (2007) mentioned that Beaujean et al. (1977) carried out the first survey of global and international energy models based on earlier reviews of energy models by Charpentier (1974-1976), followed by Meier (1984) who compared energy models for developing countries and developed a classification typology describing a variety of modeling techniques and their usefulness for developing regions [80].

Table 2.2: Classification of Energy-Economy Models (Source: Pandey, 2002)

Paradigm	**Space**	**Sector**	**Time**	**Examples**	**Issue Addressed**
Top-down Simulation	global national	Macro-economic energy	Long-term	Integrated assessment (e.g., AIM) and general equilibrium models, input-output models, and system dynamics models (e.g.,FOSSIL2)	Impact of market measures and trade policies on cost to economics and global national emissions Impact of market structure, competition and uncertainties on capacity investment, technology-mix, cost to consumers and emissions
Bottom-up Optimization/ accounting	national regional	Energy	Long-term	Optimization(e.g., MARKAL,EFOM) and accounting(e.g., LEAP)models	Impact of market measures and other policies(e.g., regulations)on technology mix, emission, and cost to energy system, capacity investment planning
Bottom-up Optimization/ accounting	national regional local	Energy	Long-term	End use sectors (e.g., AIM/End use),Power sector, Coal sector modules	Impact of sectoral policies on sectoral technology-mix, fuel-mix, costs and emissions, planning for generation-mix; limit scheduling; logistics.

Shukla (1995) compared greenhouse gas models for developing nations and assessed the advantages and disadvantages of top-down and bottom-up models for this purposes, whereas Bhattacharya (1996) compared applied general equilibrium models for energy studies [55],[109]. The Table 2.3 shows the main energy models that are commonly used in energy planning process [54].

Table 2.3: The Main Energy Models (Source: Van Beeck, 2003)

Energy Model	Specific Purpose
MARKAL	Energy supply with constrains. The objective includes target-oriented integrated energy analysis and planning through a least cost approach
ENERPLAN	Energy supply, energy demand, matching demand and supply
MESSAGE-III	Energy demand and supply, environmental impacts. Modular package. The objective includes generation expansion planning, end-use analysis, environmental policy analysis, investment policy
LEAP	Demand, supply, environmental impacts. Integrated approach. The objective includes energy policy analysis, environmental policy analysis, biomass-and land-use assessment, pre-investment project analysis, integrated energy planning, full (all) fuel cycle analysis. Applicable to industrialized as well as developing countries.
EFOM-ENV	Energy supply, subject to technical, environmental and political constraints. Detailed description of (renewable) technologies possible. The objective includes energy and environment policy analysis and planning in particular regarding emission reduction.
MARKAL-MACRO	Demand, supply, environmental impacts. Integrated approach for economy-energy-environmental analysis and planning. The objective is to maximize utility (discounted sum of consumption) from a neo-classical macro-economic perspective.
MESAP	Modular package. Demand, supply, environmental through different modules: ENIS=database; PLANET/MADE=demand which can be coupled to supply module; INCA=comparative economic assessment of single technologies; WASP=generation expansion based on least-cost analysis; MESSAGE=integrated energy systems analysis
ENPEP	Energy demand, supply, matching demand and supply, environmental impacts. Detail analysis for electricity based on least cost optimization. Integrated approach. Allows for energy policy analysis, generation expansion planning and environmental policy analysis
MICRO-MELOIE	Energy demand, supply, environment. Integrated approach. The objective includes an analysis of macro-economic energy and environment linkages
RET screen	Energy Supply. Specially designed for renewable energy technologies

On the basis of analytical modeling approach, models are classified as top down and bottom up models. Kydes et al. (1995) highlighted that bottom up models represents different activities like energy supply process, conversion technologies and end- use demand pattern in detail [65]. On the other hand, Pandey (2002) argued that the top down models can answer energy policy questions regarding macroeconomic indicators and energy-wide emissions, due to their clear inclusion of inter-linkages between energy and economy [64]. Table 2.4 shows the difference between the two types of models [54].

Table 2.4: Difference between Top-Down and Bottom-up Models

(Source: Van Beeck, 2003)

Top-Down Models	Bottom-Up Models
• Use an 'economic approach' • Give pessimistic estimates on 'best' performance • Can not explicitly represent technologies • Reflect available technologies adopted by the market • The 'most efficient ' technologies are given by production frontier(which is set by market behavior) • Use aggregated data to forecast the future • Are based on observed market behavior • Disregard the technically most efficient technologies available, thus underestimate potential for efficiency improvements • Determine energy demand through aggregate economic indices, but vary in addressing energy supply • Indigenize behavioral relationships • Assume there are no discontinuities in historical trends	• Use an 'engineering approach' • Give optimistic estimates on 'best 'performance • Allow for detailed description of technologies • Reflect technical potential • Efficient technologies can lie beyond the economic production frontier suggested by market behavior • Use disaggregated data to explore the future • Are independent of observed market behavior • Disregard market thresholds(hidden cost and other constraints),thus overestimate the potential for efficiency improvements • Represent supply technologies in detail using disaggregated data, but vary in addressing energy consumption • Assess cost of technological options directly • Assume that interactions between energy sector and other sectors are negligible

However, the planning models can be classified according to various dimensions, but on the basis of planning purpose, it can be commonly classified as energy information system, microeconomic models, energy demand and supply models, modular package models and integrated models respectively [54],[63].

2.3.2 Energy Information Systems

Energy information systems are typically database for management and presentation of statistic and technical data in graphical and table formats. Apart from the management and presentation of the data, some databases offer opportunities to analyze and compare technologies. Some common examples of these databases are CO2DB, DECPAC, and IKARUS etc. [63].

2.3.3 Macro Economic Models

Macroeconomic models are an analytical tools design to describe for a question on how the price and availability of energy influence the economy in terms of gross domestic product (GDP), employment and inflation rate and vice versa, of a country or a region. They are related to the level of outputs and prices based on the interactions between aggregate demand and supply. Two examples under this category are MACRO and MIS models [63].

1. **MACRO:** The MACRO model was developed by the International Institute of Applied System Analysis (IIASA). The model has eleven regional versions and is widely used to compute size of economy, investment flows, and demand for electric and non electric energy. The model's strength is that it treats the economy of coherent regions of the world in an integrated fashion and estimates energy demand. Its weakness is that the model has little resolution of technological choices and the choice of technologies determines emissions and environmental impacts [66].

2. **Macroeconomic information system (MIS):** It was developed by University of Oldenburg as a module in IKARUS[2] project. The system provides framework data for the economic consistency. It is based on dynamic input/output approach. The overall economy of Germany is aggregated into 30 sectors, 9 of which are energy sectors, corresponding to the functional structure. The MIS system consists of an input/output generator, a growth-model and several sub-models, namely electricity, transport and dwelling [63],[67].

2.3.4 Energy Demand Models

The energy demand models are used to forecast the energy demand for a specified time horizon. They are used either for specific sector or entire economy of a region (i.e., local level, regional level, national or international). Among the energy demand models, the techno-economic models are widespread, but econometric models are also used. Popularly known energy demand models are MADEE, and MAED. The MAED was developed based on earlier version of MEDEE by IAEA into its present form, while MADEE remains the model of the original authors and is supported by their energy consulting firm ENERDATA [68].

1. **MEDEE**: Modele d' Evaluation de la Demande En Energie (MEDEE) was developed by the Institute of Energy Policy and Economics, Grenoble, France. It is a techno-economic bottom – up model for forecasting the demand of a region or a country. In the model, the aggregate demand of the economy is disaggregated into standardized subgroups (like agriculture, industry etc.). By addressing the direct and indirect determinates of these subgroups demands, the model is able to evaluate the future energy demand of the region or a country. [63].

2. **MAED**: The Model for Analysis of Energy Demand (MAED) is developed by International Atomic Agency for estimation of the demand for different time horizons of a region or a country. The simulation model needs various technical and political parameters as model inputs; such as varying social needs of people, policy measures of a county for development & industrialization etc. The demand is first determined at the disaggregated level and then added up to obtain the overall final demand. It uses a bottom-up approach to project future energy demand based on medium to long term scenarios of socio-economic, technological and demographic development of the region or a country [69].

2.3.5 Modular Packages

Modular package incorporates different kind of models like a macro-economic component, an energy supply and demand balance, an energy demand alone, etc. within the package. Based on the scope and required application, user can choose the particular module application from the package. Some of the well known tools are ENPEP, LEAP and MESAP.

1. **ENPEP**: The Energy and Power Evaluation Program (ENPEP) is a simulation type of model. It is developed by the Argonne National Laboratory in the USA. It is used to model a country's entire energy system. The model incorporates the

dynamics of market processes related to energy by an explicit representation of market equilibrium, i.e., the balancing of supply and demand. It consists of an executive module and ten technical modules. The main module is BALANCE. This module uses a non-linear and market-based equilibrium approach to determine energy supply and demand balance for the entire energy system [70]. Equilibrium is reached when ENPEN-BALANCE finds a set of market cleaning prices and quantities that satisfy all relevant equations and inequalities. Connolly et al. (2010) mentioned that the model has been used for Mexico's future energy needs and estimated the corresponding environment burdens, green house-gas emission projections for Turkey and GHS mitigation analysis for Bulgaria [71].

2. **MESAP**: The Modular Energy System Analysis and Planning (MESAP) model is developed for integrated energy and environment planning. Baumhogger et al. (1998) developed it not only for energy and environmental management on local and regional scales but also in global scale. It consists of general information system based on relation database theory that is linked to different modeling tools. It supports energy phase of the structural analysis procedure to assist the decision-making process in a pragmatic way. The model is used for demand analysis, integrated resource planning, and demand side management purposes. [72], [73].

3. **LEAP**: LEAP means Long-range Energy Alternatives Planning System and is developed by the Stockholm Environment Institute in Boston, USA. It is an energy and environmental policy analysis tool for planning medium to long-term time horizon. Various scenarios (business as usual, policy, alternative) can be created using the tool. The energy requirements, their social costs & benefits, and their environmental impacts can be evaluated and compared for different scenarios by using the tool [74].

2.3.6 Selection of Energy Modeling Tool

Although there are different types of models available for energy planning purpose, but the selection of particular modeling tool for a country is a difficult task. For selection of a model for planning purposes, Rath-Nagel (1981) suggested that there are no models which can provide the answer to all questions due to the complexity of energy policy and energy strategy issues; therefore, it will be required several models with different objectives and specifications in order to effectively support the development of energy policies and planning [75]. Van Beeck (2003) realized for capturing impossibility to every aspect of reality in a model and informed that the best model addresses maximum degree of a simplified representation of reality [54]. The examination of model quality is difficult, hence IIASA (2005) stated that a model quality cannot be measured exactly and further suggested that an important assessment criterion of long-term models is that their ability to handle uncertainties and adequately map the real-world system [76].

The selection of a proper model for energy planning process is a tradeoff between availability of planning models and their characteristics and capabilities. Shukla (1995) mentioned that the most of the energy models were built and used in industrialized countries, and it was also assumed that the development of energy systems of developing countries would be followed the same pattern like industrialized countries [55]. The required data for modeling based on model is also challenge for developing countries like Nepal. Worrell et al. (2004) highlighted a number of modeling challenges like data quality, capturing technological potential and technological penetration [77]. According to Jung et al. (2000), the development trajectory of developing countries will be followed the path of the industrialized countries, first a decline of the agriculture sector, then heavily growing industry and later a shift towards the service sector [78]. But in India, it has been observed that the development trajectory has followed a modest industry sector towards the service sector [79]. Thus, the energy system path of developing countries like India has been shown that the path of development is different than the predefined path of developed countries. According to Urban et al. (2007) the main issues for developing countries' energy system are the informal economy, supply shortages, poor performance of power sector, structural economic change, electrification, traditional bio-fuels and urban-rural division [80]. Being a developing country, those characteristics are easily observed in Nepalese energy system too. In addition, the unavailability of appropriate database is also a crucial issue for long term Nepalese energy sector's modeling and planning.

Urban et al. (2007) illustrated that based on the number of characteristics of developing countries address per model, the LEAP model address a large number of characteristics whereas MARKAL model address a medium number of characteristics. It has been concluded that none of the present-day energy models fulfill all requirements adequately by addressing the energy systems and economics of developing countries [80]. Seebregts et al. (2001) emphasized that the MARKAL model is the most widely used and best known in the family of optimization models for supply side planning [81].

The LEAP model has been adopted by thousand of organizations in more than 190 countries worldwide, including governmental agencies, academics, non-governmental organizations, consulting companies and energy utilities [74]. Similarly, MARKAL model has been used more than 70 countries and 230 institutions for energy planning purposes [82]. In connection with this, there are number of studies that have been conducted using LEAP, and MARKAL tools in the world from highly developed to list developed countries and their methodologies are well established and worldwide accepted.

The economic growth and energy demand are closely related [83]. Evan Lau et al. (2011), found that there is casual linkage exist from GDP to energy consumption for seventeen selected Asian countries, including Nepal [84]. Similarly, Ozturk et al. (2012) showed that there is a bidirectional casual linkage between them in the case of India [85].

2.4 Economic Growth of the Country

After the establishment of democratic government in 1991, Nepal adopted open economic policies and started promoting private sectors involvement in business [86]. To demonstrate the adopted policy, government privatized many public enterprises during 1990s. As a result, an accelerated economic growth was observed in some years but, it could not be continued later [87]. In 1996, armed conflict began in the country which caused political instability. The process of economic reforms came in low priority of the nation due to shift of its focus for addressing the solution of emerged new challenge of law and order situation across the country. The armed conflict was ended through comprehensive peace accord between concerned stakeholders in 2006. In 2008, the people elected constitutional assembly and the assembly abolished monarchy and established the country as a federal democratic republic. Unfortunately, the constitutional assembly also could not promulgate constitution thus, it was dissolved. After then, again a new constitutional assembly election was held in 2013, and the newly elected constitutional assembly is under the process for formulating the new constitution of the country.

Figure 2.13 shows the trend of historical GDP growth of the country [88]. From the trend, it has been observed that country's GDP growth was up and down annually. During the period from 1986 to 2011, the average annual GDP growth of the country was about 4.5%.

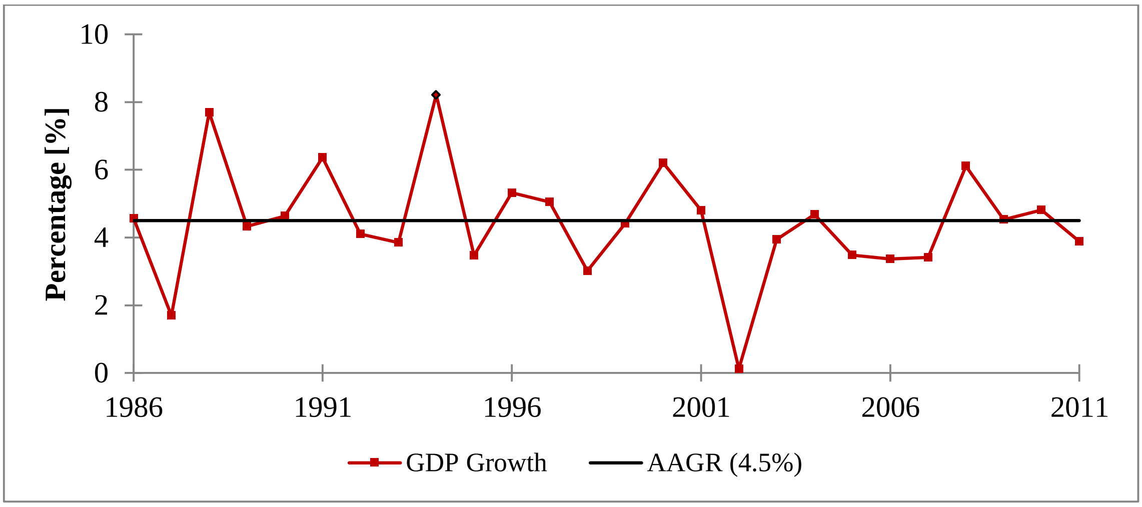


Figure 2.13: Historical GDP Growth Scenario (Source: WB, 2012)

The noticeable concern about the historical GDP growth of the country is that- the past first decade of twenty-first century was not encouraging in terms of economy achievement of the country. There is still political instability in the country and it is really difficult to predict when it will be stabilized. The economy of the country can be classified into three major sectors called agriculture, industrial and service sectors. The Annual average growth rate (AAGR) of value added during the period from 1986 to 2011 was maximum 5.3% in service sector, followed by industrial sector 5% and agriculture sector 3.2% respectively as shown in Table 2.5. The constant price has been chosen for removing the effects of inflation on the economy.

Table 2.5: Historical Sectoral Value Added Values

Amount in Billion NRs	Year						AAGR (%)
Sectors	1986	1991	1996	2001	2006	2011	1986-2011
Agriculture, value added	98.5	119.5	131.6	155.7	183.1	214.8	3.2
Industry, value added	27.9	37.9	56.9	73.6	83.5	93.9	5.0
Services, etc., value added	77.8	102.5	139.4	184.3	213.9	278.7	5.3
GDP (Constant_2000)	216.5	275.4	351.1	441.6	514.5	642.6	4.5

The historical value added trends of agriculture, industrial and service sectors are shown in Figure 2.14, Figure 2.15 and Figure 2.16 respectively. The trends illustrate that the value added growth rates of agriculture and service sectors were more homogenous with their annual average growth rates during the period. But, the value added growth of the industrial sector has been sharply declined since last decade and it has been observed that the maximum growth of the value added was even less than the average value added during the period.

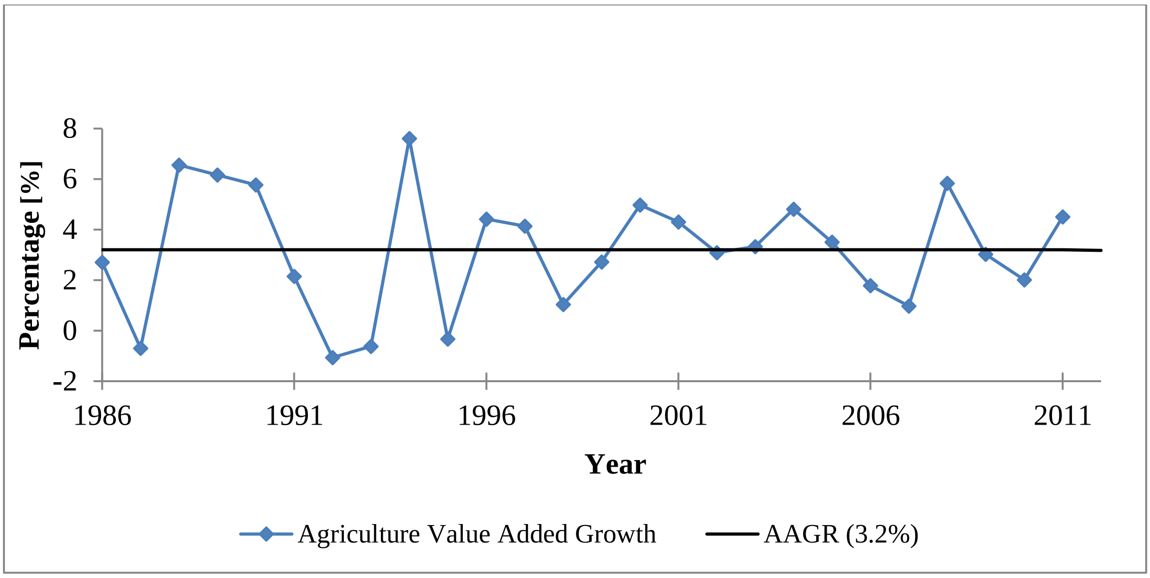


Figure 2.14: Historical Agriculture Sector Value Added Growth Scenario (Source: WB, 2012)

The major problems of industrial sector's development in the country are political instability, industrial insecurity, unfavorable labor relation, minimal availability of energy, week industrial infrastructures, lack of competent human resources, lack of capacity to adopt new technology, low productivity, lack of diversification of exportable items and weak supply management [89]. In reflection of the mentioned problems; the sector is performing poorly in national economy. As a result, its contribution on national GDP was 22.9% in 1997 while it was reduced to 15.3% in the year 2009. To address the sectoral problems, government of Nepal promulgated an industrial policy 2010, including measures to remove weakness of the sectoral development and to promote industrial environment within the country. The policy has taken the objective of increasing the exports of industrial products to make remarkable contribution in national economy. Although, it has aimed the sectoral significant contribution on national economy, it seems hard to achieve in near future because the trend of sectoral contribution on national economy has been decreased. There are some considerable barriers for the sector being ill. Like, the country is a land lock country which lies between India and China. Internal markets are small and possibility of exports of the products is constrained by low efficiency of manufacturing sector in comparison to the neighbors. In addition to this, exporting to third countries is delayed by the additional disadvantages of local infrastructure along with long transport route for accessing to the sea ports [86],[87].

The historical industrial value added (IVA) trend of the country has been shown in the Figure 2.15. The trend has declined that is why the share of contribution of industrial sector in national GDP has also been decreased.

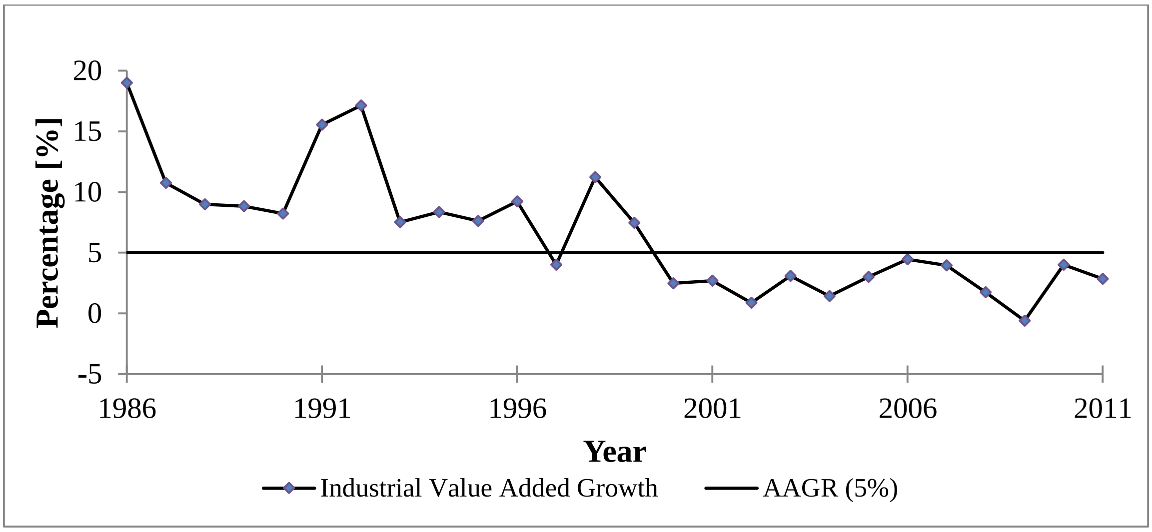


Figure 2.15: Historical Industrial Sector Value Added Growth Scenario
(Source: WB, 2012)

In the GDP structure, the contribution of industrial and agriculture sectors have been decreased where as the contribution of service sector has been increased. Thus, there has been a significant change in the country's economic structure, which is an important factor for the national energy planning process.

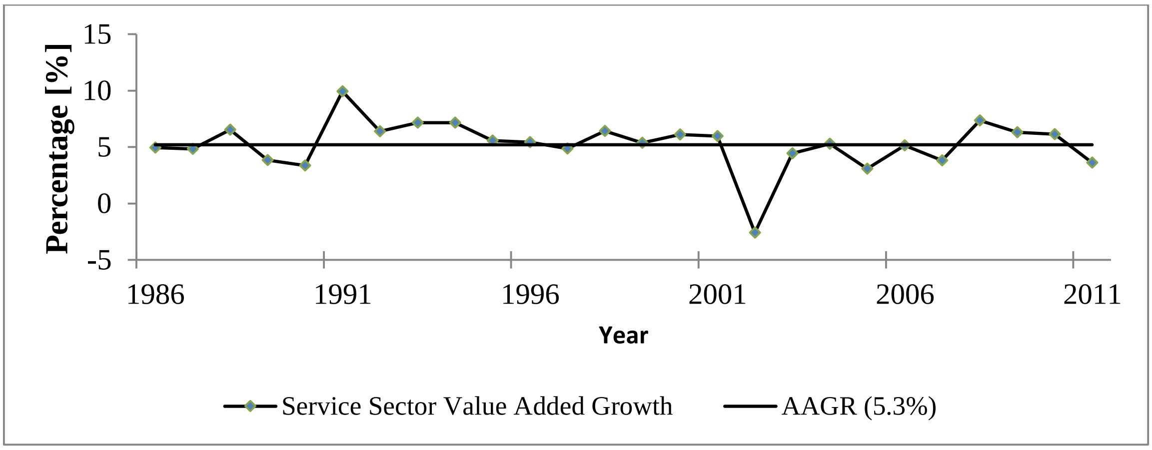


Figure 2.16: Historical Service Sector Value Added Growth Scenario
(Source: WB, 2012)

In recent years, service sector has been emerged as a robust sector for Nepalese economy. It accounts for around half of the GDP and absorbs around 18% of total employment in the country [86]. The service sector is largely composed of traditional activities but financial services are gradually gaining ground.

From 2001 to 2011, Nepal's service sector has grown by an average of 3.9 % per year, which was greater than growth in agriculture (3.4%) and industrial (2.6%) sectors during the same period. Among the biggest contribution in the growth of the sector, the contribution from wholesale and retail trade, transport storage and communications sub-sectors were significant. Wholesale and retail tread has remained the biggest sub- sector, sustained by strong remittance inflows and tourism earnings [90].

2.5 Population Structure of the Country

The total population of the country (June 22, 2011) was 26.5 million showing the growth of 1.35% per annum [48]. Table 2.6, shows the inter-census population with their respective growth rates along with population densities. During 1991 to 2001, the annual population growth was 2.25%, while from 2001 to 2011; the growth was reduced to 1.35%. Despite the decrease of the growth rates, the population density of the country has increased as shown in the Table 2.6.

Table 2.6: Historical Inter-Census Population Changes (Source: CBS, 2003, 2011)

Census Year	Population in Million	Percent (%)	Annual Growth (%)	Per sq.km.
1911	5.64			38
1920	5.57	-1.15	-0.13	38
1930	5.53	-0.74	-0.07	38
1941	6.28	13.58	1.16	43
1952/54	8.26	31.40	2.27	56
1961	9.41	14.01	1.64	64
1971	11.56	22.77	2.05	79
1981	15.02	30.00	2.62	102
1991	18.49	23.09	2.08	126
2001	23.15	25.20	2.25	157
2011	26.49	14.44	1.35	180

The historical data shows that, the percentage of people living in Mountain and Hill zones has been decreased while in the Terai zone, it has increased. In 1971, about 9.9% and 52.5% of total population were living in the Mountain and Hill zones of the country and decreased to 6.8% and 43% respectively in the year 2011. In Terai, about 37.6% of the total population was living in 1971, was increased to 50.3% in the year 2011.

The population growth rate of Terai is greater in comparison to other two zones. From 1971 to 1981, the population growth rate of the Mountain, Hill and Terai zones were 1.4%, 1.7% and 4.1% respectively. Again in these zones, following two inter census (1981-1991), the growth rates were 1.1%, 1.6% and 2.8% respectively. Similarly, during the census (1991 - 2000) the growths rates of population in these three corresponding zones were 1.6%, 2.0% and 2.6% respectively. According to census 2011, the growths were recorded 0.5%, 1.1% and 1.7% annually from 2001 to 2011 for the regions. The historical data shows that there has been a decline in growth rates of population not only in the Mountain and Hill zones, but also in Terai zone of the country. Table 2.7 shows the structure of population on the three ecological zones of the country. The table demonstrates that the percentage of population living in the Mountain and Hill has decreased while the percentage of population living in the Terai has increased. According to the 2011 census, there was more than half of total national population living in Terai zone of the country alone, which holds only 17% land area of the country having major agricultural purpose [48],[91].

Table 2.7: Structure of Population in Ecological Zone of Nepal
(Source: CBS, 2003, 2011)

Census Year	Mountain (%)	Hill (%)	Terai (%)
1971	9.9	52.5	37.6
1981	8.7	47.7	43.6
1991	7.8	45.5	46.7
2001	7.3	44.3	48.4
2011	6.7	43.0	50.3

The shares of people living in the five development regions of the country are not uniform and varying in nature. The tabulated historical data in Table 2.8, shows that there has been a change in structure of population among the development regions. According to the table, the percentage shares of people living in Eastern Development Region (EDR) and Western Development Region (WDR) have decreased while the shares of people living in remaining Centre Development Region (CDR), Mid Western Region (MWD), and Far Western Development Region (FWDR) have increased.

Table 2.8: Historical Population Structure on Based on Development Regions (Source: CBS, 2003, 2011)

Development Region	1971	1981	1991	2001	2011
Eastern (%)	24.2	24.7	24.0	23.1	21.9
Central (%)	33.4	32.7	33.4	34.7	36.5
Western (%)	21.2	20.8	20.4	19.7	18.6
Mid Western (%)	12.9	13.0	13.1	13.0	13.4
Far Western (%)	8.3	8.8	9.1	9.5	9.6
Total(Million People)	11.6	15.1	18.5	23.2	26.5

There are also the structural changes of population within the eco-zones of the development regions of the country. Within the development regions, the population structures on the different ecological zones were different as shown in Table.2.9. The share of population living in the Mountain has been decreased while the shares of population living in Hill and Terai ecological zones have been increased, except the Hill ecological zone of the Central Development region. The percentage increase of population on the region is due to the high population growth in Kathmandu Valley which also includes the capital city Kathmandu, of the country.

Table 2.9: Structure *of Population in Different Eco-Development Regions of Nepal (Source: CBS, 2003)*

Dev. Region	Year	1971	1981	1991	2001
EDR	[%] of Nepal	24.2	24.7	24.1	23.1
	EM	10.9	9.1	8.1	7.5
	EH	39.5	33.9	32.1	30.8
	ET	49.6	57.0	59.8	61.7
CDR	[%] of Nepal)	33.4	32.7	33.4	34.6
	CM	9.2	8.4	7.6	6.9
	CH	45.0	43.0	43.3	44.1
	CT	45.8	48.6	49.1	49.0
WDR	[%] of Nepal	21.2	20.8	20.4	19.8
	WM	1.4	0.6	0.5	0.5
	WH	74.2	68.8	64.2	61.1
	WT	24.4	30.6	35.3	38.4
MWDR	[%] of Nepal	12.9	13.0	13.0	13.0
	MWM	13.9	13.8	10.8	10.3
	MWH	59.5	51.9	50.6	48.9
	MWT	26.6	34.3	38.6	40.8
FWDR	[%] of Nepal	8.3	8.8	9.1	9.5
	FWM	24.9	21.9	19.8	18.1
	FWH	54.4	43.8	40.0	36.5
	FWT	20.7	34.3	40.2	45.4

The percentage of urban population along with the number of urban places in each of successive census from the year 1952/54 to the year 2011 has been tabulated in Table 2.10. Only 2.9% of the total population were living in 10 urban places of the country in 1952/54, but the percentage of people living in 58 urban places rose to about17% of total population in 2011 as shown in the table [48], [91].

Table 2.10: Historical Urban Places and Population Structure of Nepal

(Source: CBS, 2003, 2011)

Census Year	Number of urban Places	Urban population(Thousand)	Urban Pop. (%)
1952/54	10	238	2.9
1961	16	336	3.6
1971	16	461	4.0
1981	23	956	6.4
1991	33	1695	9.2
2001	58	3227	13.9
2011	58	4523	17

2.6 Previous Studies Related to Energy Demand of the Country

Pradhan et al. (2006) estimated the consequences in fuel consumption and greenhouse gas emission due to the possible intervention of the electric run trolley buses in Kathmandu till 2025 using Long-range Energy Alternative Planning (LEAP) framework [92]. In the study, the future passenger travel demand was projected using population and income. In the analysis, the final energy demand was calculated through projected plying vehicles on the road and corresponding fuel economy and emission values of the vehicles. Pokharel (2007) used the econometric model to provide medium-range energy demand projections from 2007 to 2012 of the country [83]. Parajuli et al. (2013) also used the econometric approach for energy consumption projections of the country from the year 2010 to 2030 under different growth scenarios of national economy [93]. Shrestha et al. (2010) analyzed the potential implications of adopting a policy of CO_2 emission reduction from Kathmandu Valley using Market Allocation (MARKAL) framework from 2005 to 2050 [94]. In the study, the future service demands of residential and road transport sectors were projected by using population and GDP. Similarly, GDP only was used for estimation of the demands of air passenger, air freight and road fright whereas, sectoral GDP was used for estimation of agriculture, commercial, industrial and service sectors demand projections. Shakya et al. (2011) analyzed the effects of different levels of road transport systems electrification over a long term horizon from the year 2015 to 2050 in Nepal using MARKAL framework [95]. In the study, the methodology used by Shrestha et al. had been used for service demand projections. In both of the study, the projected service demands were used to MARKAL framework exogenously for supply side energy planning with analyzing the implications of technology, economy and environment respectively.

Chapter 3
Research Methodology

3.1 Approach and Scenario Developments

The final energy demand of the country has been determined by adding energy demands of residential, transport, industrial, commercial, agricultural and others sectors. The demands of the residential, road transport, industrial, agriculture and commercial sectors are determined through end use methodological approach on the base year 2005, and further projections of the demand are based on the function of population, GDP per capita, and corresponding economic sectoral value added of the country. For road transport, the actually plying vehicles on the road in the base year have been estimated and further projected with econometric as well as trend analysis approach. The final energy demand of the sector has been determined by using the information about - the actually plying vehicles on the road, the annual average distance travelled and the fuel economy of the corresponding vehicles. The two remaining energy demanding sectors - aviation transport and others energy demand projections are based on econometric approach. The applied methodological approach, along with formulated sector wise model has been elaborated in following sections of this chapter.

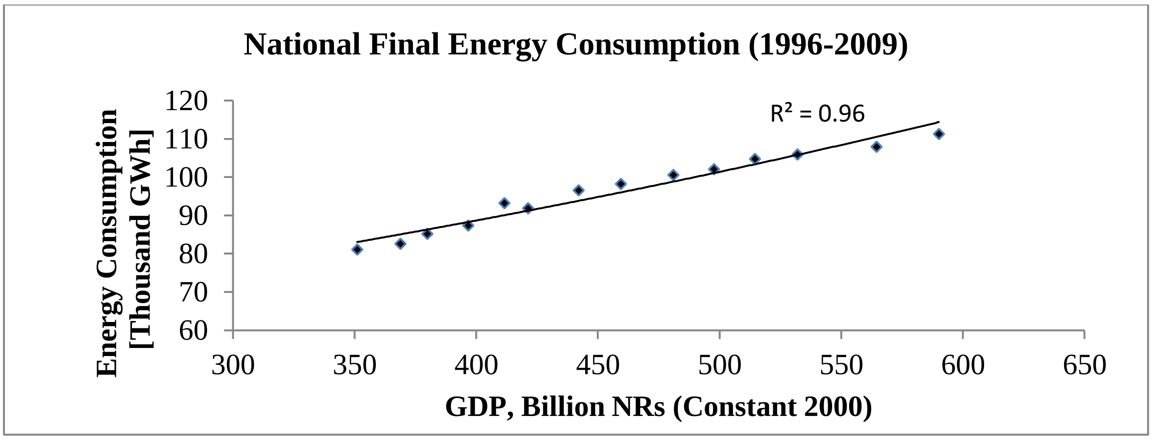


Figure 3.1: Relation between National Energy Consumption and GDP Growth (Source: WECS, 2010 & WB, 2012)

Figure 3.1 shows the relationship between the total energy consumption of the country and the national GDP during the period from 1996 to 2009. The figure clearly illustrates that, the energy consumption demand of the country has been guided by national economic condition of the country. The sector wise relationship between the energy consumption and economic situation of the country has been illustrated in corresponding sections of this chapter.

Scenarios are foresight of the forthcoming trend. They help to capture the image of alternative future and have been used by a number of global studies as a tool to assess possible future paths of energy system developments. To capture the future energy demand of the country, this study has been considered following four annual growth scenarios, by analyzing the historical economic growth pattern of the country:

1. Business as usual scenario (3.9% GDP growth)
2. Low growth scenario (4.4% GDP growth)
3. Medium growth scenario (5.6% GDP growth),and
4. High growth scenario (6.5% GDP growth)

Among the selected growth scenarios, the medium growth scenario has been chosen for further policy intervention on residential and industrial sectors of the country.

3.2 Formulation of the Models

For residential, industrial, commercial, and road transport sectors, the LEAP demand model for each sector has been formulated for analyzing the structure of the sectoral energy demand of the country. Each of the formulated sectoral energy demand models has been described in following sections:

3.2.1 Model for Residential Sector

A long-term residential sector's energy demand model has been formulated for the study using the LEAP framework as shown in Figure 3.2. End –use methodology combined with econometric and trend analysis has been used for energy demand projections of the sector. For the base year, the consumptions of the energy in different applications are calculated from end-use methodology. Energy demand analysis has been carried out for various end use applications. For urban sub - sector there are seven end uses, which are cooking, lighting, heating & cooling, agro-processing, animal food processing, electric appliances and others. Similarly in rural areas, there are also seven end-use applications which are cooking, heating, cooling, lighting, water boiling, use of electric appliances and other uses. The historical energy consumption data from 1996 to 2009 are used for regression and trend analysis purpose in this study [24].The selected models values for future projections of the intensities of fuels are presented in the Appendix-1.

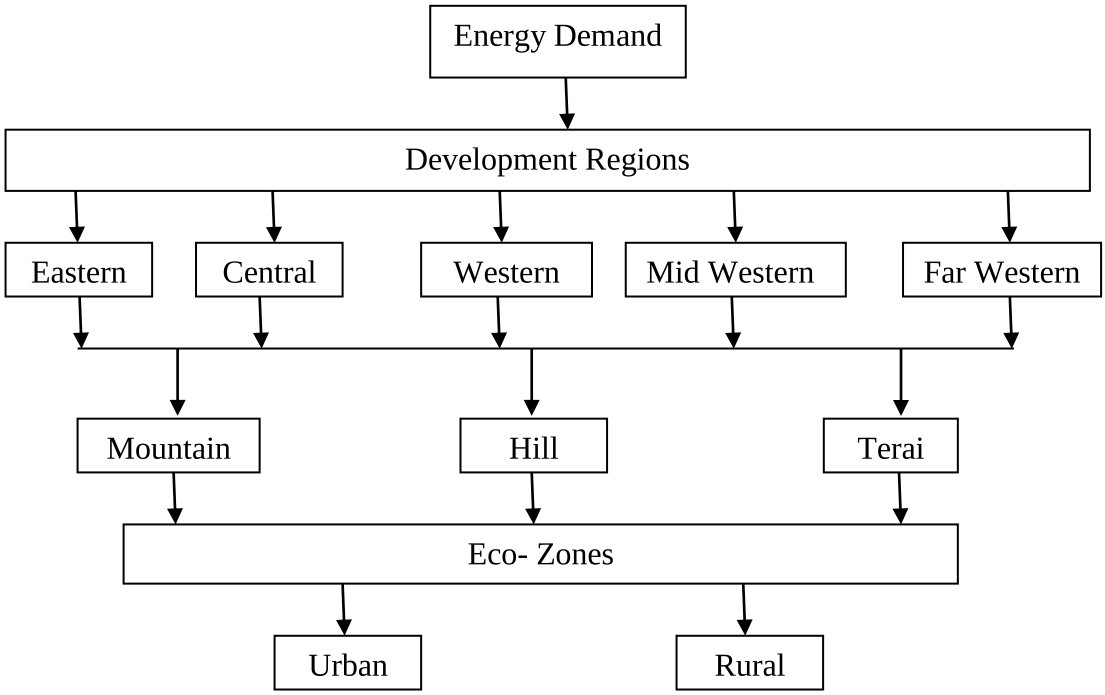


Figure 3.2: Modeling Framework for Residential Sector Energy Demand
(Source: Author)

In the sector, the population and income per capita have been considered for future energy demand projections. Figure.3.3 illustrates about how the per capita energy consumptions of the people have been changed with the change in their per capita incomes. To capture the sectoral future energy demand, several growth scenarios have been selected by analyzing the historical GDP growth scenario of the country.

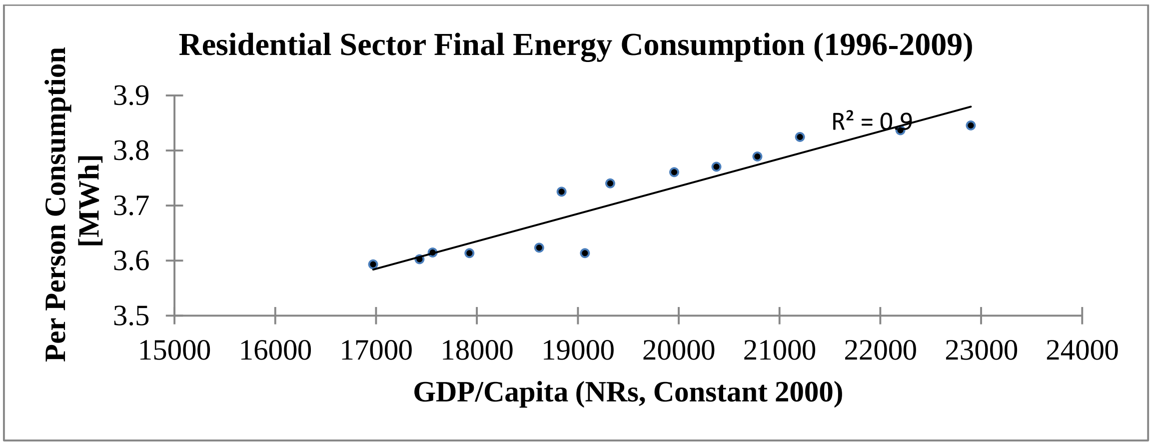


Figure 3.3: Relation between Residential Energy Consumption per Capita and GDP per capita (Source: WECS, 2010 & WB, 2012)

The selected different growth scenarios are business as usual (3.9% GDP growth), low economic growth (4.4% GDP growth), medium growth (5.6% GDP growth) and high growth (6.5% GDP growth). Among the growth scenarios, the medium growth scenario has been taken for reference case for LPG substitution (policy scenario) in the sector.

Mathematically (adopted from LEAP planning tool),

$$D_{b, s, t} = TA_{b, s, t} \text{ x } EI_{b, s, t} \quad (3.1)$$

Where D is energy demand, TA is total activity, EI is energy intensity, b is the branch, s is scenario and t is the year (ranging from the base year [0] to the end year). All scenarios evolve from the same current accounts data, so that when t=0, the above equation can be written as:

$$D_{b, 0} = TA_{b, 0} \text{ x } EI_{b, 0} \quad (3.2)$$

The energy demand calculated for each technology branch is uniquely identified with a particular fuel . Thus, in calculating all technology branches, the model also calculates the total final energy demand from each fuel.

The total activity level for a technology is the product of the activity levels in all branches from the technology branch back up to the original demand branch. Mathematically,

$$TA_{b, s, t} = A_{b', s, t} \text{ x } A_{b'', s, t} \text{ x } A_{b''', s, t} \text{ x} \quad (3.3)$$

Where A_b is the activity level in a particular branch b, b' is the parent of branch b, b'' is the grandparent, etc.

3.2.2 Models for Industrial Sector

End – use methodology combined with historical trend analysis has been used for energy demand projections for the sector. In the model, the data are assembled in a hierarchical order from sector (industrial) level to technology (fuel use) level. The sector level has been followed by seven sub sector levels which are food beverage & tobacco, textile & leather, chemical, rubber & plastic, mechanical engineering & metal products, electric engineering products, wood & paper products and other manufacturing.

In each sub - sector, there are five end uses (i.e., motive power, boiler, process heat, lighting and others). Finally, the data are arranged according to fuel use (i.e., coal, electricity, diesel etc.) for each application. For base year, the energy consumption has been calculated from end-use methodology. In the formulated methodological framework, the energy demand has been calculated by multiplying the activities (energy services) by energy intensities (fuels intensities) of corresponding end uses. The prediction of growth rates of activities and energy intensities are exogenous to the model. The way for the sectoral demand projections is based on industrial value added approach. Figure 3.4 shows the historical relationship between industrial energy consumption and industrial value added of the country.

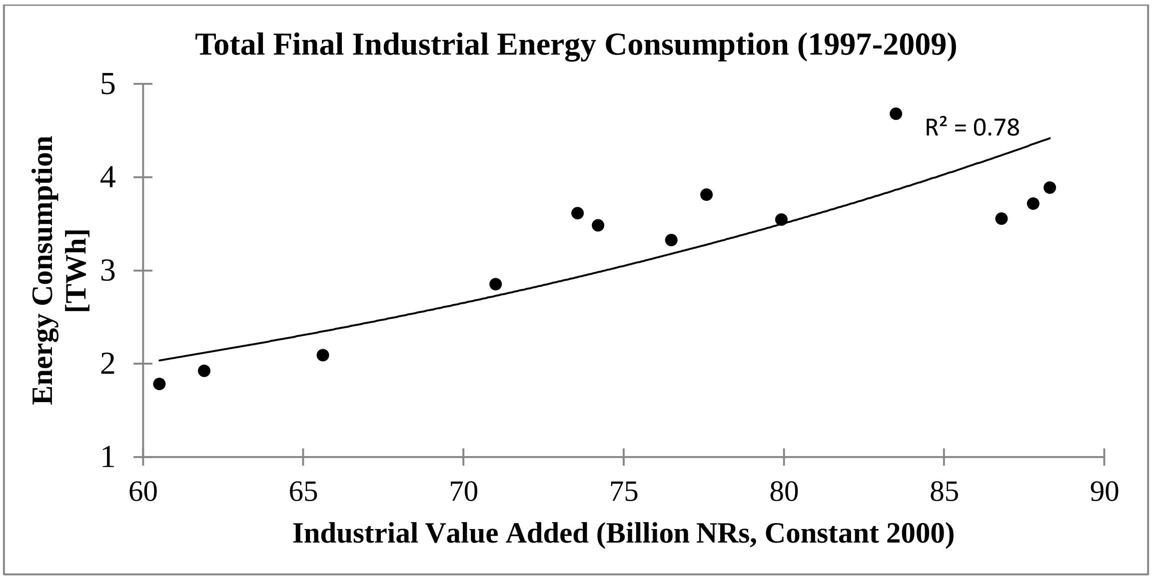


Figure 3.4: Variation of Energy Demand due to Variation of Industrial Value Added (Source: WECS, 2010 & WB, 2012)

The energy intensity for industrial sector has been calculated on the basis of quantity of energy used in particular year to the value added for the sector in the year. In the analysis, energy intensity for each fuel used in the sector has been taken in MJ/ $ (1 US $ equals 71 NRs in the year 2000). The future projections of the intensities of the fuels are elaborated in the Appendix-2.

In model, the final energy demand has been calculated as the product of the total activity levels and energy intensity at each given technological branch.

Mathematically, the demand of the sector has been calculated and further projected by using the equations (3.1), (3.2), and (3.3) respectively.

3.2.3 Models for Commercial Sector

A commercial sector energy demand model has been formulated for this study using LEAP framework. End –use methodology combined with trend analysis has been used for energy demand projections. In this model, the data are assembled in a hierarchical order from sector level (commercial) to technology (fuel use) level. Sector level (commercial), is followed by eight sub - sectors which are restaurant, hotel, academic institution, essential and non essential, hospital, institution, cinema hall and water supply. In each sub- sector, there are seven end uses (i.e., cooking, space heating, space cooling, water boiling, electric appliances, lighting and others).

Finally, the data are arranged based on each end use according to fuel use (i.e., fuel wood, kerosene, electricity and LPG). For base year, the energy consumption has been calculated from end-use methodology. In the formulated methodological framework, the energy demand has been calculated by multiplying the activities (energy services) by energy intensities (fuels intensities) of corresponding end uses. The prediction of growth rates of the activities and energy intensities are exogenous to the model. Figure 3.5 shows the historical relationship between commercial sector energy consumption and service sector value added of the country.

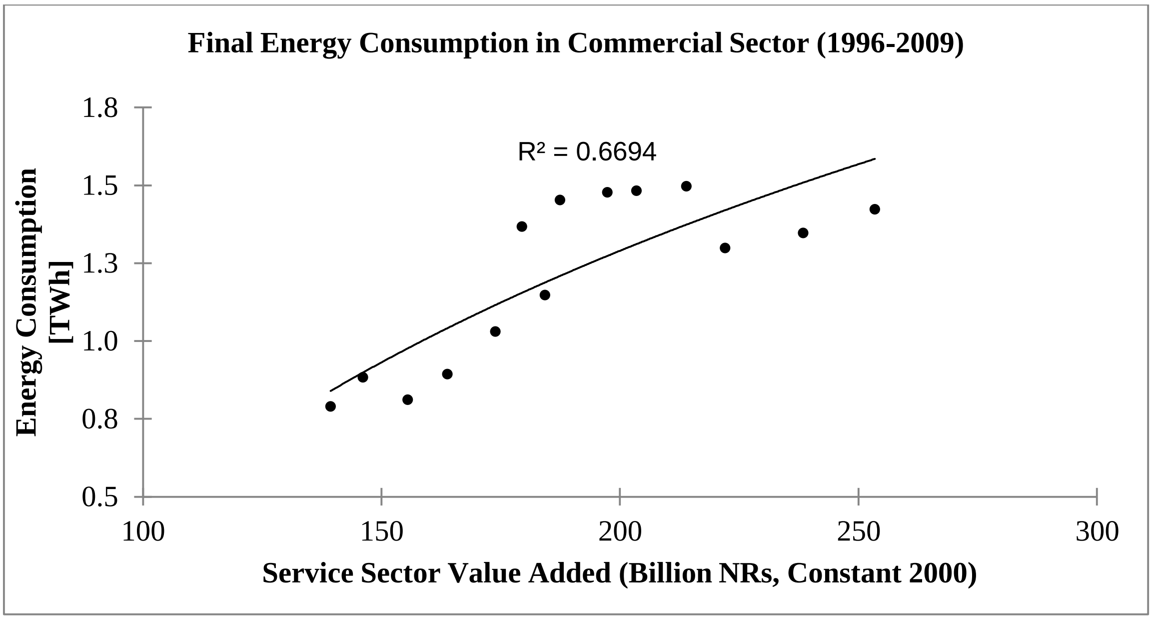


Figure 3.5: Variation of Energy Demand due to Variation of Service Sector Value Added (Source: WECS, 2010 & WB, 2012)

The energy intensity for the sector has been calculated on the basis of quantity of energy used in particular year to the value added for the sector in that year. Due to limitation of database, service sector value added has been considered instead of commercial sector. The energy intensity for each fuel used in the sector has been taken in MJ/ \$ (1 US \$ equals 71 NRs in 2000) in the study. The future projections of the intensities of the fuels are elaborated in the Appendix-3.

In the model, the final energy demand has been calculated as the product of the total activity level and energy intensity of each given technological branch. Mathematically, the demand has been calculated and projected for future by using the equations (3.1), (3.2), and (3.3) respectively.

3.2.4 Model for Transport Sector

A bottom-up energy demand model for road transport has been formulated using the LEAP framework. Following equation has been used for demand calculation and further projection of it:

$$D_{i,j} = \sum V_i(t) \times VKT_i\,(t) \times E_i(t) \tag{3.4}$$

Where,

$D_{i,j} = Energy\ demand\ by\ vehicle\ type\ i\ and\ fuel\ type\ j$

$V_i(t)\ = Total\ number\ of\ vehicles\ type\ i, in\ year\ t\ plying\ on\ road$

$VKT_i(t) = Annual\ average\ distance\ travelled\ by\ Vehicle\ i\ in\ year\ t$

$E_i(t)\ = Fuel\ economy\ of\ Vehicle\ type\ i\ in\ year\ t$

The actual plying vehicles on the road are unavailable but, the database of Department of Transport Management, Government of Nepal provides annual vehicular registration since 1991 [97]. There are also limited practice for keeping the information regarding de-registration of the vehicles which are out of service. Thus from available database, the actual plying vehicles on the road are estimated by using the following probability based estimation [96], [98], [99].

$$V_i(t) = 0.5\ \times R_{i,t} + \sum_{x=1991}^{t-1} R_{i,x}\ \times S_{i.}\,(t-x) \tag{3.5}$$

Where,

$V_i(t)\ = Number\ of\ vehicles\ type\ i\ actually\ plying\ on\ the\ road\ for\ the\ year\ t$

$R_{i,t}\ = The\ number\ of i\ type\ of\ vehicles\ sold\ in\ year\ t.$

$S_{i.(t-x)} = Survival\ rate\ of\ vehicle\ category\ i\ for\ age\ (t-x)$

The survival rates of the vehicles are estimated with following function.

$$S_{i,k}\ =\ P_i(k) = exp\left[-\left(\frac{k-\alpha_i}{T_i}\right)^{\beta i}\right]\ and\ P_i(0) = 1 \tag{3.6}$$

Where,

$'T'\ is\ the\ characteristics\ service\ life\ of\ the\ vehicle,$

$'\alpha', and\ '\beta'\ are\ the\ failure\ steepness\ and\ ; 'i'\ is\ the\ type\ of\ vehicle$

$'k' is\ the\ age\ of\ vehicle$

For high survival rate α=0, and for low survival rate $\alpha = \beta$. In the study, low survival rate has been considered and the value of 'α' for different vehicles are taken from

Baidya et al. (2009) [99]. The characteristics service life of vehicles 'T' has been taken from Shakya et al. (2012), and Bajracharya et al. (2013) [95], [96]. The selected values are presented in Appendix-4.

The base year stocks, lifecycle profiles, future sales along with survival profile of the vehicles are used to estimate future plying vehicles on the road. Figure 3.6 shows the historical relationship between land transport and GDP of the country. The separate models bases on econometric and trend analysis approach have been formulated for future projection of sales of the vehicles from available database during 1990 to 2010. The selected models for the study are explained in Appendix-5.

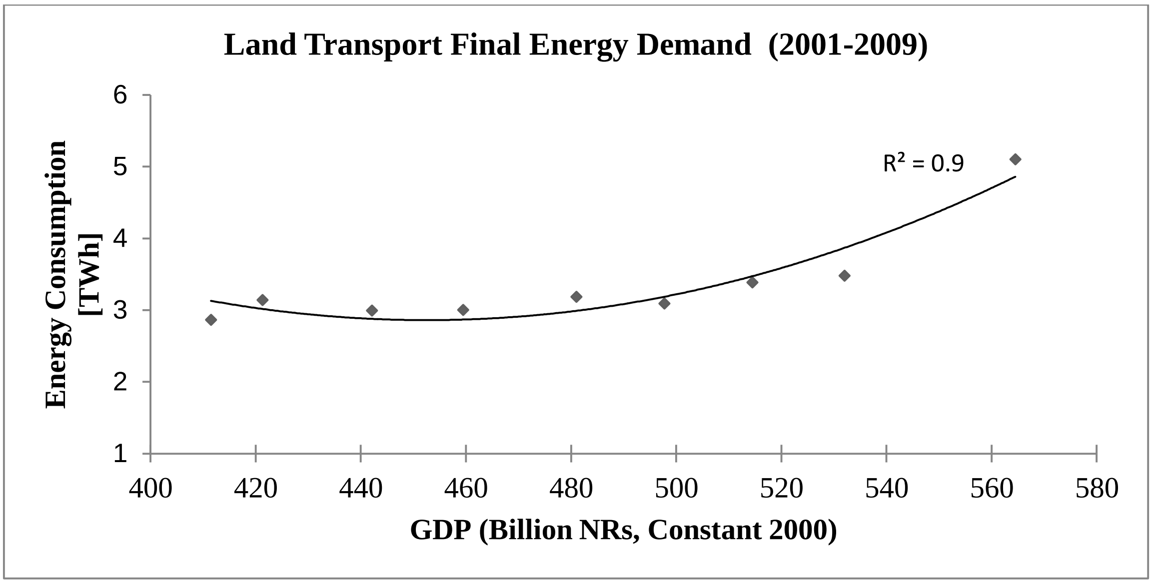


Figure 3.6: Relation between land transport and GDP

(Source: WECS, 2010 & WB, 2012)

The values of annual distance travelled by vehicles type $VKT_i(t)$, and vehicle fuel economy $E_i(t)$, have been taken from the survey conducted by AEPC (2013), Bajracharya et al. (2013), and Dhakal (2003) [96], [100],[101]. In the study, the annual distance travelled and fuel economies have been considered uniform throughout the projected period. The values of $VKT_i(t)$ and $E_i(t)$ are presented in the Appendix-6&7.

Figure.3.7 shows the energy demand of an aviation sector in relation with GDP of the country. Only the aviation turbine fuel has been used in the sector for meeting the demand.

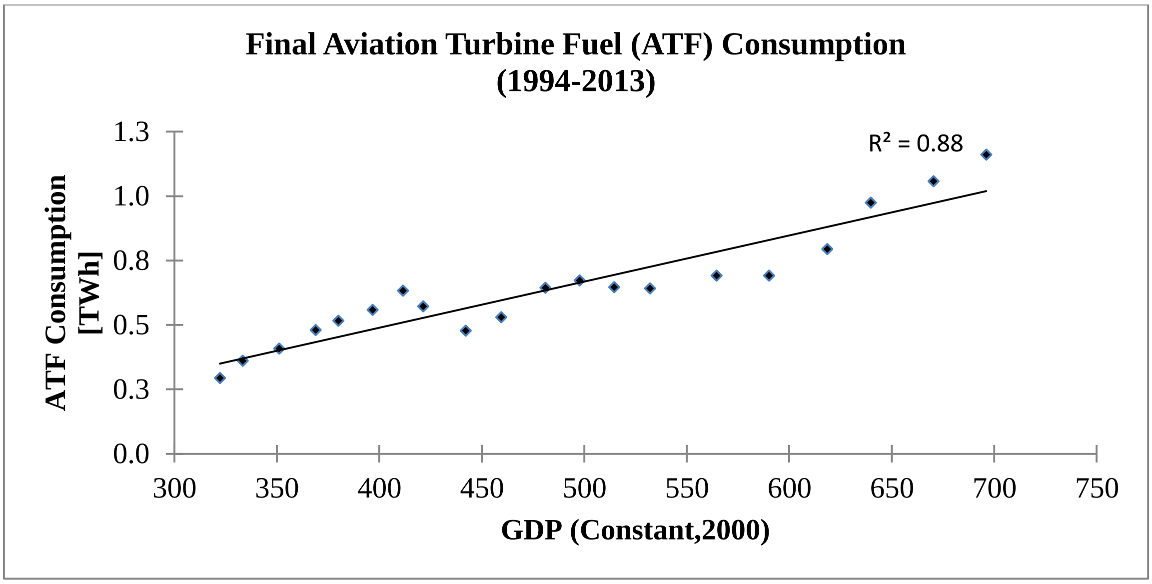


Figure 3.7: Relation between GDP and ATF Fuel Consumption

(Source: WECS, 2010 & WB, 2012)

The aviation transport fuel demand has been projected with an econometric approach. The selected model for the air fuel demand is as follows:

$$Air\ Fuel\ Demand(TJ) = -817.318 + 6.44 \times GDP(in\ Billion\ NRs) \tag{3.7}$$

$$(\ t - stat) \qquad (-2.823) \qquad (11.077)$$

$$R^2 = 0.88$$

3.2.5 Model for Agriculture Sector

The sectoral energy demand model has been formulated for this study using LEAP framework. End –use methodology combined with trend analysis has been used for energy demand projections. In this model, the data are assembled in a hierarchical order from sector level (Agriculture) to technology (fuel use) level. There are three end uses (i.e., Irrigation, Threshing and Tillage). Finally, the data are arranged with each end use application along with the fuel uses (i.e., electricity and diesel) for the application.

For the base year, the consumption of energy has been calculated from end-use methodology. In formulated methodological framework, the energy demand has been calculated by multiplying the activities (energy services) by energy intensities (fuels intensities) of corresponding end uses. The prediction of growths of activities and energy intensities are exogenous to the model. The basis for the demand projections is depended on the agriculture sector value added along with energy intensity approach.

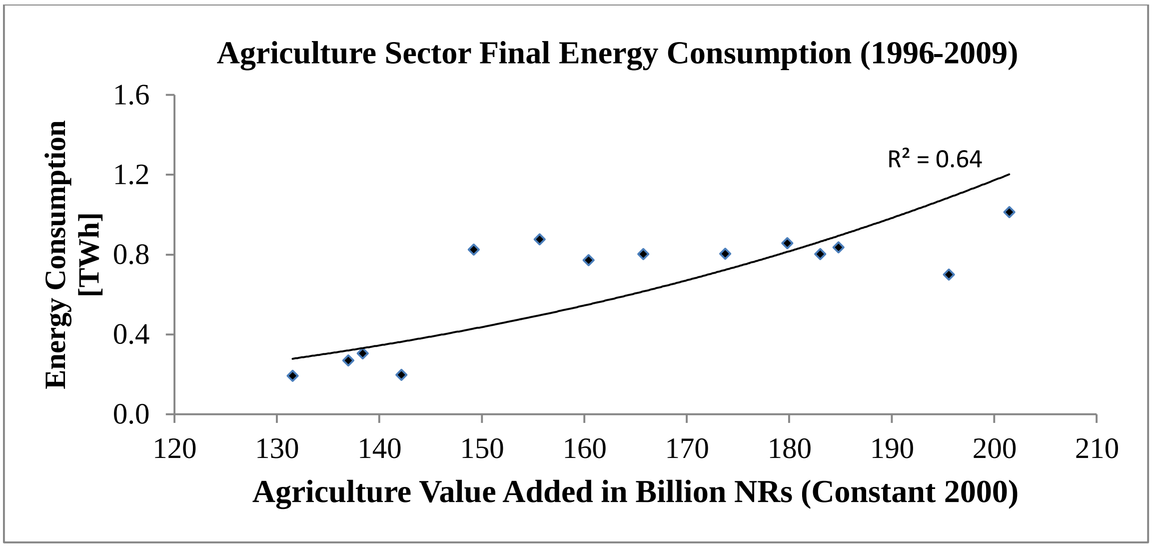


Figure 3.8: Relation between agriculture sector energy consumption and agriculture value added (Source: WECS, 2010 & WB, 2012)

The energy intensity of the sector has been calculated on the basis of quantity of energy used in particular year to the value added for the sector in that year. The energy intensity for each fuel used in the sector has been taken in MJ/ $ (1 US $ equals 71 NRs in 2000) in the study. The projected future intensities of the fuels are elaborated in the Appendix-8.

3.2.6 Model for Others Sector

The others sector only consumes electrical energy. Figure 3.9 shows the relationship between historical electricity consumption of the sector in relation with the country's GDP growths.

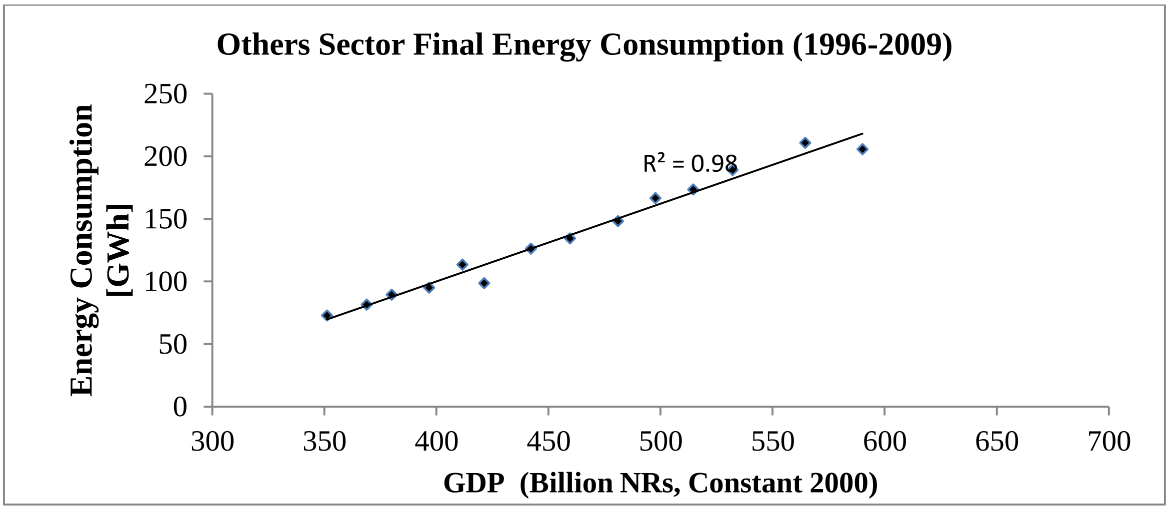


Figure 3.9: Relation between GDP and Energy Consumption in Others Sector (Source: WECS, 2010 & WB, 2012)

The electricity demand for the future has been projected with econometric approach. The selected model for other's sector electricity demand is as follows:

$$Demand\ (PJ) = -0.532 + 0.0022 \times GDP(in\ Billion\ NRs) \quad (3.8)$$

$$(\ t - stat) \qquad (-12.13) \qquad (23.58)$$

$$R^2 = 0.98$$

3.3 Sources of Data

The energy intensities for different end use applications are taken from Water and Energy Commission Secretariat (WECS) reports [102],[103], [104], [105], [106].The historical GDP and value added data are taken from world bank (WB) database [88]. The demographic data are taken from various publications of the Nepal Bureau of Statistics [48], [107], [108]. Similarly, the historical energy consumption data of the country has been taken from the WECS report [24].

The annual distance travelled by vehicles type $VKT_i(t)$, and vehicle fuel economy $E_i(t)$, have been taken from the survey conducted by Alternative Energy Promotion Centre (AEPC) (2013), Bajracharya et al. (2013) and Dhakal (2003) [96], [100],[101]. In the study, the annual distance travelled and fuel economy has been taken as being uniform during the projected period. Besides the mentioned sources, other various types of data have also been used to carry out the research, and their sources are mentioned in corresponding sections of this study.

3.4 Key Driver Projections and Boundaries of the Study

The population, GDP, sectoral value added, and energy intensities are the key drivers for this study. Therefore, as per requirement for the study, these variables have been projected as follow:

3.4.1 Demographic Developments

The total population of the country on the census day (June 22, 2011) was 26.5 million showing population growth of 1.35% per annum from the year 2001[48]. For this study, the total population of the country has been projected with 1.35% annual growth up to 2030. For structural changes of population across the nation, medium variant growth up to 2021 has been considered and beyond it, the projections have been carried out based on historical patterns. The urban sub sector population (different places) are computed from CBS medium variant growth by taking account of structural changes of the population across the country [107], [108]. Figure 3.10 shows the projections of the total and urban population of the country till 2030.

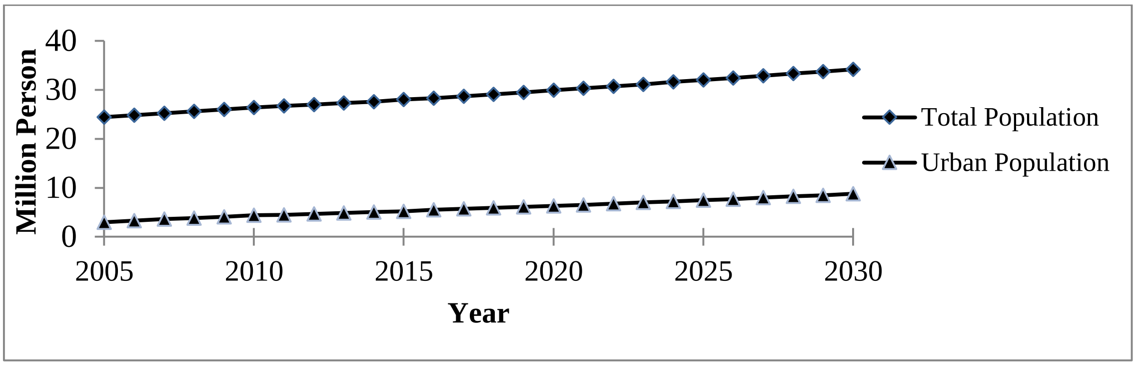


Figure 3.10: Projected Total and Urban Population of the Country

(Source: CBS, 2003, 2011 & Author)

According to the projection, the total population of the country will be reached to 34.2 million by the year 2030. The share of the urban population in the year 2030 will be about 25.8 % of the total population of the country. Table 3.1 shows the structures of projected country's population. The annually projected urban and rural populations of the country are presented in the Appendix-9.

Table 3.1: Projected Population Structures of the Country

(Source: CBS, 2003, 2011 & Author)

Population	Year					
in Million	2005	2010	2015	2020	2025	2030
Urban	3.6	4.2	5.2	6.3	7.5	8.8
Rural	20.8	21.9	22.8	23.6	24.5	25.4
Total	24.4	26.1	28.0	29.9	32.0	34.2

People living in the five development regions of the country are not homogeneous but varying in nature. In 1997, about 24.2% of the total population was living in EDR of the country. The percentage of population living in the region was gradually decreased to 23.1% in 2001. By following the historical trend, it has been projected that by 2030 about 22.4 % of population will be living in this region. Table 3.2, shows the historical and projected structures of the population in different ecological zones of the country. This table shows the changing structure of the population structures across the country during the study period.

Table 3.2: Historical and Projected Structure of Population in Different Ecological Regions of the Country (Source: CBS, 2003 & Author)

Dev. Reg.		Year									
	Year	1971	1981	1991	2001	2006	2011	2016	2021	2026	2030
EDR	(%)	24.2	24.7	24.1	23.1	23.2	22.7	22.7	22.6	22.3	22.4
	EM	10.9	9.1	8.1	7.5	7.4	7.3	7.2	7.1	7.0	6.9
	EH	39.5	33.9	32.1	30.8	30.4	30.2	30.0	29.9	29.6	29.4
	ET	49.6	57.0	59.8	61.7	62.2	62.5	62.8	63.0	63.4	63.7
CDR	(%)	33.4	32.7	33.4	34.6	34.7	35.1	35.2	35.3	35.5	35.7
	CM	9.2	8.4	7.6	6.9	6.7	6.6	6.5	6.5	6.3	6.2
	CH	45.0	43.0	43.3	44.1	44.4	44.5	44.8	44.8	45.3	45.2
	CT	45.8	48.6	49.1	49.0	48.9	48.9	48.7	48.7	48.4	48.6
WDR	(%)	21.2	20.8	20.4	19.8	19.9	19.7	19.5	19.4	19.4	19.2
	WM	1.4	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
	WH	74.2	68.8	64.2	61.1	60.4	59.8	59.4	59.0	58.4	57.9
	WT	24.4	30.6	35.3	38.4	39.1	39.7	40.0	40.4	41.0	41.5
MWDR	(%)	12.9	13.0	13.0	13.0	13.0	13.1	13.1	13.1	13.1	13.0
	MWM	13.9	13.8	10.8	10.3	10.1	9.9	9.9	9.9	9.8	9.7
	MWH	59.5	51.9	50.6	48.9	48.5	48.0	47.9	47.7	47.3	47.1
	MWT	26.6	34.3	38.6	40.8	41.4	42.1	42.2	42.4	42.9	43.2
FWDR	(%)	8.3	8.8	9.1	9.5	9.2	9.4	9.5	9.6	9.7	9.7
	FWM	24.9	21.9	19.8	18.1	17.6	17.5	17.2	17.0	16.7	16.4
	FWH	54.4	43.8	40.0	36.5	36.1	35.1	34.5	34.6	33.7	33.3
	FWT	20.7	34.3	40.2	45.4	46.3	47.4	48.3	48.4	49.6	50.3

3.4.2 Economic Growth Targets

Figure 3.11 shows the historical GDP growth trend along with its projected values under anticipated four growth scenarios of the country [88]. From the trend, it has been observed that country's GDP growth was up and down annually. Thus, it is difficult to predict exact single value of GDP growth for future. As the energy demand varies according to the growth, and if the projected growth will not match in the future, then there will be a possible mismatch between the national energy demand and supply system. To capture the future energy demand, the four anticipated growth scenarios have been considered in this study by analyzing the historical growth trend of the country. The selected different growth scenarios for the purpose are business as usual (3.9%, GDP growth), low economic growth (4.4%, GDP growth), medium economic growth (5.6%, GDP growth), and high economic growth (6.5%, GDP growth) respectively. Among the growth scenarios, medium growth has been taken as reference scenario for LPG substitution in residential sector and energy saving in industrial sector (policy scenarios).

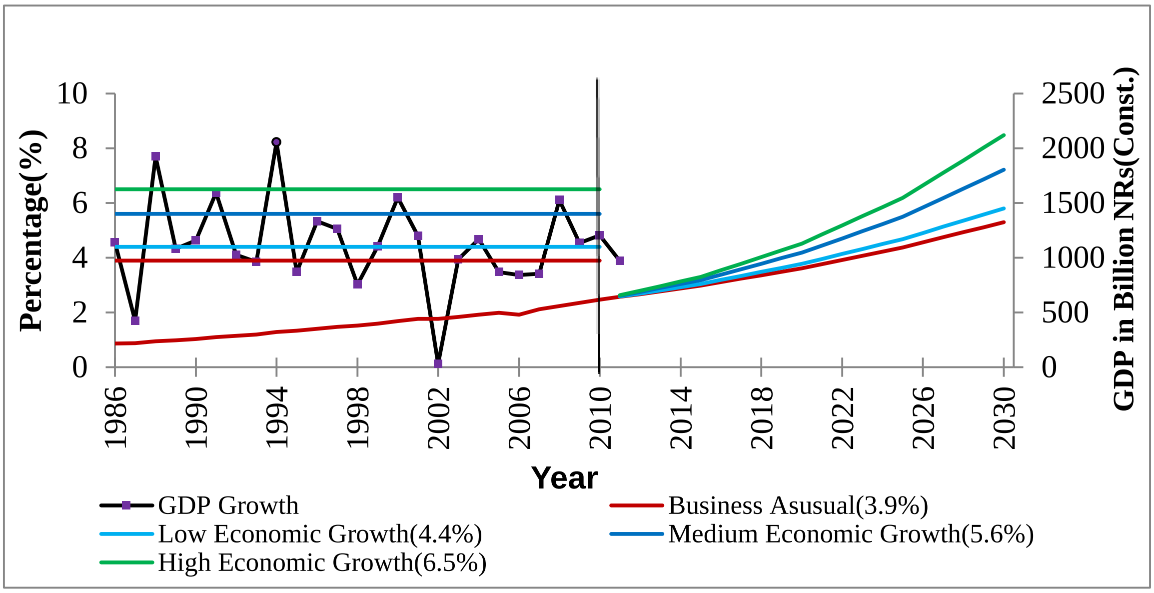


Figure 3.11: Projection of GDP under Selected Scenarios

(Source: WECS, 2010 & WB, 2012)

The Gross Domestic Product (GDP) value at 2005 was NRs 496.1 billion. In this study, the actual historical growth rate of GDP up to 2010 has been considered. From 2011, four GDP growth scenarios have been taken for analysis purpose. For business as usual scenario, the GDP growth of the year 2011 has been taken and assumed the growth will be continued during the study period. The projected growth scenarios have been shown in the Figure 3.11. In the year 2030, the projected value of GDP in business as usual, low growth, medium growth and high growth will be NRs 1324.5 billion, NRs 1451.0 billion, NRs 1802.4 billion and NRs 2118.4 billion respectively as shown in Table 3.3.

Table 3.3: Structure of GDP under Selected Growth Scenarios of the Country

(Source: WB, 2012 & Author)

Billion NRs	2005	2010	2015	2020	2025	2030
Business As usual (3.9%) GDP Growth	496.1	616.2	746.1	903.4	1093.9	1324.5
Low Growth (4.4%) GDP Growth	496.1	616.2	760.6	943.3	1169.9	1451.0
Medium Growth (5.6%) GDP Growth	496.1	616.2	796.2	1045.5	1372.9	1802.4
High Growth (6.5%) GDP Growth	496.1	616.2	823.7	1128.5	1546.2	2118.4

In this study, the actual observed service sector value added (SSVA) growth rates up to 2010 have been taken. From 2011, corresponding values of SSVA for the four GDP growth scenarios have been considered. For business as usual scenario, 3.6 % service sector value added has been taken and also has been projected till 2030. The 3.6 % SSVA was observed in 2011, when the overall GDP growth of the country was 3.9%.

The projected values of SSVA for the four growth scenarios of GDP have been shown in Table 3.4.

Table 3.4: Service Sector Value Added Structure under Selected Growth Scenarios (Source: WB, 2012 & Author)

Service Sector Value Added (Constant, 2000)	Year					
Value in Billion NRs	2005	2010	2015	2020	2025	2030
SSVA (3.6%), For BA Scenario (GDP, 3.9%)	203.4	268.9	321.0	383.1	457.2	545.6
SSVA (4.8%), For LG Scenario (GDP, 4.4%)	203.4	268.9	340.0	429.8	543.4	686.9
SSVA (6.5%), For MG Scenario (GDP, 5.6%)	203.4	268.9	368.5	504.9	691.7	947.7
SSVA (8%), For HG Scenario (GDP,6.5%)	203.4	268.9	395.2	580.6	853.1	1253.6

For the low growth GDP projection, 4.8 % annual growth of SSVA has been used from 2011 to 2030. The selected 4.8 % SSVA was AAGR from 1996 to 2011 of the country. For medium GDP growth, 6.5 % of SSVA has been considered. Historical data shows that, the country had achieved more than 6% SSVA repeatedly (i.e., 1991, 6.4%; 1994, 8.2%, 2000, 6.2% and in 2008, 6.1%). For high GDP growth of 6.5%, the 8% SSVA has been considered in this study. The three year approach paper (2014 to 2016) prepared by government of Nepal has also considered the service sector growth rate to 6.4%, 7.1% and 7.7% for 2014, 2015 and 2016 respectively.

In the study, the actual observed IVA growth up to 2010 has been taken. From 2011, four GDP growth scenarios have been considered for analyzing purpose. For business as usual scenario, 2.9% industrial value added has been taken and projected the same growth up to 2030. The growth of 2.9% industrial value added was observed in 2011, when the overall GDP growth of the country was 3.9%. Table 3.5, shows the projected values of IVA till 2030.

Table 3.5: Industrial Value Added Structures under Selected Growth Scenarios (Source: WB, 2012 & Author)

Industrial Value Added (Constant, 2000)	Year					
Value in Billion NRs	2005	2010	2015	2020	2025	2030
IVA (2.9%), For B.A (3.9%) GDP Growth	79.9	91.3	93.9	96.7	99.5	102.4
IVA (3.5%), For L.G.(4.4%) GDP Growth	79.9	91.3	94.5	97.8	101.2	104.8
IVA (3.7%), For M.G.(5.6%) GDP Growth	79.9	91.3	94.7	98.2	101.8	105.6
IVA (4%), For H.G (6.5%) GDP Growth	79.9	91.3	94.9	98.7	102.7	106.8

For low growth GDP projection, 3.5% annual growth of IVA has been taken from the year 2011 to 2030. The 3.5% IVA was AAGR from the year 1996 to 2011 of the country. For high growth of GDP, the 4% IVA has been taken and the 4% annual growth rate was observed in 1997, 2007 and 2010 respectively. For medium GDP growth, 3.7% of the IVA has been taken for the projection purpose.

For business as usual scenario, 4.5 % agriculture sector value added has been considered and projected the same growth rate up to the year 2030. The 4.5 % ASVA was observed in 2011 when the overall GDP growth of the country was 3.9%. For high GDP growth of 6.5%, the 5% ASVA has been considered in this study. The three year approach paper (2014 to 2016) prepared by government of Nepal has also considered the sector's growth rate to 4.3%, 4.5% and 4.8% for the year 2014, 2015 and 2016 respectively. For low growth and medium growth 4.6% and 4.8% annual growths of ASVA has been considered. Table 3.6 shows the projected values of the agriculture sector in national economy under the selected scenarios of national GDP.

Table 3.6: Agriculture Sector Value Added structure under selected growth scenarios (Source: WB, 2012 & Author)

Agriculture Value Added (Constant, 2000)	Year					
Value in Billion NRs	2005	2010	2015	2020	2025	2030
ASVA (4.5%), For BA Scenario (GDP, 3.9%)	179.8	205.5	256.1	319.2	397.8	495.7
ASVA (4.6%), For LG Scenario (GDP, 4.4%)	179.8	205.5	257.3	322.2	403.5	505.2
ASVA (4.8%), For MG Scenario (GDP, 5.6%)	179.8	205.5	259.8	328.4	415.2	524.9
ASVA (5%), For HG Scenario (GDP, 6.5%)	179.8	205.5	262.3	334.8	427.3	545.3

3.4.3 Energy Demand Intensities

The final energy demand per person has been taken for residential sector. Similarly, final energy demand per US $ has been taken for the commercial, agriculture and industrial sectors. The changes of intensities of corresponding sectors have been projected through trend analysis and econometric analysis. For road transport sector, the number of vehicles actually plying in the road has been estimated and further projected by econometric and trend analysis approach. The energy consumption per vehicle and distance travelled by the vehicle has been taken form field survey conducted by AEPC. All the consuming demand intensities for base year have been taken from various studies/surveys conducted by the WECS listed in bibliographies section of this study.

3.5 Calibration and Validation of Models

In the formulated models, the year 2005 has been considered as base year and the year 2030 has been taken for the end of the projection. The total energy consumption in the year 2005 has been calibrated with the actual consumption of the year. After calibration, the validation of the models has been carried out with actual energy consumption in the sectors from 2005 to 2009. The validation of the output of national level energy demand with actual consumption and corresponding deviations are shown in Figure.3.12.

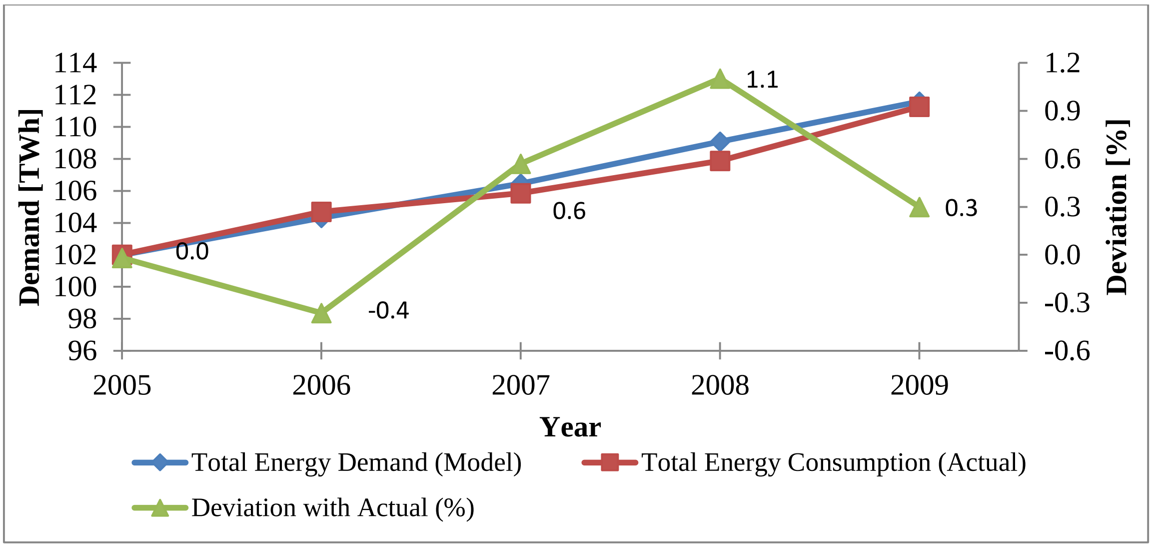


Figure 3.12: Deviation of Model Outputs from Actual Consumptions (WECS, 2010 & Author)

3.6 Boundary Condition of the Study

Although, there are number of organizations working in the field of energy in Nepal but, since up to now there is no existence of independent energy based statistical organization in the country. The data for this study has been collected from different organizations (i.e., national and international) working in the field. For processing the collected data, special consideration has been taken to synchronize the data consistently. Due to the lack of technological based energy consumption database in the country, this study has been carried out on the basis of final energy consumption for different end use applications. Only, in the transport sector, technology based analysis has been carried out due to the availability of historical technological database of the sector. The scope of this study is limited to energy and economic aspects of the country.

Chapter 4
Results and Findings

4.1 Sectoral Energy Demand Projections

The sectoral levels energy demand projections are carried out with the adopted methodologies. To project the national level energy demands, first sectoral levels energy demands have been projected and further all the corresponding projected energy demands are added. Following sections describe the results and findings of the sectoral and national levels energy demands of the country.

4.1.1 Energy Demand for Residential Sector

Table 4.1 shows the total sectoral energy demand values under the selected growth scenarios till the year 2030. It has been found that the annual average growth rate (AAGR) of the demand will be 2%, 2.1%, 2.3% and 2.4% under the BA, LG, MG and HG scenarios respectively. Similarly, the corresponding projected end year to base year demand ratios will be 1.65, 1.68, 1.75 and 1.81 in the growth scenarios.

Table 4.1: Total Residential Energy Demand Projection under Different Scenarios (Source: Author)

Demand (TWh)	Year						AAGR (%)	Ratio
Scenario	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
B.Asusual	92.1	101.3	110.6	122.6	136.4	152.2	2.0	1.65
L.Growth	92.1	101.3	110.8	123.3	137.8	154.5	2.1	1.68
M.Growth	92.1	101.3	111.4	125.1	141.4	161.0	2.3	1.75
H.Growth	92.1	101.3	111.9	126.6	144.5	166.8	2.4	1.81

The energy demand scenarios from the base year 2005 to the end year 2030 have been shown in the Figure 4.1. The scenarios show the possible energy paths of the sector according to the national economic and demographic situation of the country. By the year 2030, the total energy demands of the sector will be 152.2 TWh, 154.5 TWh, 161 TWh and 166.8 TWh respectively in the selected BA, LG, MG and HG targets as shown in the table.

To meet the changing energy demands, the contributing shares of demanding fuels have to be changed. Table 4.2 shows the various fuels projections, AAGR along with contributing fuels shares on base year and end year of the sectoral energy demands. It also illustrates that the projected end year values along with ratios of end year to base year fuels demands in the BA scenario. It has been found that the overall total energy demand of the country will be grown with AAGR of 2 % from 2005 to 2030 in the scenario. Among the fuels, the modern and clean fuels like electricity, LPG and biogas will be highly demanded in coming years.

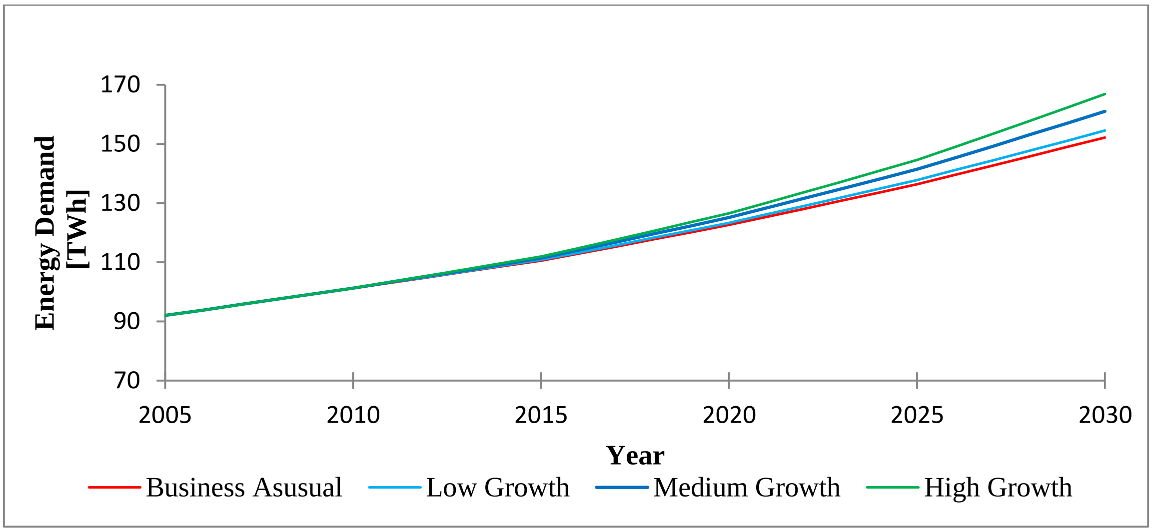


Figure 4.1: Total Residential Energy Demand Scenarios (Source: Author)

Among the commercial fuels, the demand of the kerosene will be decreased in following years because people are using LPG instead of using kerosene due to removal of subsidies on it. In coming years also, the demand of traditional fuels like - wood, animal waste, agriculture residue will be increased for meeting the sectoral energy needs especially rural settlements. As shown in Table 4.2, although the demand of the traditional fuels will be grown, but the growth rates will be lower than commercial fuels. It has been found that the role of traditional fuels will be more dominating in coming years for meeting the country's energy needs despite the growths of commercial and non commercial local renewable clean fuel like biogas.

Table 4.2: Projected Fuel types for Business As usual Scenario (Source: Author)

Demand (TWh)	Year						AAGR (%)	% Share	
Fuel	2005	2010	2015	2020	2025	2030	2005-2030	2005	2030
Animal Wastes	5.9	6.5	7.1	7.7	8.6	9.5	1.9	6.4	6.2
Biogas	0.5	0.8	1.2	1.6	2.1	2.8	7.0	0.6	1.8
Biomass	3.5	3.8	4.1	4.5	5.0	5.4	1.8	3.8	3.6
Electricity	0.8	1.3	1.9	2.7	3.7	5.1	7.9	0.8	3.3
Coal	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Kerosene	1.9	0.4	0.3	0.3	0.2	0.2	-8.6	2.1	0.1
LPG	0.6	1.0	1.6	2.4	3.4	4.7	8.9	0.6	3.1
Wood	78.8	87.4	94.3	103.2	113.3	124.4	1.8	85.6	81.8
Total(TWh)	92.1	101.3	110.6	122.6	136.4	152.2	2.0	100	100

As the socio-economic conditions of the five development regions of the country are not uniform, the energy consumptions of the regions are also non uniform on the basis of quality and quantity. Table 4.3 shows the energy demands of the development regions for the base year and end year of the projection along with AAGR. It has been found that, the growth rates of FWDR will be more in comparison with other development regions. The total energy demands of CDR region will be more dominating during the study period due to the fact that, the capital city Kathmandu lies in it.

Table 4.3: Development Region Wise Total Demand Projection under Different Scenarios (Source: Author)

D.Region	Demand in 2005 (TWh)	AAGR (%) [2005-2030]				Demand in 2030 (TWh)			
		B. A	L.G	M.G	H.G	B. A	L.G	M.G	H.G
EDR	21.9	1.9	1.9	2.1	2.2	34.8	35.3	36.6	37.8
CDR	30.6	2.0	2.1	2.3	2.4	50.1	51.0	53.5	55.7
WDR	17.1	2.0	2.1	2.3	2.4	27.9	28.4	29.8	31.1
MWDR	13.0	2.0	2.0	2.1	2.2	21.3	21.5	22.2	22.6
FWDR	9.5	2.6	2.6	2.8	2.9	18.1	18.3	18.9	19.6
Total	92.1	2.0	2.1	2.3	2.4	152.2	154.5	161.0	166.8

Urban Energy Demand Projections

The urban energy demand of the country will be increased in future due to growth of urban population along with changing their life styles. Figure 4.2 shows the urban energy demand of the country till 2030 under the selected four growth scenarios of the country.

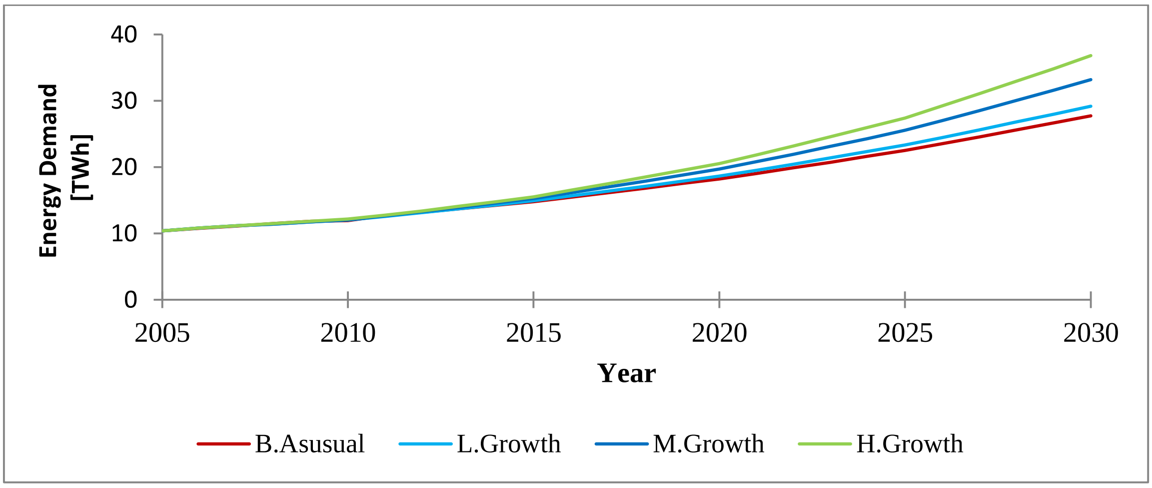


Figure 4.2: Urban Residential Energy Demand Scenarios (Source: Author)

Table 4.4 shows the urban energy demands under the selected growth scenarios. By the year 2030, the urban energy demand will have reached 27.8 TWh, 29.2 TWh, 33.3 TWh and 36.8 TWh under the BA, LG, MG and HG targets respectively. According to the analysis, it has been found that, the urban energy demand of the country will be increased by 2.7, 2.8, 3.2 and 3.5 folds from the base year 2005 to the end of the projection in the year 2030 under the growth scenarios.

Table 4.4: Total Urban Energy Demand Projection under Different Scenarios (Source: Author)

Demand in TWh	Year						Ratio
Scenarios	2005	2010	2015	2020	2025	2030	[2030/2005]
B.Asusual (3.9%)	10.4	12.0	14.8	18.3	22.5	27.8	2.7
L.Growth (4.4%)	10.4	12.0	14.9	18.7	23.4	29.2	2.8
M.Growth (5.6%)	10.4	12.0	15.3	19.7	25.6	33.2	3.2
H.Growth (6.5%)	10.4	12.2	15.5	20.6	27.4	36.8	3.5

The trends of total, urban and rural energy demands under the projected BA scenario have been shown in Figure 4.3. According to the scenario, the urban energy demand of the country will be reached to 18.3 % of the total energy demand by the year 2030.

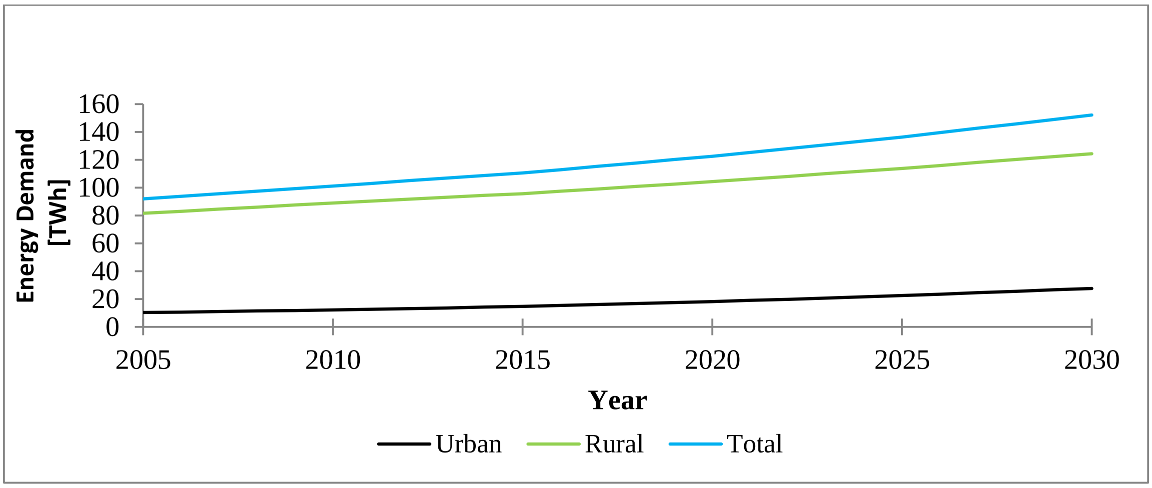


Figure 4.3: Urban and Rural Energy Demand in Business As usual Scenario (Source: Author)

Table 4.5 shows the development region wise urban energy demands of the country. In base year 2005, the CDR had the largest demand share while FWDR had the lowest share. According to current projections, the demands of EDR, CDR, WDR, MWDR and FWDR will be increased by 2.1, 2.8, 3.1, 2.5 and 2.8 folds during the year 2005 to 2030. At the same period, the total energy demand in the urban residential sector will be increased by 2.7 fold.

Table 4.5: Urban Residential Energy Demand Projections under Business as Usual Scenario (Source: Author)

Energy Demand in TWh	Year						Ratio
D.Region	2005	2010	2015	2020	2025	2030	[2030/2005]
EDR	2.0	2.3	2.5	2.9	3.5	4.3	2.1
CDR	4.5	5.3	6.6	8.1	10.1	12.4	2.8
WDR	1.6	2.0	2.5	3.1	3.8	4.9	3.1
MWDR	1.0	1.1	1.4	1.7	2.1	2.5	2.5
FWDR	1.3	1.5	1.8	2.5	3.0	3.7	2.8
Total(Urban)	10.4	12.2	14.8	18.3	22.5	27.8	2.7

The urban energy demand scenarios of five development regions under the BA scenario have been shown in Figure 4.4. From the figure, it can be observed that the maximum demand of the sector will be generated from the CDR of the country. In the base year also, the maximum demand was come from the region. According to analysis, by the year 2030, the shares of the sectoral energy demands of the EDR, CDR, WDR, MWDR, and FWDR will be reached to 15.5%, 44.6%, 17.6%, 8.9%, and 13.4% from 19.3%, 43.2%, 15.4 %, 9.6%, and 12.5% respectively in the base year 2005. The projections have shown that the demand of the WDR will exceed the demand of the EDR. It is mainly due to the higher growth of urban population in the WDR in comparison to the EDR of the country.

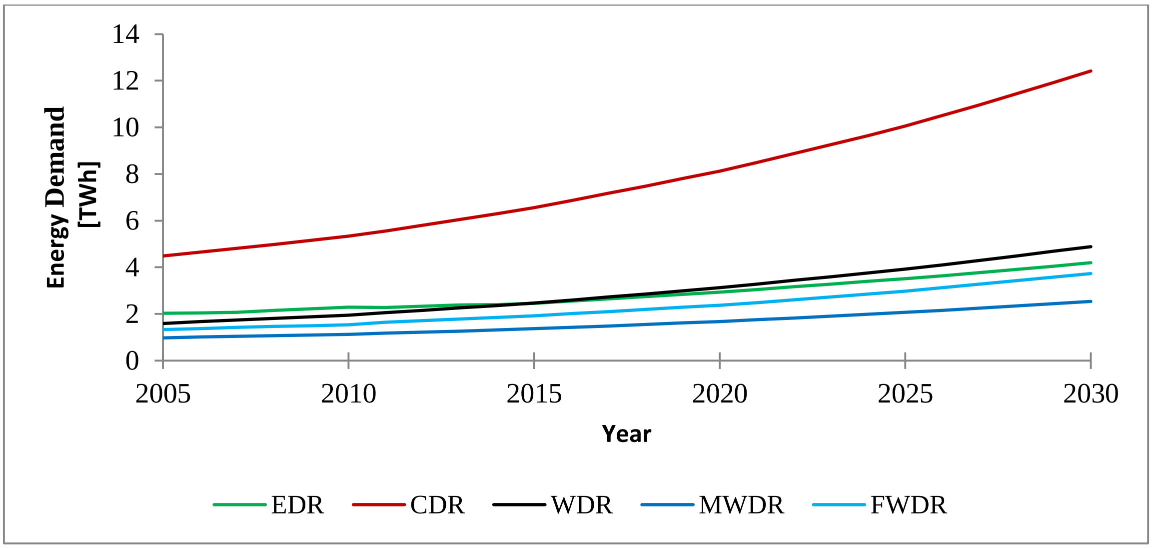


Figure 4.4: Urban Residential Energy Demand in Business As usual Scenario (Source: Author)

4.1.2 Energy Demand for Industrial Sector

The sectoral energy demand scenarios from base year 2005 to end year 2030 have been shown in the Figure 4.5. The scenarios show the possible energy paths of the sector according to the selected national economic situations of the country.

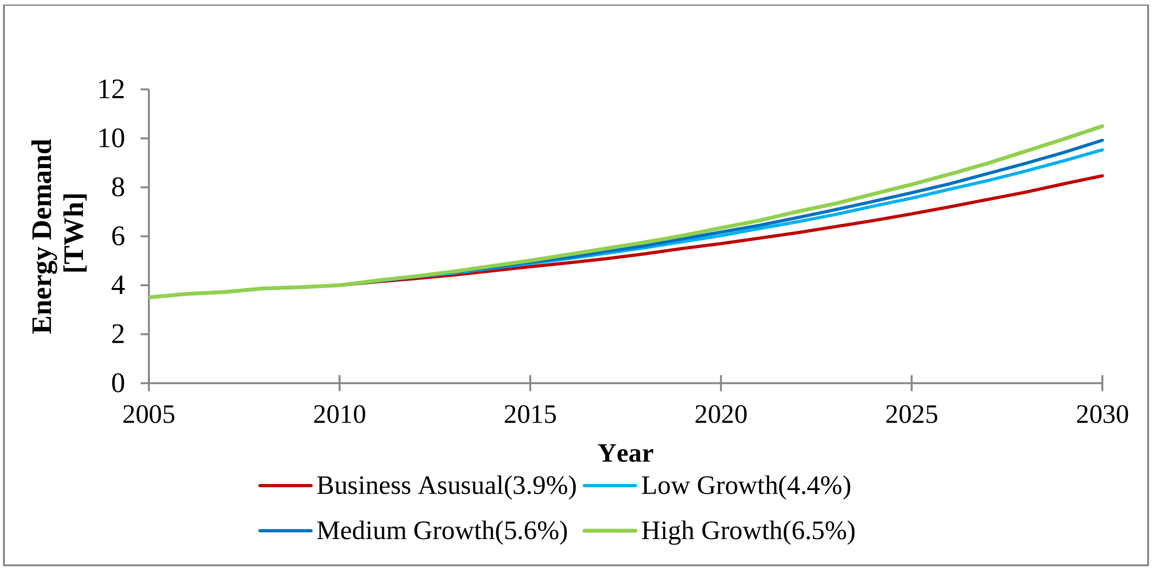


Figure 4.5: Total Industrial Energy Demand Scenarios (Source: Author)

The total industrial energy demand values of the country under the selected scenarios are presented in Table 4.6. By the year 2030, the total sectoral energy demand will be reached to 8.5 TWh, 9.5 TWh, 9.9 TWh, and 10.5 TWh by increasing 2.4, 2.7, 2.8 and 3 folds from the base year under the BA, LG, MG and HG scenarios respectively.

Table 4.6: Projected Total Energy Demand under Different Growths (Source: Author)

Demand in TWh	Year						Ratio
Scenario	2005	2010	2015	2020	2025	2030	[2030/2005]
Business Asusual (3.9%)	3.5	4.0	4.8	5.7	6.9	8.5	2.4
Low Growth (4.4%)	3.5	4.0	4.9	6.0	7.6	9.5	2.7
Medium Growth (5.6%)	3.5	4.0	4.9	6.2	7.8	9.9	2.8
High Growth (6.5%)	3.5	4.0	5.0	6.3	8.1	10.5	3.0

Table 4.7 shows various fuels projections, AAGR, along with percentage shares in BA scenario. It also shows the projected end year values and ratios of end year to base year fuels in the scenarios. In future, the demand of coal, electricity and oil will be increased in one side whereas in the other side, the demand of remaining fuels will be decreased. The growth rate of electricity demand on the sector will be the highest followed by coal and oil. Although, the demand of some fuels will be decreased, the total energy demand of the sector will be increased with AAGR of 3.6 % as shown in the table.

Table 4.7: Structure of Fuels under BA Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Fuel	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
Coal	1.8	2.1	2.5	3.1	3.7	4.4	3.7	2.5
Electricity	0.7	1.0	1.4	1.8	2.4	3.3	6.0	4.7
Biomass	0.4	0.4	0.4	0.3	0.3	0.3	-1.3	0.8
Wood	0.2	0.2	0.2	0.2	0.2	0.2	0.0	1.0
Oil	0.2	0.2	0.2	0.2	0.2	0.2	0.5	1.0
Diesel	0.1	0.1	0.1	0.1	0.1	0.1	0.0	1.0
Kerosene	0.1	0.0	0.0	0.0	0.0	0.0	-23.9	0.0
Total	3.5	4.0	4.8	5.7	6.9	8.5	3.6	2.4

The energy demand projections for industrial sub sectors in the BA scenario have been shown in Table 4.8. It has been found that, the growth rate of food beverage and tobacco sub-sector will be more in comparison with other remaining sub-sectors. However, the energy demand of electrical engineering and products sub-sector will be reduced; the total energy demand in the year 2030 will be reached to 8.5 TWh with AAGR of 3.6% in the scenario.

Table 4.8: Projection of Industrial Sub-Sector Demand for BA Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Industry Sub-sector	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
Other Manufacturing	1.1	1.3	1.5	2.0	2.3	2.8	3.7	2.5
Food Beve.&Tobacco	1.0	1.2	1.5	1.8	2.3	2.9	4.4	2.9
Mach Eng.& Metallurgy	0.6	0.6	0.7	0.7	0.9	1.0	2.3	1.7
Textile and Leather	0.4	0.4	0.5	0.6	0.7	0.9	3.7	2.3
Chemical Rub.& Plastics	0.2	0.3	0.3	0.3	0.4	0.5	2.8	2.5
Wood Prod. & Papers	0.2	0.2	0.2	0.3	0.3	0.4	3.4	2.0
Electrical Eng. Products	0.02	0.01	0.01	0.01	0.01	0.01	-1.1	0.8
Total	3.5	4.0	4.7	5.7	6.9	8.5	3.6	2.4

Five end-use applications are considered in the sector. Among them, most of the energy has been used in boiler, process heat and motive power. In base year 2005, boiler consumed largest share of sectoral energy consumption followed by process heat, motive power, others and lighting applications as illustrated in Table 4.9. According to projections, the demand shares of motive power, boiler, process heat, lighting and others will be reached to 35.7%, 35.7%, 25.2%, 1.1% and 2.3% respectively by the year 2030 under the BA scenario.

Table 4.9: Projected End-Use Demand under LG Scenario (Source: Author)

Demand (TWh)	2005	Share (%)	2010	Share (%)	2020	Share (%)	2030	Share (%)
Boiler	1.3	37.2	1.6	40.0	2.3	38.4	3.4	35.7
Process Heat	1.0	28.6	1.1	27.5	1.6	26.6	2.4	25.2
Motive Power	0.8	22.8	1.0	25.0	1.8	30.0	3.4	35.7
Others	0.3	8.6	0.2	5.0	0.2	3.3	0.2	2.3
Lighting	0.1	2.8	0.1	2.5	0.1	1.7	0.1	1.1
Total	3.5	100	4.0	100	6.0	100	9.5	100

4.1.3 Energy Demand for Commercial Sector

The sectoral energy demand scenarios from base year 2005 to end year 2030 have been shown in the Figure 4.6. The scenarios illustrate the possible future energy paths of the sector according to the anticipated national economic situations of the country.

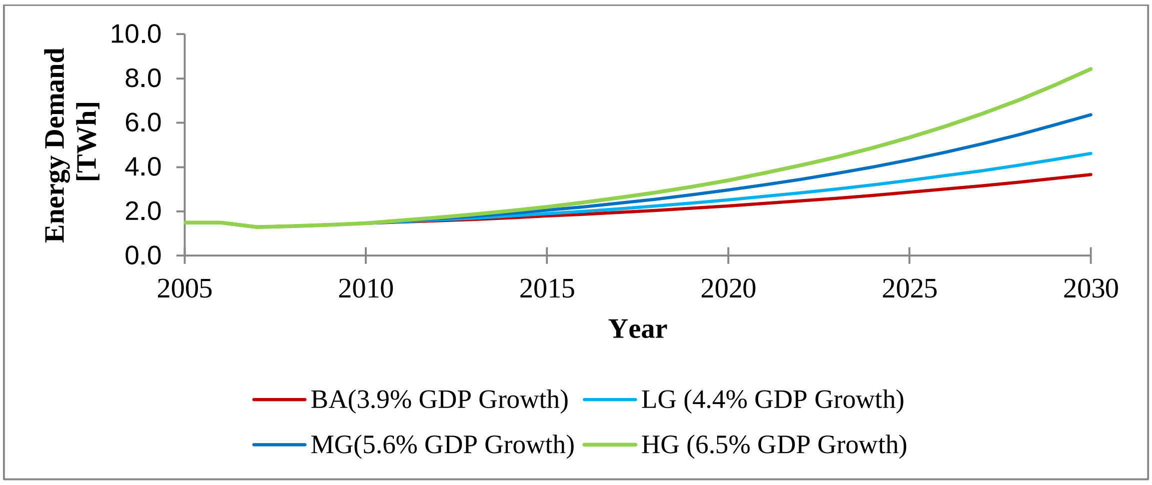


Figure 4.6: Scenario of Commercial Energy Demand under Anticipated Growths (Source: Author)

Table 4.10 shows the total service sector energy demands of the country under different anticipated growth scenarios of the nation. According to study, by 2030, the total energy demands of the sector will be increased by 2.5, 3.1, 4.3 and 5.7 folds and reached to 3.7 TWh, 4.6TWh, 6.4TWh and 8.4 TWh in the BA, LG, MG and HG scenarios respectively as shown in the table.

Table 4.10: Commercial Sector Energy Demand Projection under Selected Growth Scenarios (Source: Author)

Demand in TWh	Year						Ratio
Scenarios	2005	2010	2015	2020	2025	2030	[2030-2005]
BA(3.9% GDP Growth)	1.5	1.5	1.8	2.3	2.9	3.7	2.5
LG (4.4% GDP Growth)	1.5	1.5	1.9	2.5	3.4	4.6	3.1
MG(5.6% GDP Growth)	1.5	1.5	2.1	3.0	4.3	6.4	4.3
HG (6.5% GDP Growth)	1.5	1.5	2.2	3.4	5.3	8.4	5.7

The projection of the demanding fuels, AAGR, along with final year to base year energy demand ratios under the scenario are shown in Table 4.11. In future, the demands of electricity, LPG and wood will be increased in one side whereas in the other side, the demands of kerosene will be decreased. The growth rate of LPG demand on the sector will be the highest followed by the electricity and wood fuels. The total energy demand of the sector will be increased with AAGR of 2.5% during the period despite, the decrease (-22.5%) of kerosene demand in the same period.

Table 4.11: Structure of Fuel types for BA Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Fuel	2005	2010	2015	2020	2025	2030	2005-30	[2030/2005]
Wood	0.6	0.5	0.6	0.7	0.8	0.9	1.7	1.5
LPG	0.5	0.7	1.0	1.3	1.7	2.3	6.5	4.6
Kerosene	0.3	0.1	0.0	0.0	0.0	0.0	-22.5	0.0
Electricity	0.1	0.2	0.2	0.3	0.4	0.5	6.2	5.0
Total	1.5	1.5	1.8	2.2	2.9	3.7	3.7	2.5

The energy demand projections for commercial sub- sectors under the BA scenario have been shown in Table 4.12. It has been found that, the growth rate of cinema halls sub - sector will be more in comparison with other remaining sub - sectors. However, the energy demand of essentials and non essential sub sector will be reduced; but the total energy demand of the sector will be increased to 3667 GWh by the year 2030.

Table 4.12: Commercial Sub-Sectors Energy Demand in BA Scenario (Source: Author)

Demand in GWh	Year						AAGR (%)	Ratio
Commercial Subsectors	2005	2010	2015	2020	2025	2030	2005-30	[2030/2005]
Restaurant	547	581	728	936	1218	1592	4.4	2.9
Hotels	333	383	486	628	818	1070	4.8	3.2
Academic Institutions	31	23	26	30	35	42	1.3	1.4
Essentials & N. Essent.	187	106	105	117	135	158	-0.7	0.8
Hospitals	26	18	19	22	25	29	0.4	1.1
Institutions	364	359	427	515	630	774	3.1	2.1
Cinema Halls	0.3	0.4	0.5	0.7	0.9	1.1	6.1	3.7
Water Supply	0.3	0.4	0.5	0.6	0.8	1.0	6.0	5.0
Total	1488	1471	1792	2249	2862	3667	3.7	2.5

4.1.4 Energy Demand for Transport Sector

1. Road Transport

Table 4.13 shows the total sectoral energy demands under anticipated growth scenarios of the country. It has been found that the sectoral demands will be increased annually by 7.4%, 7.7%, 8.5% and 9.1% under the BA, LG, MG and HG scenarios respectively. By 2030, the sectoral energy demands will be raised by 5.9, 6.4, 7.7 and 8.9 folds and will be reached to 19 TWh, 20.6 TWh, 24.7 TWh, and 28.4 TWh respectively under the corresponding scenarios.

Table 4.13: Road Transport Demand Projections under Selected Growth Scenarios (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Scenarios	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
BA(3.9% Growth)	3.2	5.6	8.6	11.8	15.2	19.0	7.4	5.9
LG(4.4% Growth)	3.2	5.6	8.7	12.2	16.1	20.6	7.7	6.4
MG(5.6% Growth)	3.2	5.6	9.0	13.2	18.4	24.7	8.5	7.7
HG(6.5% Growth)	3.2	5.6	9.2	14.0	20.3	28.4	9.1	8.9

The various fuels projections, AAGR, along with the ratios of end year to base year fuels demands in the BA scenario have been shown in Table 4.14. It has been found that the overall total energy demand of the country from 2005 to 2030 will be grown with AAGR of 7.4% in the scenario. The consumption of electrical fuel will be negligible in comparison to other fuels. The difference of values on Table 4.13 under the scenario and total fuel demand in Table 4.14 gives the amount of electrical fuel on the scenario.

Table 4.14: Road Transport Fuels Demands under BA scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Fuel	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
Diesel	2.6	4.1	5.9	7.9	10.0	12.4	6.5	4.8
Gasoline	0.6	1.5	2.7	3.9	5.2	6.6	9.8	11.0
LPG	0.02	0.01	0.01	0.01	0.01	0.01	-3.7	0.5
Total	3.2	5.6	8.6	11.8	15.2	19.0	7.4	5.9

2. Aviation Transport

The total energy demands under the selected growth scenarios for aviation transport have been presented in Table 4.15. It has been found that the demand of the sector will be annually increased by 4.8%, 5.3%, 6.3% and 7.1% respectively from 2005 to 2030 in the BA, LG, MG and HG scenarios. Similarly, under the scenarios, the corresponding projected end year to base year energy demands ratios will be reached to 3.2, 3.4, 4.4 and 5.3 folds respectively.

Table 4.15: Aviation Transport Demand Projections under Selected Scenarios (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Scenarios	2005	2010	2015	2020	2025	2030	2005- 2030	[2030/2005]
BA(3.9% GDP Growth)	0.7	0.8	1.1	1.4	1.7	2.2	4.8	3.2
LG(4.4% GDP Growth)	0.7	0.8	1.1	1.5	1.9	2.4	5.3	3.4
MG(5.6% GDP Growth)	0.7	0.8	1.2	1.7	2.3	3.1	6.3	4.4
HG(6.5% GDP Growth)	0.7	0.8	1.3	1.9	2.6	3.7	7.1	5.3

4.1.5 Energy Demand for Agriculture Sector

Table 4.16 shows the total energy demand under the selected growth scenarios from base year to projected end year. It has been found that the AAGR of the sector's demands will be 3.2%, 3.6%, 3.3% and 3.5% under the BA, LG, MG and HG scenarios respectively. Similarly, the corresponding projected end year to base year demand ratios will be 2.11, 2.33, 2.11 and 2.22 respectively.

Table 4.16: Agriculture Sector Energy Demand Projections under Selected Growth Scenarios (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Scenarios	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
BA(3.9% GDP Growth)	0.9	0.9	1.1	1.3	1.6	1.9	3.2	2.11
LG(4.4% GDP Growth)	0.9	0.9	1.1	1.4	1.7	2.1	3.6	2.33
MG(5.6% GDP Growth)	0.9	0.9	1.1	1.3	1.6	1.9	3.3	2.11
HG(6.5% GDP Growth)	0.9	0.9	1.1	1.4	1.6	2.0	3.5	2.22

The sectoral fuels projections, AAGR along with ratios of end year to base year fuels demands under the BA scenario has been presented in Table 4.17. It has been found that the overall total energy demand of the country from 2005 to 2030 will be grown with AAGR of 3.2 % in the scenario.

Table 4.17: Agriculture Sector Fuels Demands Projections under BA Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Fuel	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
Diesel	0.8	0.9	1.0	1.3	1.5	1.8	3.4	2.3
Electricity	0.1	0.0	0.1	0.1	0.1	0.1	0.6	1.0
Total	0.9	0.9	1.1	1.3	1.6	1.9	3.2	2.1

4.1.6 Energy Demand for Others Sector

The total energy demand values under the selected growth scenarios from base year to projected end year are presented in Table 4.18. It has been found that, the AAGR of the demands will be 5.8%, 6.3%, 7.4 % and 8.3 % under the BA, LG, MG and HG scenarios. Similarly, the corresponding energy demands in the year 2030 will be increased by 3.5, 4.0, 5.0 and 6.0 folds during the same period.

Table 4.18: Energy Demand Projections under Selected Growth Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Scenarios	2005	2010	2015	2020	2025	2030	2005- 2030	[2030/2005]
BA(3.9% GDP Growth)	0.2	0.2	0.3	0.4	0.5	0.7	5.8	3.5
LG(4.4% GDP Growth)	0.2	0.2	0.3	0.4	0.6	0.8	6.3	4.0
MG(5.6% GDP Growth)	0.2	0.2	0.4	0.5	0.7	1.0	7.4	5.0
HG(6.5% GDP Growth)	0.2	0.2	0.4	0.6	0.8	1.2	8.3	6.0

4.2 National Energy Demand Projections

As mentioned earlier in this chapter, the national energy demand projections of the country have been carried out by adding the energy demands of all the sectors. Table 4.19 shows the total energy demand values under different growth scenarios from base year to projected end year. It has been found that the AAGR of the demands will be 2.5%, 2.6%, 2.9% and 3.2% under the BA, LG, MG and HG scenarios. Similarly, the analysis has also shown that the corresponding projected end year demands will be increased by 1.8, 1.9, 2.0 and 2.2 folds from the base year and will be reached to 188.1 TWh, 194.3 TWh, 208.3 TWh, and 221.2 TWh respectively.

Table 4.19: National Energy Demand under Selected Growth Scenarios (Source: Author)

Demand in TWh	Year						AAGR (%)	Ratio
Scenarios	2005	2010	2015	2020	2025	2030	2005-2030	[2030/2005]
BA Scenario (3.9% GDP Growth)	102.0	114.4	128.2	145.5	165.2	188.1	2.5	1.8
LG Scenario (4.4% GDP Growth)	102.0	114.4	128.9	147.4	168.9	194.3	2.6	1.9
MG Scenario (5.6% GDP Growth)	102.0	114.4	130.1	151.0	176.5	208.3	2.9	2.0
HG Scenario (6.5% GDP Growth)	102.0	114.4	131.1	154.1	183.4	221.2	3.2	2.2

It has also been found that the residential sector will remain main energy demanding sectors, followed by transport, industrial, commercial, agricultural and others sectors.

Table 4.20: Structure of National Energy Demand under Selected Growths in Base Year and End Year (Source: Author)

Demand in (TWh)	Year 2005	Scenarios in 2030 (% Contribution)			
Sector (%)	Actual (%)	BA(3.9% GDP)	LG(4.4% GDP)	MG(5.6% GDP)	HG(6.5% GDP)
Residential	90.3	80.8	79.5	77.2	75.4
Transport	3.7	11.3	11.8	13.4	14.5
Industrial	3.5	4.5	4.9	4.8	4.8
Commercial	1.5	2.0	2.4	3.1	3.8
Agricultural	0.8	1.0	1.0	1.0	1.0
Others	0.2	0.4	0.4	0.5	0.5
Total	100	100	100	100	100
Demand	102.0	188.1	194.3	208.3	221.2

Table 4.20 shows the total energy demand values under different growths scenarios for the year 2030, and base year 2005. According to the projection, the demand share of residential sector will be decreased in all scenarios; but its share will be majorly dominated in all of the scenarios. Even by 2030, more than 75% of energy consumption demand will be generated from the sector. For following years, the consumption demand of transport sector will be increased rapidly in comparison with other remaining sectors.

In 2005, the transport sector's energy demand was only 3.7% of the total national energy consumption demand while, by the end of projection period in 2030, the demand of the sectors will be reached to 11.3%, 11.8%, 13.4%, and 14.5% in the BA, LG, MG and HG scenarios respectively. Although, Nepal is an agriculture based country, the current analysis has shown that the sectoral energy demand will be only about 1% of the national energy demand till 2030. Due to gradual rise in consumptions of energy demands in commercial sector, it has been found that the sector's contribution on national energy demands will be 2%, 2.4 %, 3.1 % and 3.8% in the BA, LG, MG and HG scenarios respectively in the year 2030. The others sector will be grown slowly during the period and its contribution on national energy demand will be about 0.5% of the total consumption demand by the year 2030.

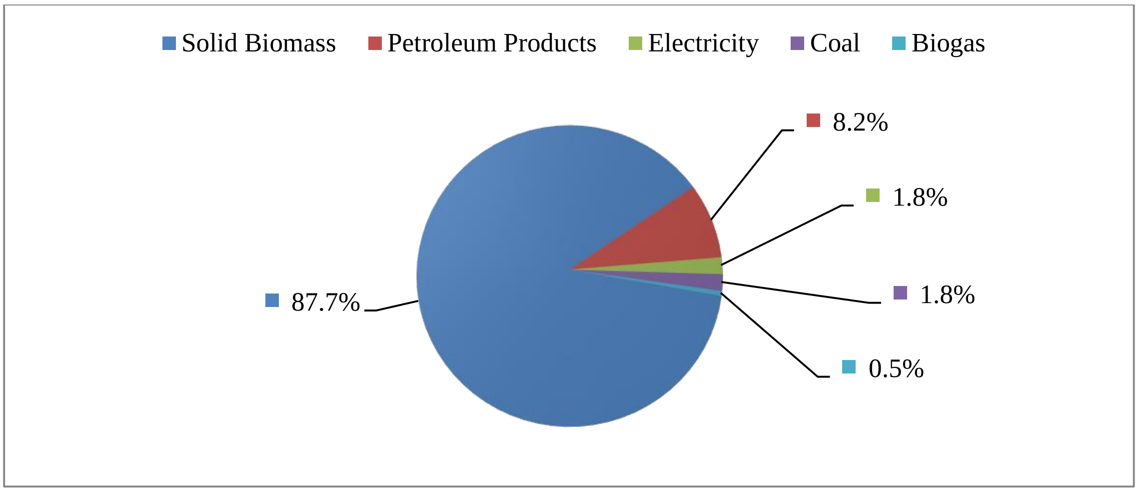


Figure 4.7: Types of Fuels for Meeting the Demand in 2005(Source: WECS, 2010)

The total energy consumption demand of the country was 102 TWh in 2005, and the demand was supplied by solid biomass, petroleum products, electricity, coal and biogas as shown in Figure.4.7. In the year, about 87.7% of the demand was met by traditional solid biomass, followed by petroleum products (8.2%), coal (1.8%), electricity (1.8%), and biogas (0.5%) respectively. The energy mix structure of the demanding fuels in 2030 under the BA scenario has been shown in Figure 4.8. According to the scenario, the contribution of solid biomass will be reached to 74.8%, followed by petroleum products (16.2%), electricity (5.1%), coal (2.4%), and biogas (1.5%) respectively in the year. During the period, it has been found that the AAGR of biomass, petroleum products, electricity, coal and biogas will be 1.8%, 5.3%, 6.8%, 3.7%, and 7.0% respectively for the corresponding growth scenarios of the BA, LG, MG, and HG.

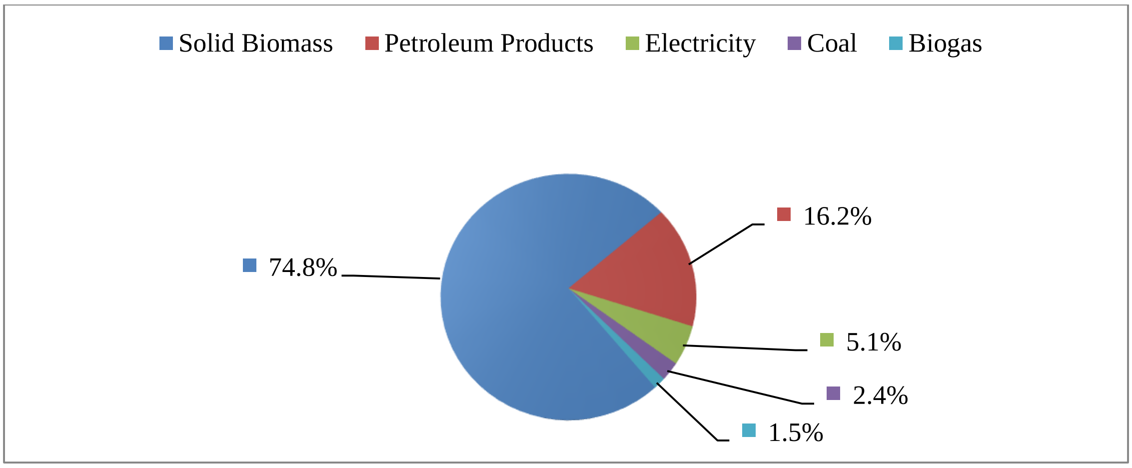


Figure 4.8: Types of Fuels for Meeting the Demand of BA in 2030(Source: Author)

Similarly, Figure 4.9 shows the shares of contributing fuels under LG scenario in the year 2030. According to the results, about 72.8% of the total energy demand will be met from the solid biomass, followed by petroleum products (17.3%), electricity (5.6%), coal (2.6%), and biogas (1.7%). From the base year, it has been observed that the annual growth of biomass, petroleum products, electricity, coal and biogas will be 1.8%, 5.8%, 7.4 %, 4.2%, and 7.6% for the corresponding BA, LG, MG, and HG scenarios respectively.

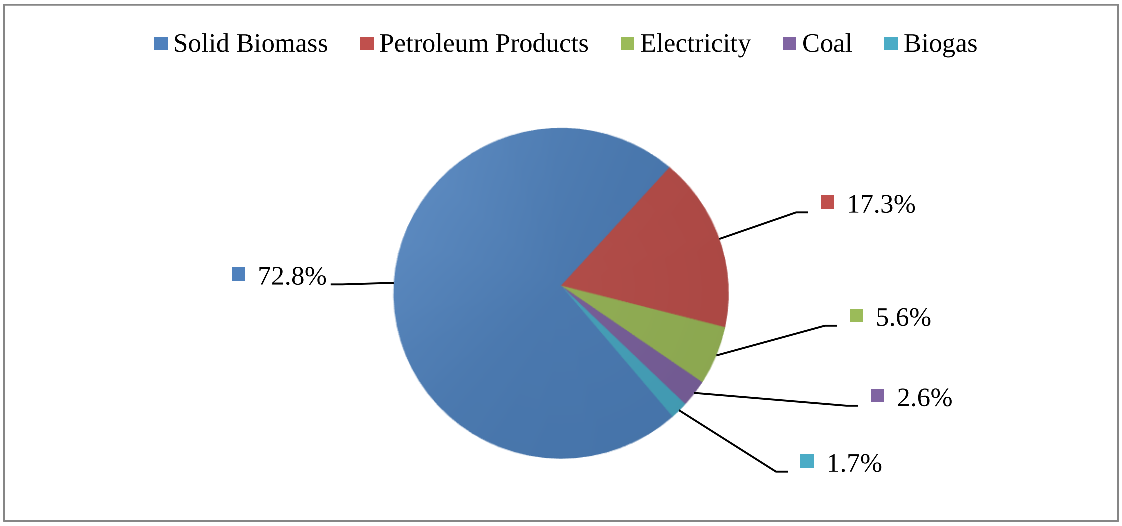


Figure 4.9: Types of Fuels for Meeting the Demand for LG in 2030(Source: Author)

If the economic growth of the country will be followed as the MG scenario, then the demands of traditional biomass fuels will be about 68.7% of the total national energy demand, followed by petroleum products (20.1%), electricity (6.5%), coal (2.5%), and biogas (2.1%) respectively as shown in Figure 4.10. It has been found that the annual growths of biomass, petroleum products, electricity, coal and biogas will be 1.9% , 6.7% , 8.3% , 4.3%, and 8.9% respectively from base year to final year of the projection .

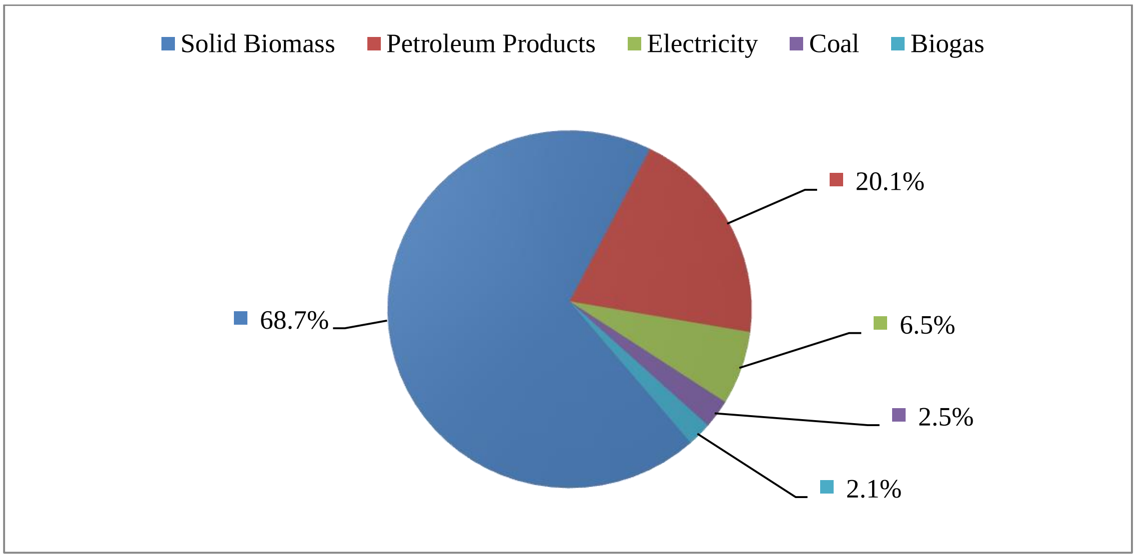


Figure 4.10: Types of Fuels for Meeting the Demand for MG in 2030. (Source: Author)

The demands of commercial and modern fuels will be increased with higher growth rates in comparison with the traditional fuels if the economic growth of the country will be followed with the HG scenario.

As shown in the Figure 4.11, for meeting the national energy demand in the year 2030, the contribution of solid biomass will be 65.4%, followed by petroleum products (22.3%), electricity (7.3%), coal (2.5%) and biogas (2.4%) respectively. The annual growth rate of biomass, petroleum products, electricity, coal and biogas will be 1.9 %, 7.4%, 9.1%, 4.5 %, and 9.8% respectively for the scenarios.

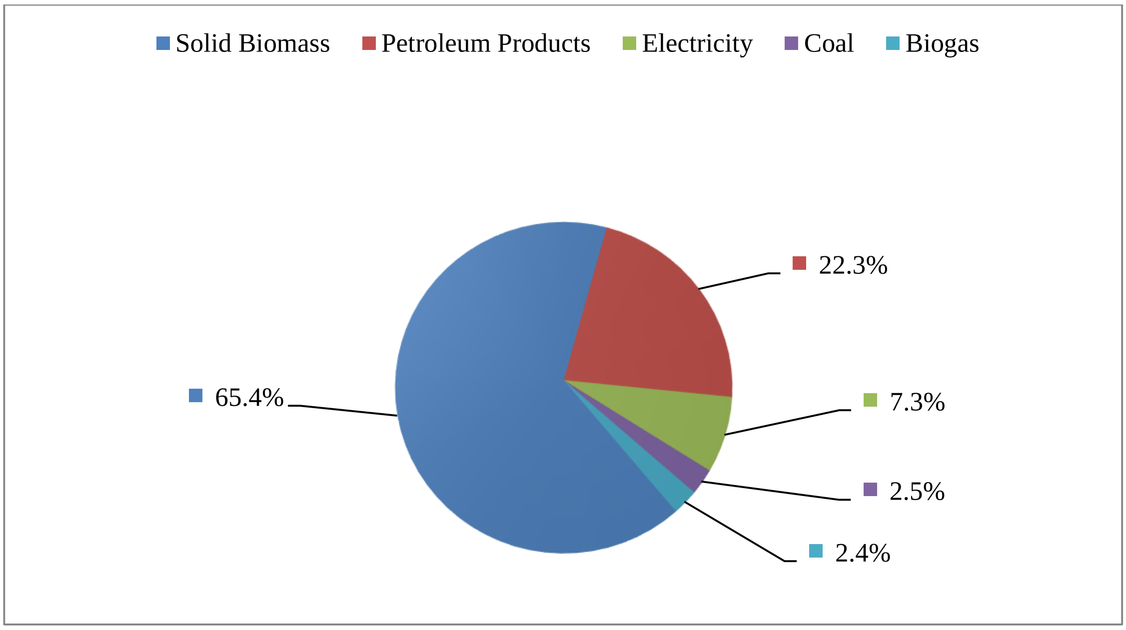


Figure 4.11: Types of Fuels for Meeting the Demand for HG in 2030 (Source: Author)

The national electricity demand of the country under the selected growth scenarios will be grown as shown in Figure 4.12. According to the analysis, the electricity demand of the country will annually grow with 6.8%, 7.4%, 8.3%, and 9.1% in the BA, LG, MG, and HG scenarios respectively. The electricity consumption demand in the base year 2005 was 1.8 TWh and it will reach to 9.6 TWh, 10.9 TWh, 13.6 TWh, and 16.3 TWh under the corresponding selected growth scenarios of national economy by the end of the projected period.

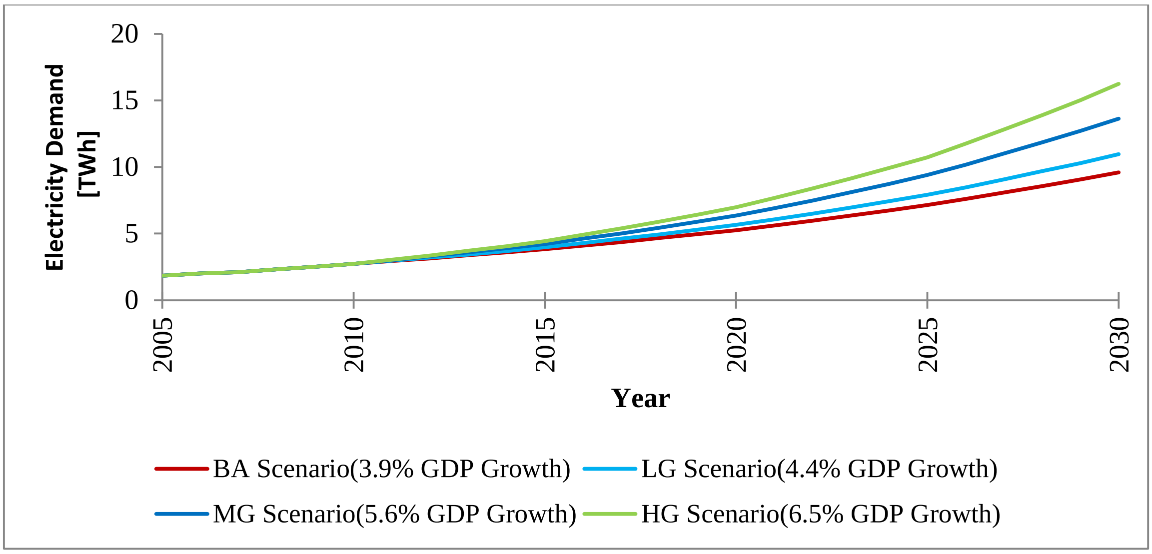


Figure 4.12: National Electricity Demand under Selected Scenario (Source: Author)

For meeting the electricity demand under the selected growth scenarios of the country, various power generation capacities will be required. Table 4.21 illustrates the power generation capacities that will be required for meeting the upcoming national electricity demands till the projected year 2030. It has been estimated that by the year 2030, about 2726 MW, 3116 MW, 3876 MW, and 4621 MW power generation capacities will be required for the BA, LG, MG, and HG scenarios respectively. For an effective utilization of the available resources to meet the demands, detail supply side energy planning has to be carried out which is beyond the scope of this study. The projected energy demands including electricity demands are pre- requisite conditions for an efficient supply side planning of the country.

Table 4.21: Power Generation Capacities Requirement for Meeting the Demands (Source: Author)

Generation Capacity (MW)	Year			
Selected Scenarios	2015	2020	2025	2030
BA Scenario(3.9% GDP Growth)	1089	1495	2032	2726
LG Scenario(4.4% GDP Growth)	1133	1605	2251	3116
MG Scenario(5.6% GDP Growth)	1199	1806	2673	3876
HG Scenario(6.5% GDP Growth)	1258	1981	3052	4621

Figure 4.13 shows the total national petroleum products demands of the country form base year to end year of the projection under the selected growth scenarios. In the base year, the total petroleum products demand was 8.3 TWh and according to the analysis, the demand will be annually increased with 5.3%, 5.8%, 6.7%, and 7.4% under the BA, LG, MG, and HG scenarios. By the year 2030, the total national demands of the products

will be reached to 30.5 TWh, 33.7 TWh, 41.9 TWh, and 49.4 TWh respectively under the corresponding growth scenarios.

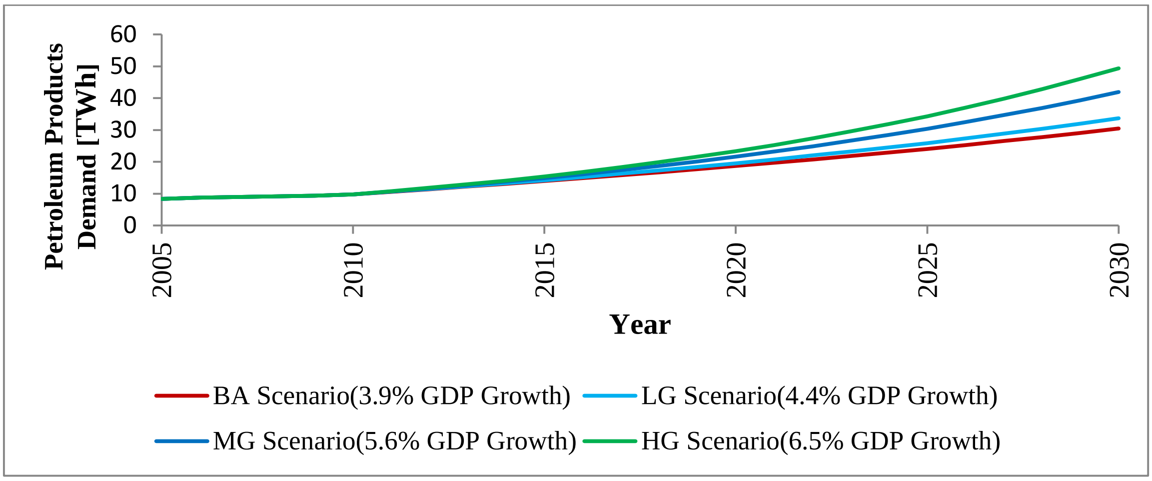


Figure 4.13: Projection of Petroleum Products under Selected Scenarios (Source: Author)

According to projections, the national LPG demands of the country will be increased with AAGR of 7.9%, 8.7%, 10.1%, and 11.2% respectively under the selected BA, LG, MG, and HG scenarios from base year 2005 to end year 2030. By the year 2030, the demands will be reached to 7.0 TWh, 8.3 TWh, 11.6 TWh and 14.7 TWh respectively from 1.1 TWh in the year 2005. Figure 4.14 shows the actual demands of the country in the years 2005 and 2009 along with projected demands under the selected scenarios by the year 2030. It is a noticeable matter that, the consumption demand of the fuel was increased by 1.5 times from 2005 to 2009. As shown in the figure, the demands of the fuel will be increased by 4.4, 5.3, 7.3, and 9.3 folds from the year 2009 to the year 2030.

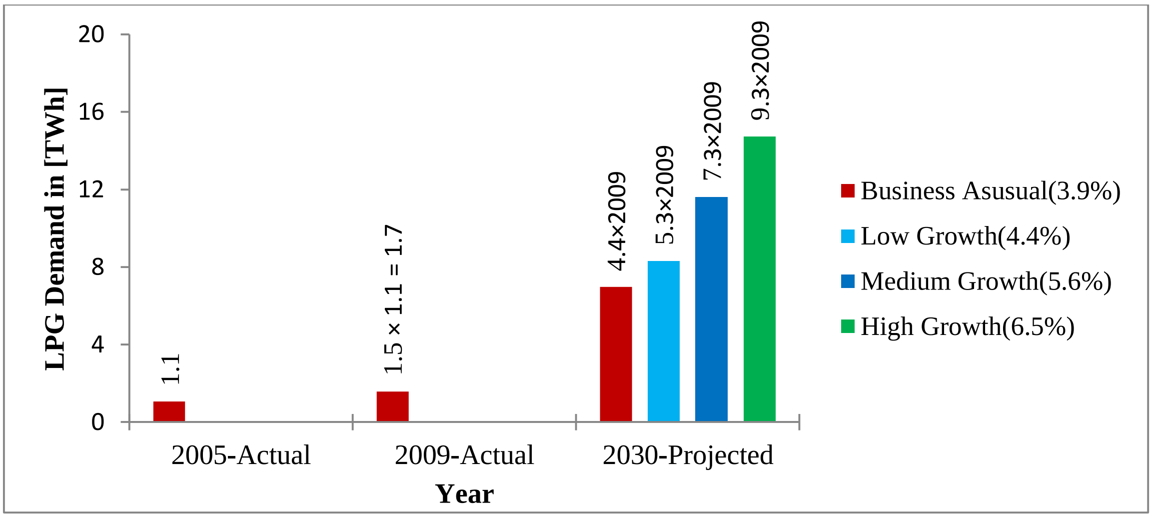


Figure 4.14: LPG Demand Projections and Comparisons (Source: Author)

4.3 Policy Scenarios

The contributing share of LPG on national total petroleum products consumption energy demand was only 12.6% in the year 2005. According to the analysis, the shares will be reached to 22.9%, 24.7%, 27.7%, and 29.8% of the demands in the BA, LG, MG, and HG scenarios respectively by the end of the projection year. Figure 4.15 shows the percentage contributions of LPG on total petroleum products under the four selected growth scenarios from the base year 2005 to the end year of the projection. The demands will be annually increased with 7.9%, 8.6%, 10.1%, and 11.2% respectively for the corresponding growth scenarios. The projected scenarios illustrate that; the demands of the LPG will increase sharply in coming years. As the country imports all of its consuming petroleum products including LPG from aboard, then the continuous growths of their consumptions will create more economic burden of the country for days to come.

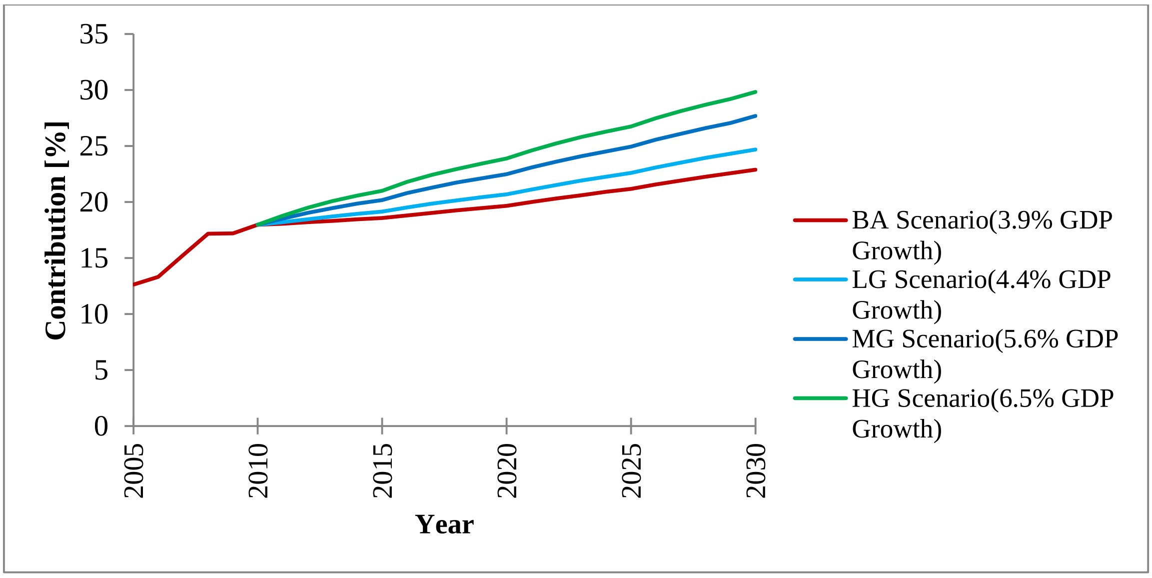


Figure 4.15: Contribution of LPG on Total Petroleum Products (Source: Author)

Although, from national energy consumption perspective, the share of total industrial sector energy consumption is low, but there is a good potential for saving significant amount of energy in the sector. The detail study conducted on 322 industries covering all industrial subsectors of the country has shown that there is a good opportunity for energy saving in these industries through implementation of energy saving measures [86]. In the study, it has been pointed out that about 4.9 % electrical energy in cement industry, 2.5% electrical & 22.5% thermal energy in pulp and paper industries, average 11.8% electrical & 15.3% thermal energy in food industry and 6.2% electrical & 22.9% thermal energy in metal industries can be saved. In soap and chemical sub sector, there is the possibility of saving 9.7% electrical & 39.5% thermal energy, whereas in brick industries about 22.6% thermal energy can be saved according to the study.

Under the policy scenarios, the possible opportunities for switching the LPG demand to electrical demand in residential sector and energy saving options in industrial sector have been analyzed. Among the selected growth scenarios, the medium growth scenario has been selected for further policy interventions on the residential and industrial sectors of the country.

4.3.1 LPG Substitution Policy Scenario in Residential Sector

In medium growth scenario, the total energy demand of the sector will be increased with AAGR of 2.3% from the year 2005 to the year 2030. The demands of electricity, biogas, and LPG will be increased annually with 9.8%, 8.9%, and 10.9% respectively, and will be reached to 7.9 TWh, 4.3 TWh, and 7.5 TWh by the year 2030. The projected demands of the fuels are shown in Figure 4.16, Figure.4.17, and Figure 4.18 respectively. The electricity demand will be grown as shown in the Figure 4.18. The AAGR of 7.9%, 8.5%, 9.8% and 10.7% will be happened in the BA, LG, MG, and HG scenarios respectively during the period. By the end of projection the demand of the fuel will be reached to 5.1 TWh, 5.8 TWh, 7.9 TWh and 9.73 TWh respectively under the scenarios.

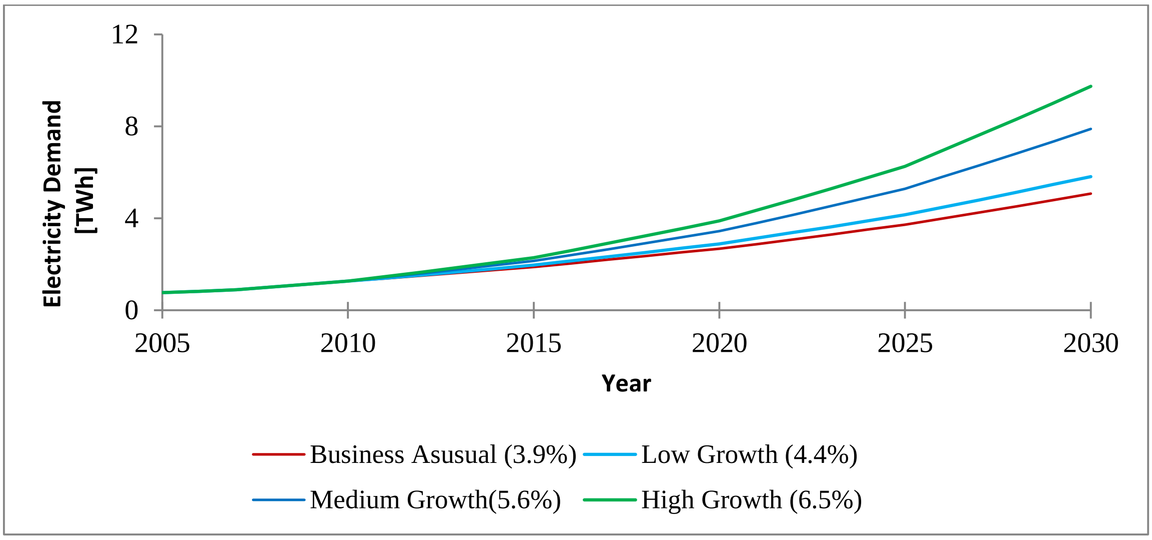


Figure 4.16: Electricity Demand Scenarios in Residential Sector (Source: Author)

The biogas and electrical fuels are originated from local natural resources, but continuous increasing trend of LPG will be a serious concern regarding economic sustainability as well as energy security of the country as discussed earlier in review section. Hence in the policy scenario, a policy intervention has been proposed for substituting LPG by locally available hydro electricity in the sector.

Figure 4.17 shows the biogas demand scenarios under different growths. It has been found that the fuel demand of the country will be increased annually with 7.9%, 8.6%, 9.8% and 10.7% respectively from 2005 to 2030. By the year 2030 the demand of the fuel will be reached to 2.8 TWh, 3.2 TWh, 4.3 TWh and 5.4 TWh respectively under the selected scenarios as shown in the figure.

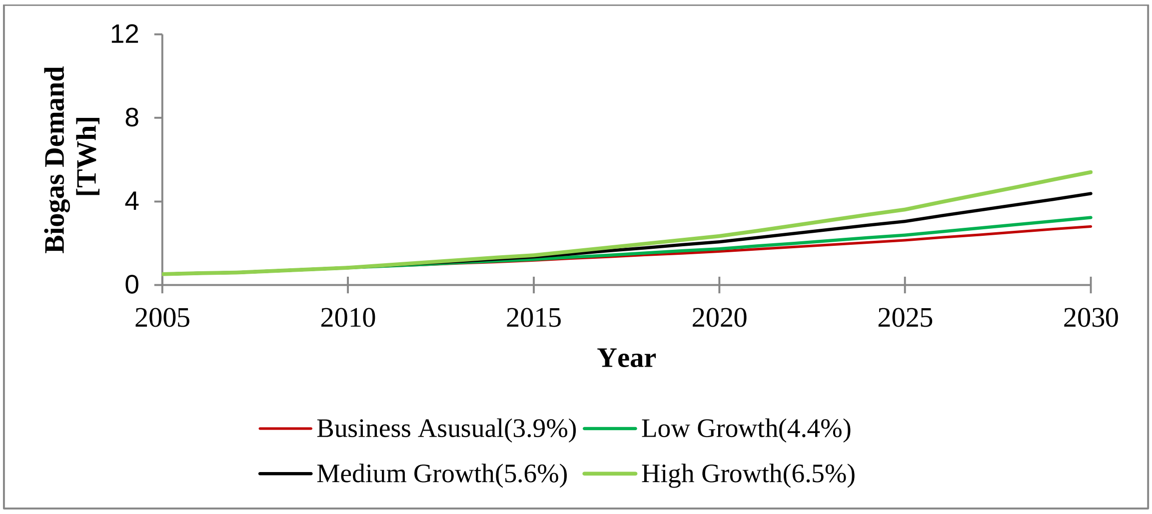


Figure 4.17: Biogas Demand Scenarios in Residential Sector (Source: Author)

The LPG demand scenarios during the study period are shown in Figure 4.18. The AAGR of 8.9%, 9.5%, 11.0% and 11.9% will be happened in the BA, LG, MG, and HG scenarios respectively during the period. According to projection the demand of the fuel will be reached to 4.7 TWh, 5.4 TWh, 7.5 TWh, and 9.3 TWh respectively under the scenarios as shown in the figure.

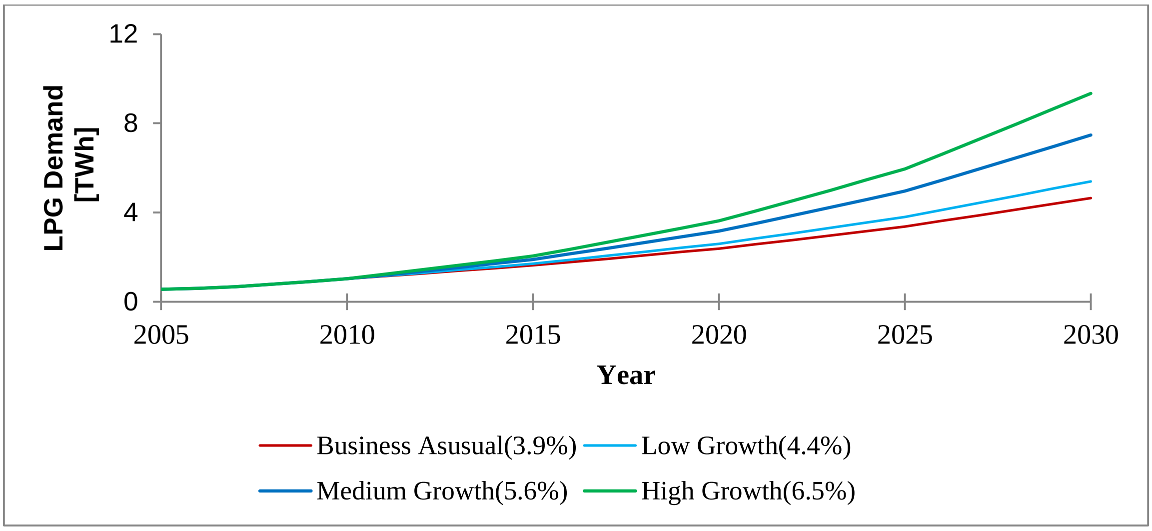


Figure 4.18: Liquefied Petroleum Gas (LPG) Demand Scenarios in Residential Sector (Source: Author)

In 2005, about 52.6% of total imported LPG was consumed in the sector. According to the analysis, it has been found that the sectoral contributing share of LPG in the BA, LG, MG, and HG scenarios will be reached to 67%, 65%, 64.5%, and 63.4% respectively by the year 2030 as shown in Figure 4.19. Thus, it is necessary for an implementation of a policy intervention on the sector such that the demand of the LPG on the sector can be reduced.

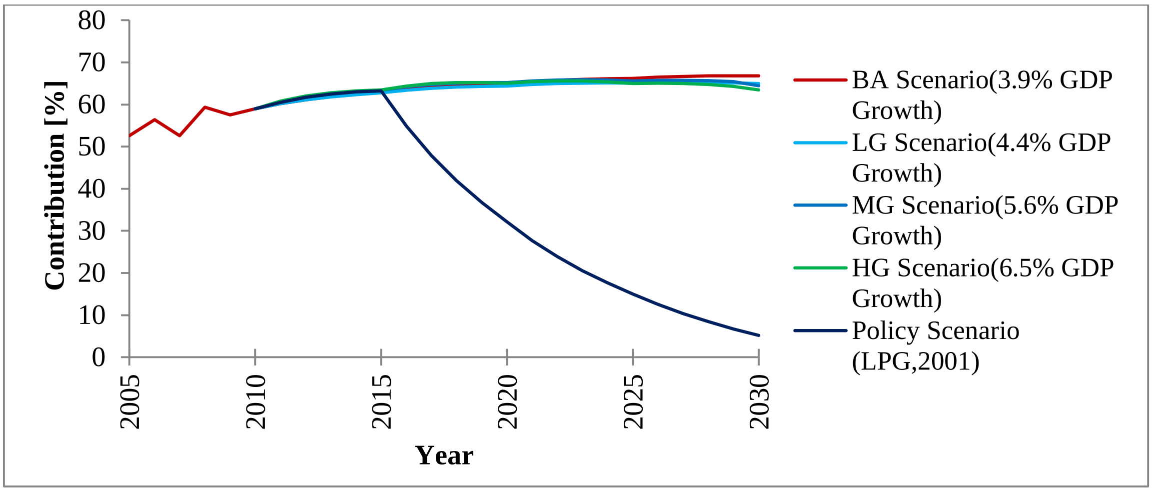


Figure 4.19: Residential Sector Contribution on Total LPG Demand (Source: Author)

The medium growth scenario has been taken as reference case for policy intervention. A policy intervention from the year 2015 has been proposed for substitution of LPG by electricity. In the scenario, the effort has been made to reduce the per capita LPG consumption linearly from the year 2015 to the year 2030. The scenario of contribution of LPG after policy intervention has been shown in Figure 4.20. After reduction, the per capita LPG consumption will be reached at 2001 level by the year 2030.

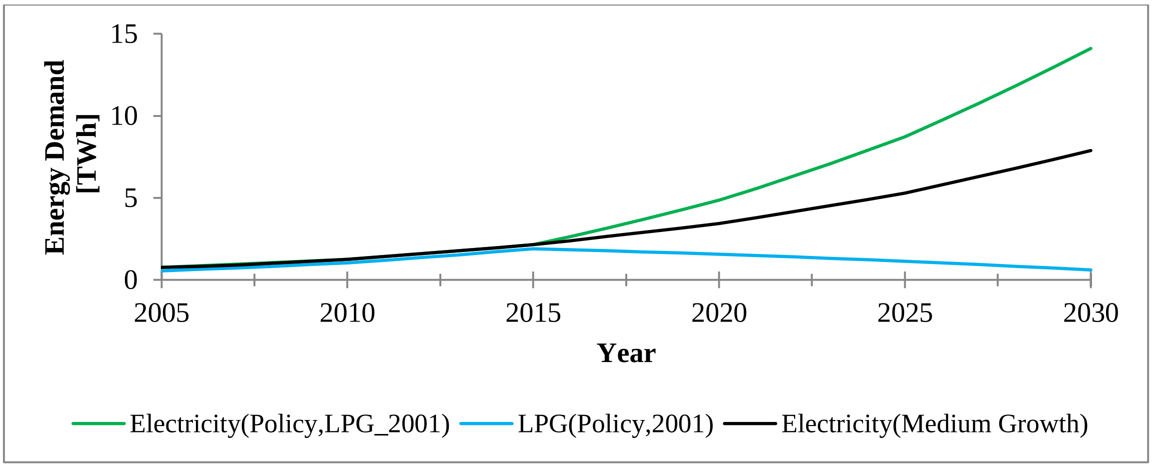


Figure 4.20: Liquefied Petroleum Gas (LPG) Substitution Policy Scenario (Source: Author)

Figure 4.21 shows the quantity of LPG that will be substituted and the equivalent quantity of electricity that will be needed for substituting the LPG. Thus, the simple policy intervention creates permanent electricity demand within the local markets and that will be a good opportunity for local hydropower development of the country for coming days.

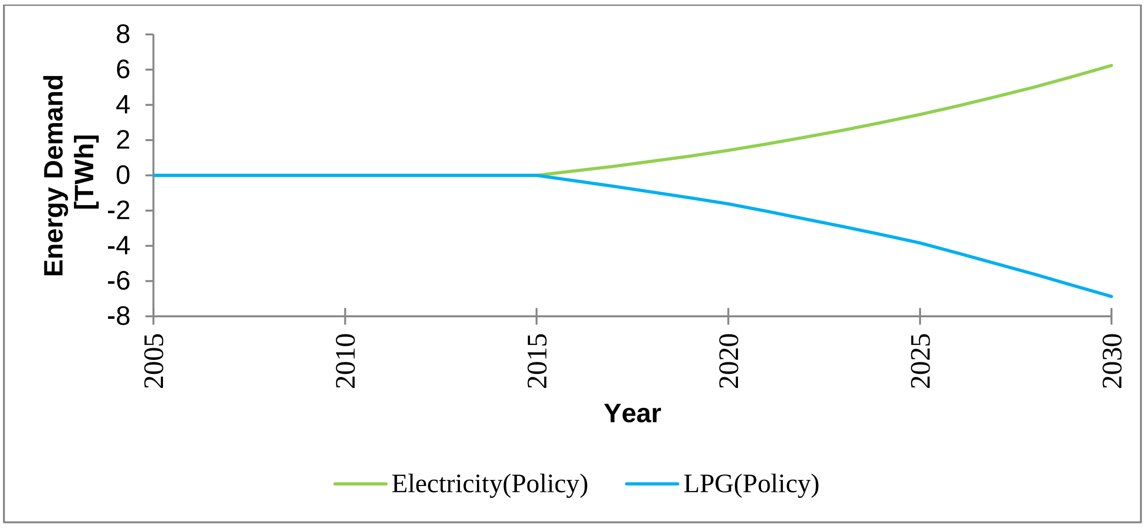


Figure 4.21: Energy Demand Switching in Policy Scenario (Source: Author)

After the policy interference, the demand of LPG will be reduced to 0.6 TWh at 2030, and total electricity demand will be increased to 14.1 TWh from 7.9 TWh in the same year as shown in the Figure 4.22.

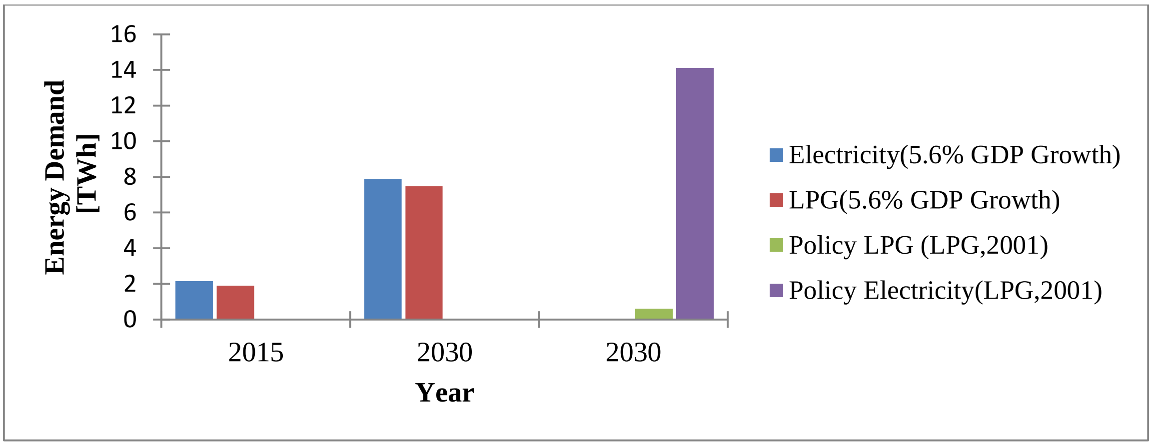


Figure 4.22: LPG Substitution Policy Scenario in Residential Sector (Source: Author)

Thus, the policy intervention in the residential sector creates a permanent electricity demand of 6.2 TWh. Given all the assumptions and uncertainties, more than 1700 MW additional power generation capacities will be required in the country to fulfill the demand by the year 2030.

4.3.2 Energy Saving Scenarios in Industrial Sector

Table.4.22 shows the projected total energy demand for the MG scenario and energy saving opportunity in policy scenario. The study has shown that, if the policy scenario will be implemented, then the projected demand will be reduced from 9.9 TWh to 8.5 TWh in the year 2030. Thus, in the year 2030, about 1.4 TWh of energy can be saved, which will be about 17% and 14% of the BA and MG scenario in the year 2030 respectively. After the policy implementation the AAGR of the demand will be reduced from 4.2% to 3.5% as shown in the table.

Table 4.22: Industrial Sector Energy Saving in Policy Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)
Scenario	2005	2010	2015	2020	2025	2030	2005-2030
MG (5.6%, GDP Growth)	3.5	4.0	4.9	6.2	7.8	9.9	4.2
Total Energy, Policy	3.5	4.0	4.9	5.9	7.1	8.5	3.6

The electricity demand under the MG scenario and electricity saving opportunities have been shown in Figure 4.23. It illustrates the quantities of electricity that can be saved by adapting the policy scenario.

Table 4.23: Industrial Sector Energy Saving in Policy Scenario (Source: Author)

Demand in TWh	Year						AAGR (%)
Scenario	2005	2010	2015	2020	2025	2030	2005-2030
MG (5.6%, GDP Growth)	0.8	1.0	1.4	2.0	2.8	3.9	6.7
Electricity Saving, Policy	0.8	1.0	1.4	1.9	2.6	3.6	6.3

According to the study, after policy interference, the sectoral electricity demand will be reduced to 3.6 TWh from 3.9 TWh in 2030. Thus, in year 2030, about 0.3 TWh of electricity can be saved, which will be about 7.7 % of the MG scenario electricity demand in the year 2030.

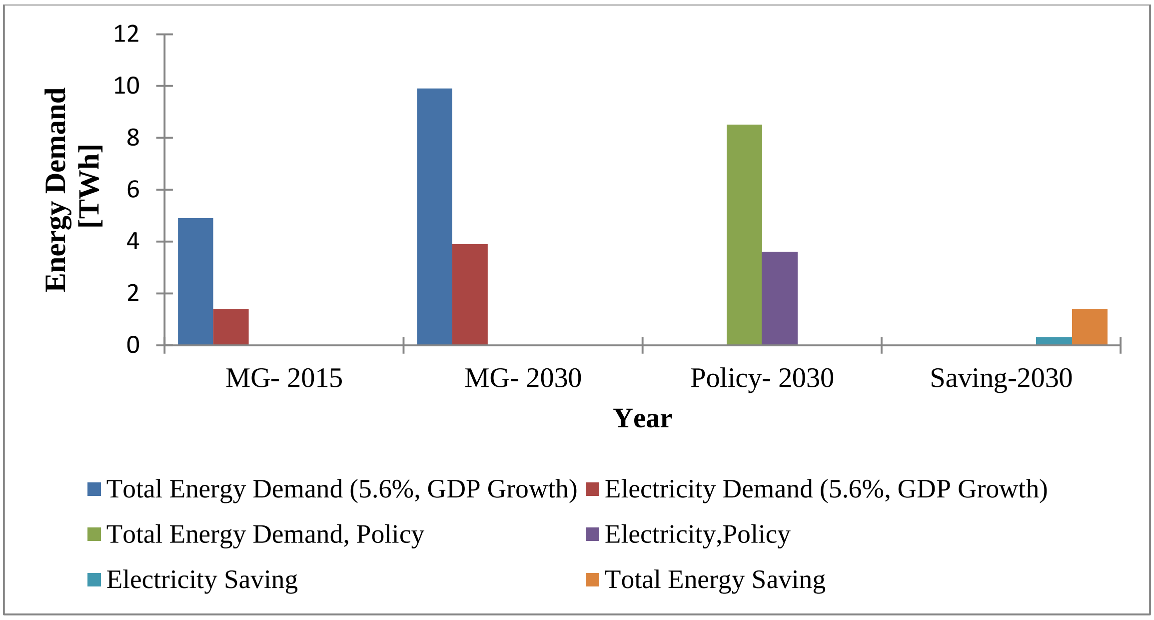


Figure 4.23: Energy Saving Opportunities in Industrial Sector (Source: Author)

4.4 Discussion on Results and Findings

The per capita electricity consumption of the country was 76 kWh in the year 2005. According to the study; the consumption demand will be grown annually with 5.4%, 6.0 %, 6.9%, and 7.7% and will be reached to 280 kWh, 321 kWh, 399 kWh, and 475 kWh under the selected scenarios respectively. It has been found that, even in the HG scenario, the per capita electricity consumption demand of the country will be reached to 475 kWh by 2030 as shown in Figure 4.24. In the year 2011, the per capita electricity consumption of some selected neighboring countries, like Pakistan, Sri Lanka, India, and the average consumption of South Asian region were 449 kWh, 490 kWh, 684 kWh, and 605 kWh respectively [88].

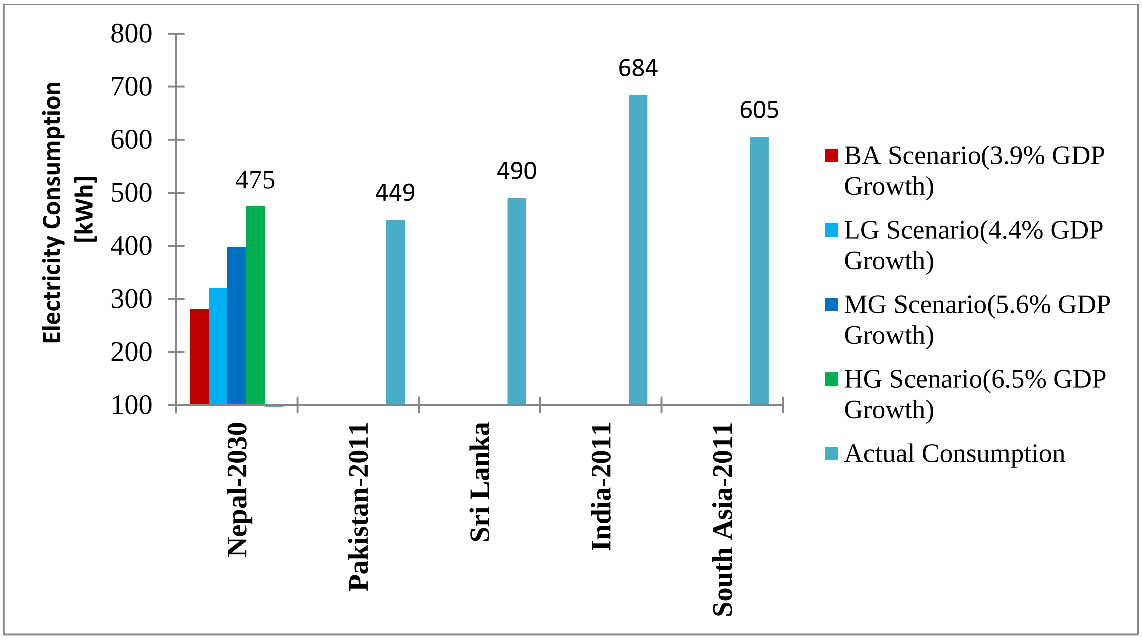


Figure 4.24: Comparison of per Capita Electricity Consumption (Source: Author)

Figure 4.25 shows the comparisons of per capita electricity demand under projected scenarios along with electricity demand after implementation of policy scenario in the residential sector. If the country economy will grow with medium growth rate, then by 2030, about 13.6 TWh national electricity demand will be generated. Again from the policy intervention, additional 6.2 TWh electricity demand will be added from the residential sector to the national demand in the year 2030. Hence by the year 2030, there will be 19.8 TWh electricity demand of the country under the situation. To fulfill the demand about 5633 MW (i.e., 3876 MW for MG scenario and 1757 MW for substitution of the LPG fuel in the residential sector) generation capacity will be needed. The per capita electricity consumption of the country under the policy scenario will be reached to 581 kWh in the year 2030. It is noticeable matter that, even under the policy scenario, the per capita electricity consumption of the country will be lower than the South Asian average per capita electricity consumption in the year 2011.

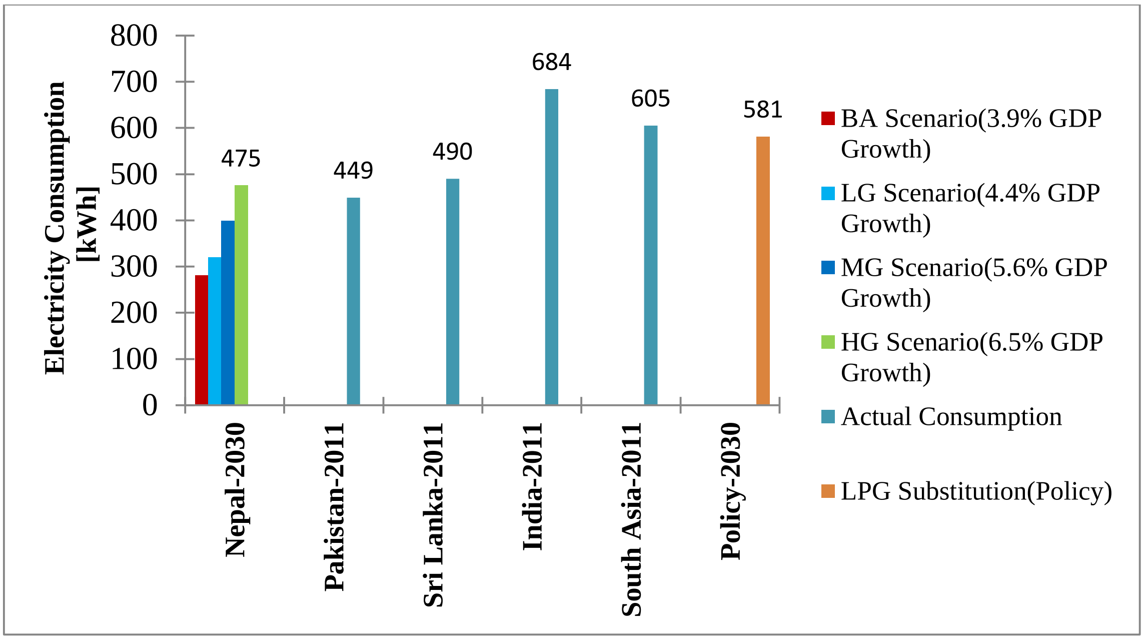


Figure 4.25: Comparison of Per Capita Electricity Demand with Policy Scenario (Source: Author)

The historical electricity consumption trends of some selected countries have been shown in the Figure 4.26. According to the trends, Nepal has the lowest per capita historical electricity consumptions among the neighboring countries [88].

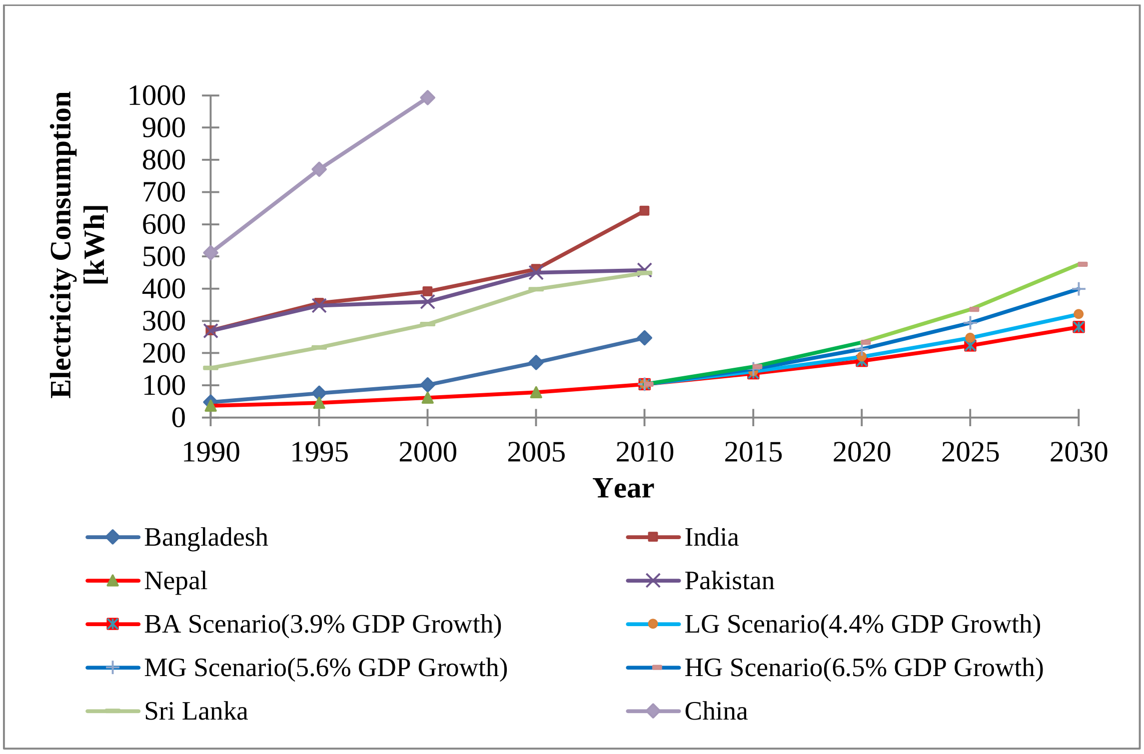


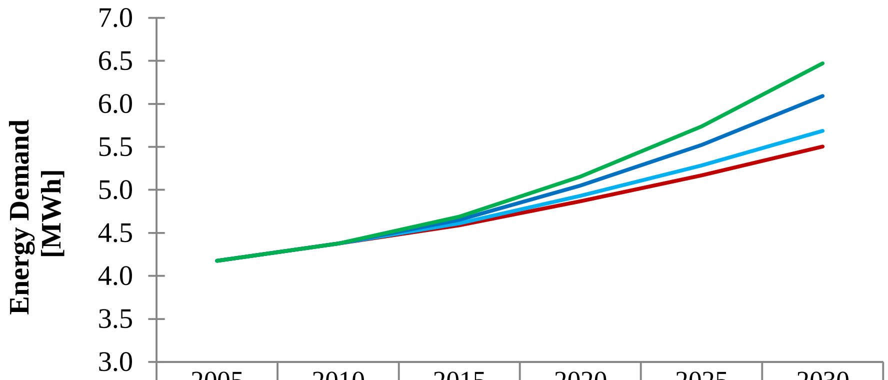
Figure 4.26: Comparison of Electricity Demand with Selected Countries

(Source: Author)

The value of projected scenarios for per capita average national electricity consumption is reasonable because the growth slopes of the projected scenarios are comparable with historical growth trends of the countries like Bangladesh, Pakistan, and Sri Lanka.

Even in India, the per capita electricity consumption has grown rapidly only after the year 2005, before it, the trend of consumption was comparable with Bangladesh, Pakistan and Sri Lanka. As shown in the figure, the per capita electricity consumption of China is the highest. The China and India both are more industrialized countries in the region, thus their per capacity electricity consumption are higher in comparisons to the others.

The Figure 4.27 shows the projected per capita energy consumption values of the country. By 2030, the per capita energy consumption of the country will be reached to 5.5 MWh, 5.7 MWh, 6.1MWh, and 6.5 MWh under the selected BA, LG, MG, and HG scenarios respectively. Goldemberg (2001) suggested that about 42 GJ (i.e, 11.7 MWh) per capita per year energy consumption is required for quality of life and further mentioned that beyond it; the consumption yields marginal improvements of the life quality [22]. But, in the case of Nepal, even in the HG scenario, the per capita energy consumption of the country will be reached to 6.5 MWh only by the year 2030.



	2005	2010	2015	2020	2025	2030
BA (3.9% GDP Growth)	4.2	4.4	4.6	4.9	5.2	5.5
LG (4.4% GDP Growth)	4.2	4.4	4.6	4.9	5.3	5.7
MG (5.6% GDP Growth)	4.2	4.4	4.7	5.1	5.5	6.1
HG (6.5% GDP Growth)	4.2	4.4	4.7	5.2	5.7	6.5

Figure 4.27: Projected per Capita Energy Consumption in Selected Demand Scenarios (Source: Author)

Despite the contributing shares of commercial and clean fuels growths in national energy system, it has been found that the most of the demands will be met by the solid biomass in all of the projected scenarios. The shares of imported fossil fuels to meet the demands will be more dominated in coming years therefore, more and more money will be demanded for importing them. Although, the percentage contribution of solid biomass in coming years will be decreased, the quantity of its demand will be increased annually. Thus, there will be a problem for sustainable supply of the fuel in the country. As mentioned in literature review section, the deforestation of the country has already been recorded due to shortage of sustainable supply of the fuel. Hence, to manage the demanding fuels in sustainable manner for coming years, proper demand side management options will be needed by switching the fuels along with the utilization of energy saving opportunities in the energy demanding sectors of the country. In connection with this, in the present study, two policy options have been analyzed - one in the residential sector LPG substitution by the electrical energy and another energy saving in the industrial sector. The analysis has quantified the possible energy substitution values in residential and energy saving values in the industrial sector of the country. It has been highly expected that the projected paths of the per capita electricity consumption, per capita energy consumption, total quantity of demand, and demanding fuels will facilitate to formulate necessary sustainable policy options regarding supply side energy planning of the country.

Chapter 5
Conclusions and Recommendations

5.1 Conclusions

The different types of energy planning tools for the national energy system planning have been reviewed. In this study, Long Range Energy Alternative Planning (LEAP) tool has been selected for residential, industrial, commercial, agriculture and road transport sectors whereas, econometric modeling approach has been selected for the aviation transport and others sector respectively. The LEAP tool has been selected because there are number of studies that have been conducted using it in the world from highly developed to list developed countries and their methodologies are well established and worldwide accepted.

In the study, the final energy demand of the country has been determined by adding energy demands of residential, transport, industrial, commercial, agricultural and others sectors respectively. In the formulated models, the year 2005 has been considered as base year and the year 2030 has been taken for the end of the projection. The total energy consumption in the year 2005 has been calibrated with the actual consumption of the year. After calibration, the validation of the model has been carried out with actual energy consumption of the country from the year 2005 to the year 2009. After calibration and validation, the model has been further used to project the national energy demand of the country by the year 2030.

The demands of the residential, transport, industrial, agriculture and commercial sectors are determined through end use methodological approach on the base year 2005, and further projections of the demand are based on the function of population, GDP per capita, and corresponding economic sectoral value added of the country. For road transport, the actually plying vehicles on the road in the base year have been estimated and further projected with econometric as well as trend analysis approach. The final energy demand of the sector has been determined by using the information about - the actually plying vehicles on the road, the annual average distance travelled and the fuel economy of the corresponding vehicles.

Further, the residential and industrial sectors models are again expanded to analyze the LPG fuel substitution by electrical fuel in residential sector and energy saving opportunities in industrial sector of the country through the proper policy interventions on the sectors.

The finding from this research provides the evidence that in all of the projected scenarios, residential sector will be the main energy demanding sector, followed by transport, industrial, commercial, agricultural and others sectors respectively. In coming years, the share of national demand of solid biomass will be decreased, while the demanding shares of petroleum products, electricity, coal and biogas will be increased in all of the projected scenarios. Among the fuels, the growth rates of the petroleum products will be the highest, followed by electricity, biogas and coal. It has also been observed that for the highest growth scenario, the demand of solid biomass will be decreased more rapidly in comparison with the other growth scenarios. Although, the total energy consumption of the country will be increased but even in the HG scenario, the per capita energy consumption of the country will be far less than the suggested acceptable benchmark level.

The projected national level energy indicators like per capita electricity consumption, per capita total energy consumption, share of sectoral energy demand, and structure of demanding fuels shares will be the useful parameters for comparing and planning of the local energy resources of the country. If the mentioned policy scenario on the residential sector will be followed, then annually a significant amount of reliable local electricity demand will be generated within the country. This would reduce the expenditure presently being spent for importing the LPG fossil fuel by greater extent and contribute towards the opportunity to invest the development of the local hydro resources. Similarly, in the industrial sector, the study has also quantified the quantities of energy that can be saved through the implementation of the suggested sectoral policy measures.

The projected structures of energy consumption mix shows that the consumption demand of the country will be dominated by traditional and imported fuels, thus a proper supply side planning can be done for achieving more desirable energy mix having higher share of local clean renewable energy resources. The utilization of the clean energy resources for long term energy planning process not only stands for sustainable development of the country but also helps to low carbon pathway to address global partnership for environmental protection and access to modern energy.

5.2 Recommendations

The outcomes of the study will be helpful for formulating necessary policy measures for policy makers and concerned stakeholders in the sector. The policy makers can use the information from this study to adopt necessary actions for sustainable utilization of the local energy resources for avoiding any negative implications for national energy system. Although, the results of the formulated objectives are obtained through the adopted methodologies, there are always some opportunities for further improvements. Therefore, following are the few recommendations for the improvements:

- Due to the lack of end use technological stocks, the current study has been carried out on the basis of fuels consumptions for various end use applications in the residential, industrial, commercial, and agriculture sectors. Therefore, it has been recommended to do further research on the sectors by carrying out the proper assessments of the technological stocks.
- The formulated models can be further used for analyzing the environmental aspects of the study.
- The current study is limited to demand side energy analysis; however, supply side energy planning can be done through utilizing the outputs of these models exogenously to the other proper supply side energy planning tools.

Bibliographies

1. IEA, 2009, World Energy Outlook, 2009, International Energy Agency, France.
2. IEA, 2010, World Energy Outlook, 2010, International Energy Agency, France.
3. IEA, 2011, World Energy Outlook, 2011, International Energy Agency, France.
4. IIASA, 2012, Global Energy Assessment, Towards a Sustainable Future, International Institute for Applied Systems Analysis, Luxemburg, Austria.
5. BP, 2010, Statistical Review of World Energy, London, UK.
6. WCE, 2010, Survey of Energy Resources. World Energy Council (WEC), London.
7. Adil Najam et al., 2003, Energy and Sustainable Development at Global Environmental Summits: An Evolving Agenda. Environment, Development and Sustainability 5: 1117-138, Kluwer Academic Publishers, printed in the Netherlands.
8. WCED, 1997, Our Commission Future, the World Commission on Environment and Development, Oxford University Press, USA, 1997.
9. UN, 2000, The General Assembly, United Nations Millennium Declaration, United Nations.
10. Moyo, D., 2009. Dead Aid: Why Aid is Not Working and How there is a Better Way for Africa. New York: Farrar, Straus and Giroux.
11. AGECC, 2010, The Secretary-General’s Advisory Group on Energy and Climate Change Summary Report and Recommendations, New-Work, 2010.
12. UN, 2010, Energy for a Sustainable Future, Report and Recommendations, 2010, United Nations, New York.
13. UN, 2012, Sustainable Energy for All, Technical Report of Task Force 1, in Support of the Objective to Achieve Universal Access to Modern Energy Services by 2030.
14. Renewable Energy Association (2009), Energy and environment. At http://www.r-e-a.net/info/energy-info(accessed 14 April 2010).
15. REN 21, 2011, Renewable 2011, Global Status Report, Paris, France.
16. E. Gupta, 2008: Oil vulnerability index of oil importing countries. Energy Policy., The Energy and Resources Institute, Darbari Seth Block, Habitat Place, New Delhi 110003, India.
17. Kruyt, B. et al. 2009, Indicators for energy security, Energy Policy, 37,2166-2181 pp.

18. Awebuch,S.,2006,Portfolio-based electricity generation planning, policy implications for renewable and energy security. Mitigation and Adaptation Strategies for Global Change,(113),693-710 pp.
19. Bazilian M. et al., 2008, Analytical Approaches to Quantify and Value Fuel Mix Diversity, Elsevier.
20. ESMAP, 2005: The Impacts of Higher Oil Price on Low Income Countries and the Poor: Impacts and Policies: Energy Sector Management Assistance Program, World Bank, Washington DC, USA.
21. IPCC, 2012, Renewable Energy Sources and Climate Change Mitigation, Special Report of the Intergovernmental Panel on Climate Change, Cambridge University.
22. Goldemberg, J.,2001, Energy and Human Well Being .Human Development Occasional paper HDOCPA-2001-02, United Nations Development Program, New York, USA.
23. Dabrase.S, et al., 2000, Integrated Renewable Energy System- Perspectives and Issues, Millennium International Conference on Renewable Energy Technologies, IIT, Chennai 9-11 Feburary, 2000.
24. WECS, 2010, Energy Synopsis Report, Water and Energy Commission Secretariat Ministry of Water Resources, Kathmandu, Nepal.
25. Pradhan.GL, 2009, Electricity: domestic consumption versus export. Hydro Nepal, 2009, 1-3pp.
26. Jha. R., 2010, Total run-of-river type hydropower potential of Nepal. Hydro Nepal, 8-13pp.
27. Sharma. RH. et al., 2013, Hydropower Development in Nepal. Science Direct, 684-693pp.
28. MoF, 2012, Economic Survey, 2012, Ministry of Finance, Government of Nepal, Kathmandu, Nepal.
29. MFSC, 1987, Master Plan for Forestry Sector Nepal: The Forest Resources of Nepal, ADB T.A.No 670.
30. NEAA, 1984, Nepal Electricity Authority Act, 2041(1984). Government of Nepal
31. Skjold, D.O., 2009, Power for Generations: The Development of Statkraft and the Role of the state in Norwegian Electrification 1830-2009. Universitetsforlaget, Oslo, Norway, 284 pp.

32. NPC,1975, Fifth Plan (1975-1980), National Planning Commission, Government of Nepal, Kathmandu, Nepal

33. NPC,1980, Sixth Plan (1980-1985), National Planning Commission Government of Nepal, Kathmandu, Nepal
34. NPC, 1992, Eighth Plan (1992-1997), National Planning Commission, Government of Nepal, Kathmandu, Nepal.
35. NPC, 2002, Tenth Plan (2002-2007), National Planning Commission, Government of Nepal, Kathmandu, Nepal.
36. NPC, 2007, Three Year Interim Plan (FY 2007/08-2009/10), National Planning Commission, Government of Nepal, Kathmandu, Nepal.
37. NPC, 2010, Three Year Plan (FY 2010/11-2012/13), National Planning Commission, Government of Nepal, Kathmandu, Nepal.
38. NPC, 2013, An Approach Paper to The Thirteenth Plan (FY 2013/14-2015/16), National Planning Commission, Government of Nepal, Kathmandu, Nepal.
39. WECS, 2005, National Water Plan 2005, Water and Energy Commission Secretariat, Ministry of Water Resources, Government of Nepal, Kathamndu, Nepal.
40. MOE, 2010, Ministry of Energy, Twenty-year Hydropower Development Plan Implementation Task Force, Government of Nepal, Kathmandu.

41. MOEV, 2010, Climate Change Policy, Ministry of Environment Government of Nepal, Kathmandu, Nepal.
42. NRB, 2007, Macroeconomic Indicators of Nepal, Nepal Rastra Bank, Kathmandu, Nepal.
43. NRB, 2011, Macroeconomic Indicators of Nepal, Nepal Rastra Bank, Kathmandu, Nepal.
44. Economic Survey, 2007, Ministry of Finance, Government of Nepal, Kathmandu, Nepal.
45. OPEC, 2014, Annual Statistical Bulletin 2013, Organization of Petroleum Exporting Countries.
46. Nepal Energy Efficiency Programme (NEEP), Final Report, Baseline Study of Selected Industries to access the potentials for more efficient use of energy, 2012, Kathmandu, Nepal
47. District Development Profile of Nepal, 2011, A Socio- Economic Development Database of Nepal, Mega Publication and Research Centre, Kathmandu, Nepal.

48. CBS,2012, National Population and Housing Census 2011, Central Bureau of Statistics National Planning Commission Secretariats, Government of Nepal ,Kathmandu, Nepal
49. CBS, 1996, Nepal Living Standards Survey, Central Bureau of Statistics National Planning Commission Secretariat, Government of Nepal.
50. CBS, 2004, Nepal Living Standards Survey, Central Bureau of Statistics, National Planning Commission Secretariat, Government of Nepal.
51. CBS, 2011, Nepal Living Standards Survey, Central Bureau of Statistics, National Planning Commission Secretariat, Government of Nepal.
52. WECS, Energy Synopsis Report: Nepal 2006, Water and Energy Commission Secretariat, Ministry of Water Resources, Kathmandu, Nepal.
53. Kahen G., 1995, Integrated Energy Planning and Techno-Economic Development: A Solid Basis for the Assessment and Transfer of Energy Technology to Developing Countries, Imperial College, University of London.
54. Van Beeck Nicole 2003, A new decision support method for local energy planning in developing countries, Tilburg University, ISBN 90-5668-116-8.
55. Shukla, P.R., 1995, Greenhouse gas models and abatement costs for developing nations. A critical Assessment, Energy Policy, Volume 8, 677-687pp.
56. Sanchez-Sierra, Gabrie 1991, Electricity Planning for Developing Countries' in ATAS(Advanced Technology Assessment System), Bulletin, Issue 6: Energy Systems, Environment, and Development: A Reader. New York: United Nations, Centre for Science and Technology for Development.
57. Mathur.J, 2001, Development of a modified dynamic energy and greenhouse gas reduction planning approach through the case of Indian power sector, Dissertation,Fachbereich12,Maschinenwesen-Energietechnik-Verfahrenstechnik, University of Essen,2001.
58. Klein, et al. 1984, Environmental assessment: An international study of corporate practice, Journal of Business Strategy, Vol.5, pages 66-75pp.
59. WRI, 1999, World Resources: A guide to the global Environment 1998-1999, joint publication of World Resource Institute, UNEP, World Bank, Published by World Bank, New Delhi, India.
60. Beeck. N, 1999, Classification of Energy Models, Tilburg University and Endhoven University of Technology.
61. Schlen 98, Schlenzig, C.; PlaNet 1998, Ein entscheidungsunterstützendes System für die Energie-used Umweltplanung(a decision supported system for energy and

environment planning), Dissertation, Institute für Energiewirtschaft und Rationelle Energieanwendung(Institute of energy economics and rational use of energy,Juli,1998)

62. Kem et al., 1997 :Volkswirtschaftliche Modelle im Vergleich.
63. Nguyen K.Q., 2005, Long- term optimization of energy supply and demand in Vietnam with special reference to the potential of renewable energy. Dissertation, University of Oldenburg.
64. Pandey R., 2002 Energy policy modeling: agenda for developing countries. Energy Policy 30:97-106 pp.
65. Kydes et al, 1995, Beyond the horizon: recent directions in long-term energy modeling. Energy 20, 131-149pp.
66. Grubler A, et al, 1999, Dynamics of energy technologies and global change. Energy Policy 27, 247-280 pp.
67. Pfaff.Pfaffenberger,W.,Ströbele,W.:ProjektIkarus1995Makroökonomische Einbettung(Ikraus project-Macroeconomic embedding),Band 1, Oldenburg.
68. World Bank, 2009, Energy Demand Models for Policy Formulation, A Comparative Study of Energy Demand Models. Development Research Group Environment and Energy Team.
69. Omer Yuksek et al., 2006, The role of hydropower in meeting Turkey's electric energy demand, Energy Policy 34, 3093-3103 pp.
70. Khalaquzzaman. M. et al., 2008, Long Term Sustainable Energy Supply and Mitigation of Greenhouse Gas Emission in Bangladesh, International Energy Journal, Volume 9, Issue 2.
71. Connolly D, et al., 2010, A review of computer tools for analyzing the integration of renewable energy into various energy systems. Appl. Energy 87: 1059-1082pp.
72. Baumhögger et al., 1998, Manual MESAP, Version 3.1, Institute of Energy Economics and the Rational Use of Energy, Germany.
73. Ramachandra.T.V, 2009, Regional integrated energy plan, Renewable and Sustainable Energy Review, Science Direct, 13, 285-317pp.
74. LEAP, 2011, Long Range Energy Alternatives Planning System, A tool for energy policy analysis and climate mitigation assessment, Stockholm Environment Institute, USA.
75. Rath-Nagel S. and Voss A.1981, Energy models for planning and policy assessment, European Journal of Operational Research, Vol.8, No.2, 99-114 pp.

76. IIASA, 2005, Leo Schrattenholzer, Energy Planning Methodologies and Tools, IIASA, Austria
77. Wirrel. E.S. et al., 2004, Advances in Energy Forecasting Models based on Engineering Economics, Ann Environ Resources, Vol 29, 345 to 381pp.
78. Jung, T.Y.et al., 2000, Structural changes in developing countries and their implication for energy-related CO_2 emission. Technological Forecasting and Social Change 63,111-136pp.
79. Urban, F. et al., 2006. Modeling transitions to renewable energy in developing countries. In Sastry, E.V.R., Reddy, D.N.(Eds.), International Congress on Renewable Energy ICORE 2006 Proceedings. Allied Publications Pvt. Ltd., Hyderabad, India, 497-502 pp.
80. F.Uraban et al., 2007, Modeling Energy Systems for Developing Countries, Energy Policy 35, 3473-3482 pp.
81. Seebregts, A.J. et al., 2001, Energy/environmental modeling with MARKAL family of models, in Operations Research Proceedings 2001-Selected Papers of the International Conference on Operations Research(QR2001).
82. Goldstein G. and Tosato G. 2008, Global Energy Systems and Common Analysis: Final report of annex X (2005-2008), ETSAP, International Energy Agency.
83. Pokharel, S., 2007, An Econometric analysis of energy consumption in Nepal, Energy Policy, 350-361pp.
84. Lau.E.et al., 2011, Energy – Growth Causality: Asian Countries Revisited, International Journal of Energy Economics and Policy, Vol.1, No.4, 140-149 pp., ISSN: 2146-4553.
85. Ozturk.I.et al., 2012, Causality among Carbon Emission, Energy Consumption and Growth in India, Economic Research, Vol-25,752-775pp.
86. WTO, 2012, Trade Policy Review Report by Nepal, World Trade Organization.
87. MoICS, 2002, Industrial Development Perspective Plan: Vision 2020, Analytical Report, Ministry of Industry, Commerce and Supplies, Government of Nepal, Kathmandu, Nepal.
88. WB, 2012, World Bank Data, Nepal, Accessed: September 5, 2012, http://data.worldbank.org/country/nepal.
89. MoI, 2010, Industrial Policy 2010, Ministry of Industry Government of Nepal, Kathmandu, Nepal.
90. ADB, 2013, The Service Sector in Lower- Income Asian Economies, Asian Development Bank.

91. CBS, 2003, Population Monograph of Nepal, Central Bureau of Statistics, National Planning Commission Secretariat, Kathmandu, Nepal.
92. Pradhan, et al., 2006, Mitigation potential of greenhouse gas emission and implications on fuel consumption due to clean energy vehicles as public passenger transport in Kathmandu Valley of Nepal: A case study of trolley buses in Ring Road. Energy 31, 1748-1760 pp.
93. Parajuli.R.et al., 2013, Energy consumption projection of Nepal: An econometric approach, Science Direct, 432-444 pp.
94. Shrestha R.M et al., 2010, Energy and environment implications of carbon emission reduction targets: Case of Kathmandu Valley, Nepal, Energy policy Vol.38, 4818-4827pp.
95. Shakya.SR et al., 2011, Transport sector electrification in a hydropower resource rich developing country: Energy security, environmental and climate change co-benefits, Science Direct, 147-159 pp.
96. Bajracharya et al., 2013, Scenario Analysis of Road Transport Energy Consumption and Greenhouse Gas Emission in Nepal, proceeding of IoE Graduate Conference, Tribhuvan University, Lalitpur, Nepal.
97. DoTM, 2014, Government of Nepal, Department of Transport Management. Accessed:March18,2014,<http://www.dotm.gov.np/uploads/files/vechicle%20registration.pdf >
98. Zachariadis, T., et al. 2001, The effect of age and technological change on motor vehicle emissions. Transportation Research Part D 6, 221 – 227 pp.
99. Bidya.S. et al., 2009, Atmospheric emissions from road transportation of India, Energy Policy 37, 3812 – 3822 pp.
100. Dhakal, S., 2003, Implications of transportation policies and environment in Kathmandu Valley, Nepal. Energy Policy 31, 1493 – 1507 pp.
101. AEPC,2013, Formulation of Low Carbon Economic Development Strategy for Nepal, Alternative Energy Promotion Centre, Ministry of Science, Technology and Environment, Government of Nepal.
102. WECS, 2005, Detail Energy Consumption Survey in Urban Residential Sector of Nepal, Kathmandu, Nepal.
103. WECS, 1997, Update and Compilation of Energy Resources and Consumption Profile of Nepal, Final Report, Volume-I, II, &III, Kathmandu, Nepal.
104. WECS, 2013, Final Report, Final Report, National Survey of Energy Resources and Consumption Profile of Nepal, Kathmandu, Nepal.

105. WECS, 2001, Agriculture Sector Energy Consumption in Nepal, Water and Energy Commission Secretariat, Government of Nepal, Kathmandu, Nepal.
106. WECS, 1999, Detail Energy Consummation Survey in the Commercial Sector of Nepal, Water and Energy Commission Secretariat, Government of Nepal, Kathmandu, Nepal.
107. CBS, 2003, Population Monograph of Nepal, Central Bureau of Statistics, National Planning Commission Secretariat, Kathmandu, Nepal.
108. CBS, 2003, Population Projections for Nepal 2001 to 2021. Central Bureau of Statistics, National Planning Commission Secretariat, Kathmandu, Nepal.

Publication from this Study

- Bhattarai, N., Bauer. C, Doujak. E, 2014, "Residential Sector Energy Demand Projections and Analysis of Nepal for Sustainable Utilization of Local Hydropower Resources." Published in the Proceeding of Innovations and Development Needs for Sustainable Growth of Hydropower, 18th International Seminar on Hydropower Plants, 26-28 November 2014, Vienna, Austria.

Appendices

Appendix-1: Residential Sector (Source: Computed)

Energy Intensity [MWh/person]	Year					
	2005	2010	2015	2020	2025	2030
Fuel Wood	3.25	3.33	3.40	3.50	3.60	3.71
Animal Dung	0.24	0.25	0.25	0.27	0.27	0.29
Agri Residue	0.14	0.14	0.15	0.15	0.15	0.16
Kerosene	0.08	0.01	0.01	0.01	0.01	0.01
Electricity	0.03	0.04	0.06	0.07	0.09	0.11
Biogas	0.02	0.03	0.04	0.05	0.07	0.08
Coal	0.01	0.01	0.01	0.01	0.01	0.01
Total	3.77	3.82	3.92	4.06	4.20	4.36

Appendix-2: Energy Intensity in Industrial Sector

Due to the traditional approach, the energy intensity of Nepalese industry is quite high as compared to other developing countries. The historical industrial intensity values from the year 1997 to 2009 have been used for the analysis purpose. The overall sectoral energy intensity was 7.5 MJ/$ in the year 1997. It grew to 10.8 MJ/$ in the year 2009 with AAGR of 6.3%. The maximum intensity, 15.7 MJ/$ was observed in the year 2000. Figure A.1 shows the intensity and intensity growth rate of the sector during the period.

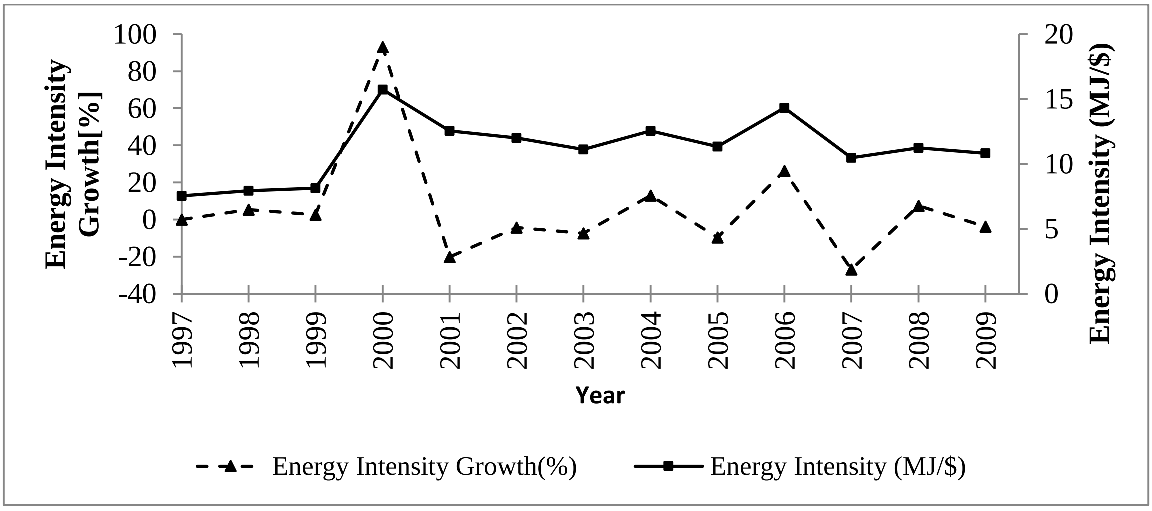


Figure A.1: Intensity and Intensity Growth rate of Industrial Sector (Source: Computed; WECS, 2010, WB, 2012)

The share of agriculture residue in 1997 was about 16.5% of total industrial energy consumption and reduced to 10.1% in the year 2009. The agriculture residue intensity in the year 1997 was 1.2 MJ/$, while in the year 2009, it was reduced to 1.1 MJ/$. The trend of the agriculture residue intensity in the sector has been decreased. Figure A.2 shows the historical patterns of the intensity and its growth scenario since 1997 to 2009. The negative annual growth (- 4.2%) of the fuel has been considered in the model for future intensity projections.

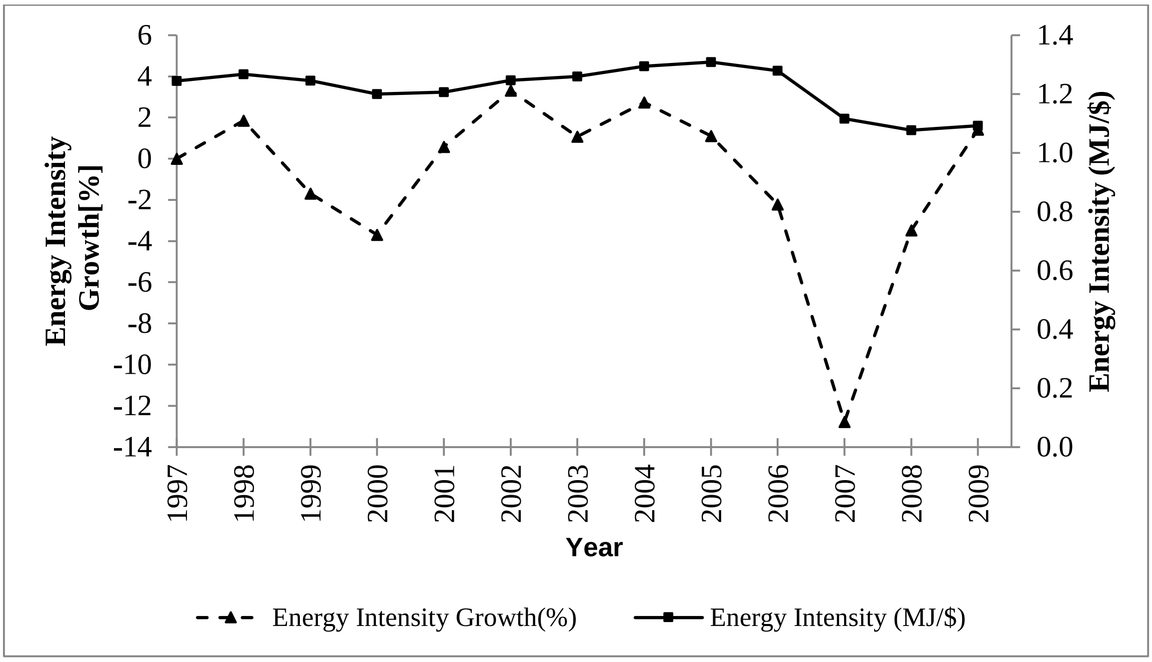


Figure A.2: Agriculture Residue Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

The contribution of fuel wood in the sector's energy consumption was 8.5% in 1997 and reduced to 5.4% in the year 2009. Figure A.3 shows that the historical pattern of intensity and its growth scenario. In 1997, the fuel wood intensity was 0.64 MJ/$ while in the year 2009 it was reduced to 0.58 MJ/$.The average intensity during the period was 0.64 MJ/$. The recent trend shows that the intensity of wood has been decreased. For projection of intensity, the annual growth rate of (-3.8%) has been considered.

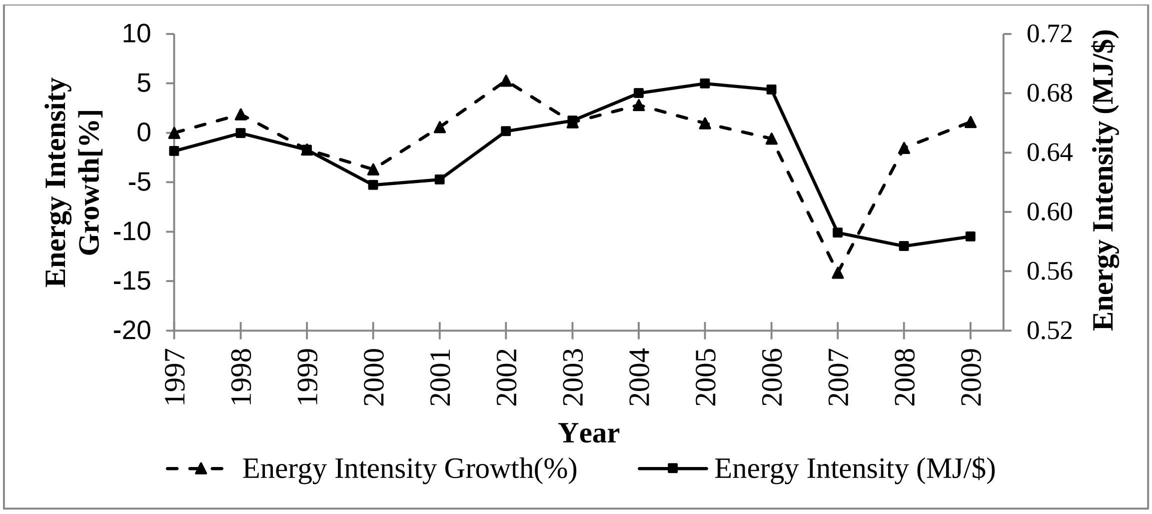


Figure A.3: Fuel Wood Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

The share of electricity was 21.2% of the sectoral energy consumption in 1997 and rose slightly to 23.2% in the year 2009. As shown in Figure A.4, during the period the intensity of the fuel had been increased from 1.59 MJ/$ to 2.51 MJ/$. The maximum intensity 2.60 MJ/$ was observed in 2008 while, the minimum intensity 1.59 MJ/$ was observed in the year 1997. The trend of the intensity was gradually increased during the period. For future projections of the intensity, 3.1% annual growth rate has been considered.

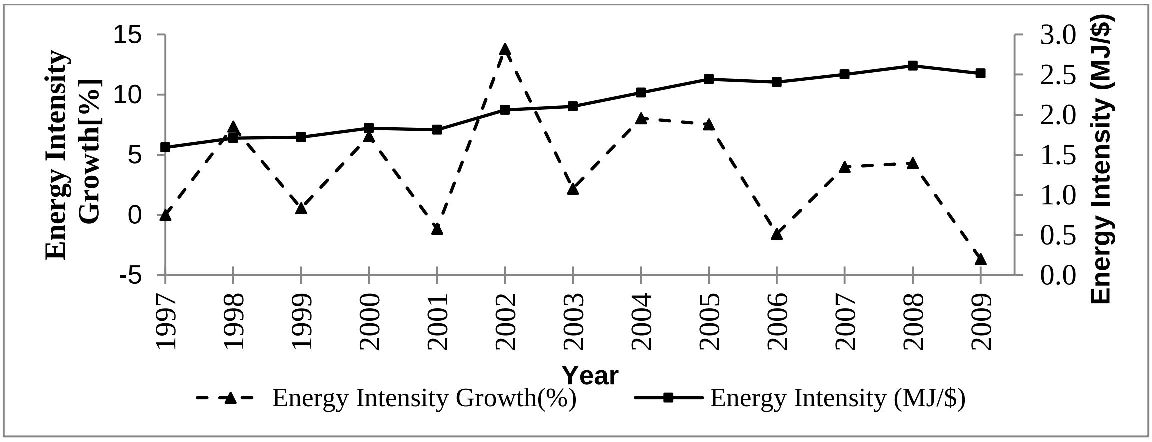


Figure A.4: Electricity Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

Although the share of diesel was 5.3 % in 1997 but reduced to 1.8 % in the year 2009. In 1997, its intensity was 0.40 MJ/$ and reached to 0.19 MJ/$ in 2009. The average intensity during the period was 0.22 MJ/$. The maximum and minimum intensities of 0.48 MJ/$, 0.13 MJ/$ were observed in the years 1998, and 2008 respectively. In this study, an annual growth rate of - 3.51% has been considered for further projection. Figure A.5 shows the intensity and its growth scenarios since 1997 to the year 2009.

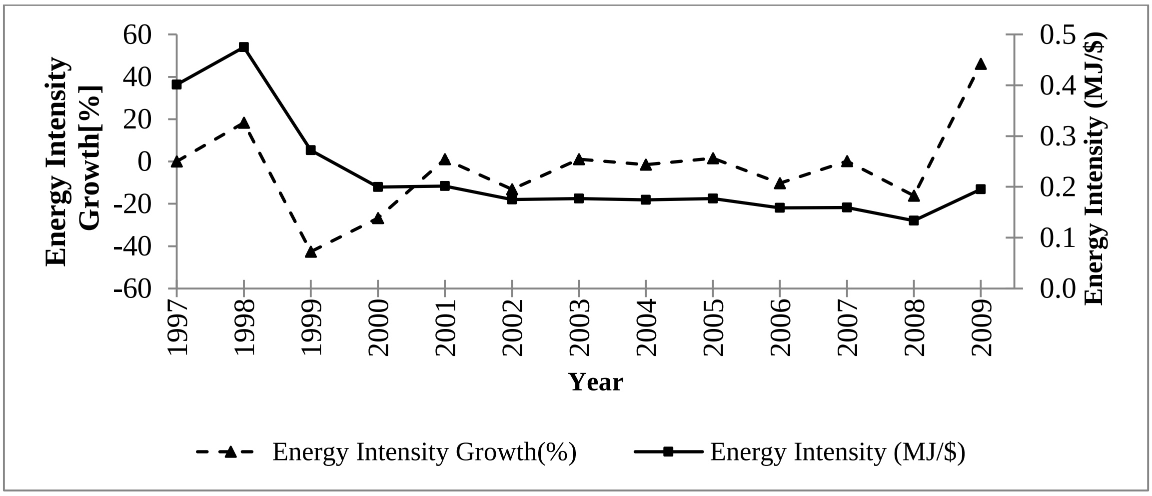


Figure A.5: Diesel Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

In 1997, the share of kerosene was about 5.7% of the sectoral energy consumption and reduced sharply to 0.83% in the year 2009. The energy intensity in 1997 was 0.43 MJ/$ while in 2009 it was reduced to 0.09 MJ/$. Its AAGR during the period was -9.6%, but from 2003, the trend was observed negative as shown in Figure A.6. The annual intensity growth (-26%) of the fuel has been consider for future projection.

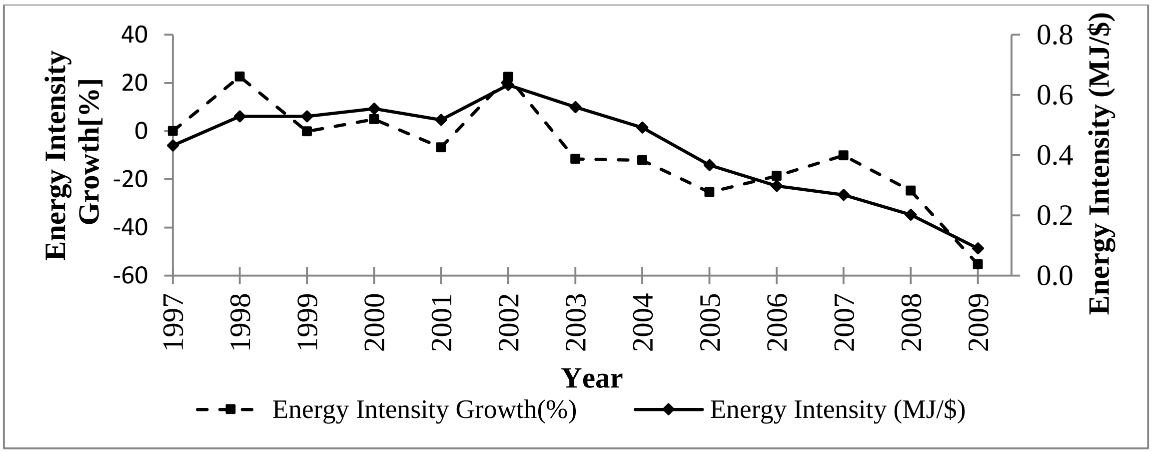


Figure A.6: Kerosene Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

The intensity of coal was 2.58 MJ/$ in 1997 and reached to 6.24 MJ/$ in 2009 as shown in Figure A.7. In the year 1997, about 34.2% of the industrial energy demand was supplied by coal and its contribution had been increased to 57.7% in the year 2009.The average intensity during the period was 5.89 MJ/$.For future projection of it, the annual growth rate of 0.8% has been considered in the research.

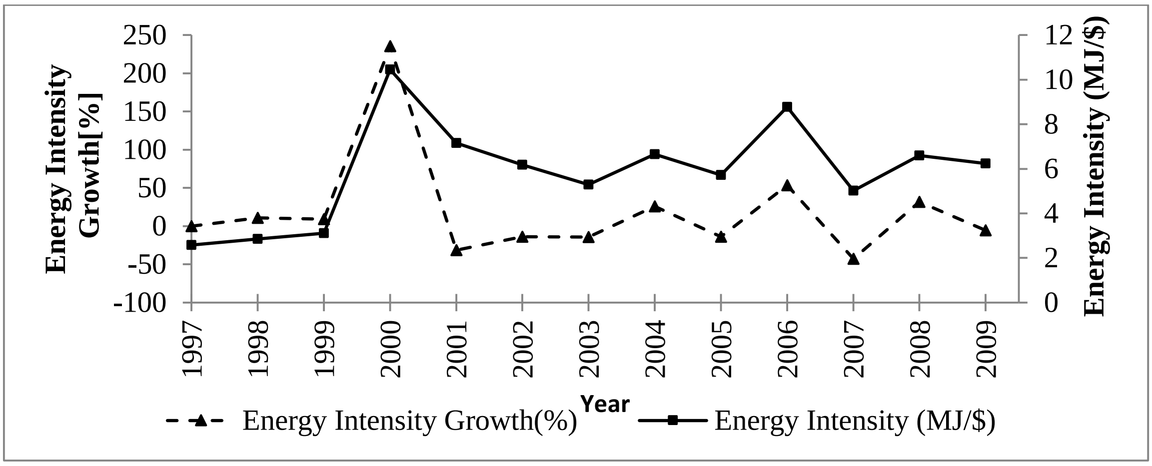


Figure A.7: Coal Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

Figure A.8 shows the historical intensity pattern of the other petroleum fuel and its growth since 1997 to 2009. In 1997, the intensity was found 0.27 MJ/$ and reduced to 0.01 MJ/$ in the year 2009. The share of other petroleum was about 8.3% of the sectoral energy consumption in 1997 and sharply reduced to 0.9% in the year 2009. The maximum intensity (1.06 MJ/$) was observed in 2003 while the minimum intensity (0.05 MJ/$) was observed in the year 2008. For future projection, -2.3% annual growths have been considered.

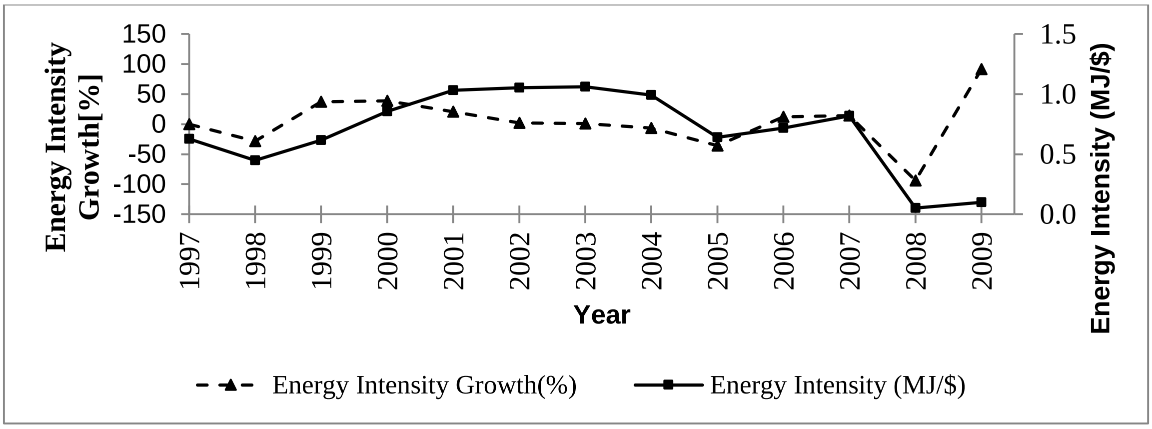


Figure A.8: Other Petroleum Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

Appendix-3: Energy Intensity in Commercial Sector

The historical commercial sector energy intensity and its growth trends are shown in the Figure A.9. The overall sectoral energy intensity was 1.44 MJ/$ in the year 1996. It had been increased to 1.43 MJ/$ in 2009 with AAGR of 0.4% during the period. The maximum intensity 1.98 MJ/$ was observed in the year 2003. Figure A.9, shows the energy intensity and the intensity growth patterns of the sector since last 1996 to the year 2009.

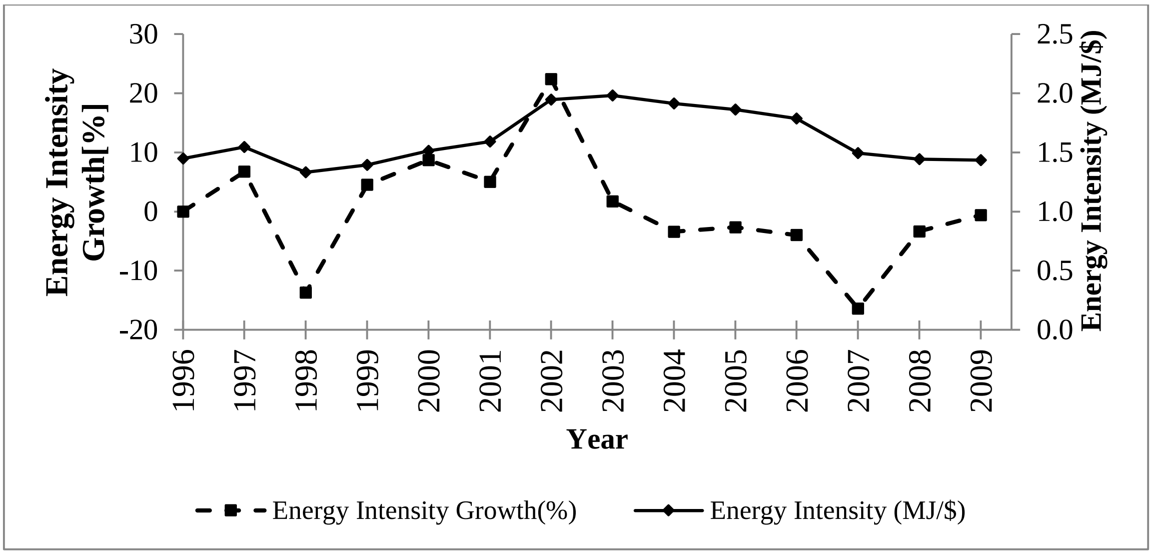


Figure A.9: Energy Intensity and Intensity Growth rate of Commercial Sector (Source: Computed; WECS, 2010, WB, 2012)

The contribution of fuel wood in the sector's energy consumption was about 33.7 % in the year 1996 and was slightly increased to 35.9 % in the year 2009. Figure A.10 shows the historical pattern of fuel wood intensity and its growth trends. In 1996, the fuel wood intensity was 0.49 MJ/$, while in 2009 it was observed to 0.52 MJ/$.The average intensity during the period was 0.60 MJ/$. The maximum intensity was 0.73 MJ/$ in 2006, while the minimum intensity was 0.49 MJ/$ in the year 1996. The recently passed trend shows that the intensity of the fuel has been decreased. For the projection of intensity, from 2006 to 2009 actual intensity growth of the fuel and after then the AAGR of -1% has been considered.

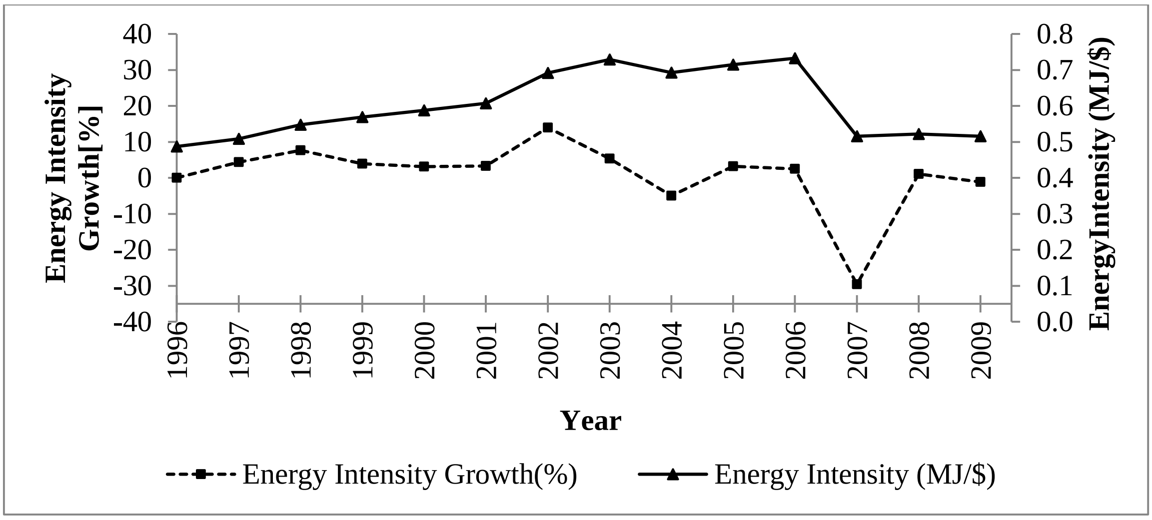


Figure A.10: Fuel Wood Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

The share of electricity was only 7.97% of the sectoral energy consumption in 1996 and increased to 11% in the year 2009. As shown in Figure A.11, the intensity had increased from 0.12 MJ/$ to 0.16 MJ/$ from 1996 to 2009. It has been found that the maximum intensity was 0.17 MJ/$ in the year 2008 while, the minimum intensity was only 0.12 MJ/$ in the year 1996. The growth of future electricity intensity has been projected using the linear equation as shown in the figure. By the year 2030, the electricity intensity of the sector will be reached to 0.24 MJ/$ according to the projection.

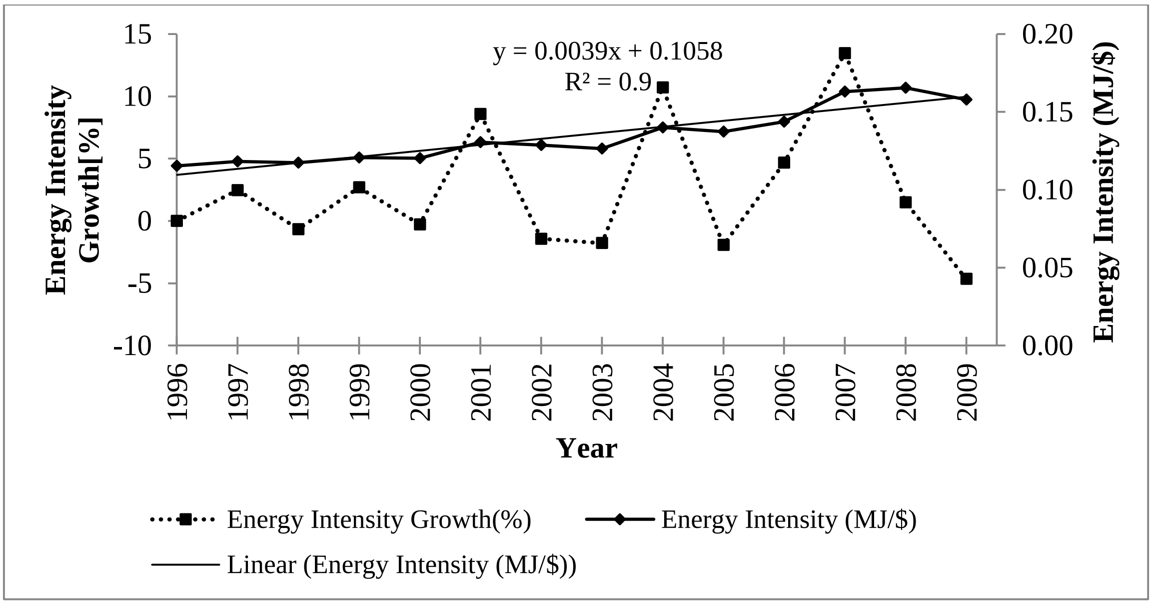


Figure A.11: Electricity Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

In 1996, the share of kerosene was about 38.6% of the sectoral energy consumption and reduced sharply to 5.9% in the year 2009. The energy intensity in 1996 was 0.56 MJ/$ while in 2009 it was reduced to 0.09 MJ/$. The AAGR during the period was -10.35 %, however, from the year 2003 the trend was observed always negative as shown in the Figure A.12. The intensity growth of -24.6% has been consider for future projection of the fuel.

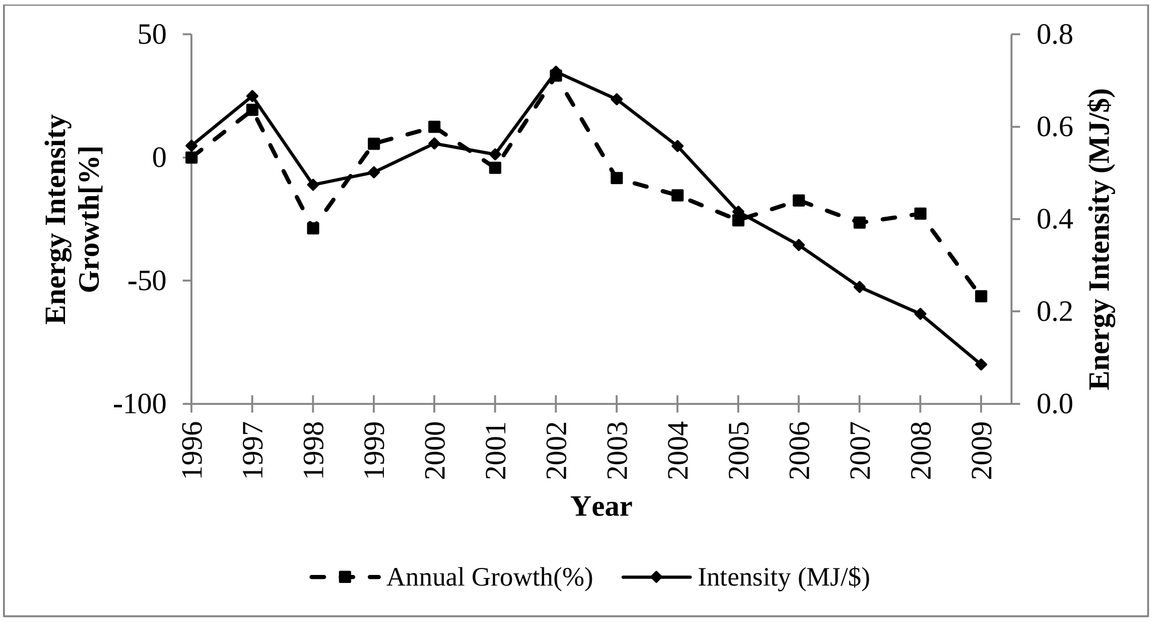


Figure A.12: Kerosene Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

The historical pattern of LPG and its growth scenarios are shown in Figure A.13. In 1996, the intensity was found 0.06 MJ/$ and increased to 0.64 MJ/$ in the year 2009. The share of the fuel was only 4.2% of the sectoral energy consumption in 1996 and sharply increased to 44.7% in 2009. The maximum intensity 0.64 MJ/$ was observed in the year 2009 while minimum 0.06 MJ/$ was found in the year 1996. For projection purpose, the annual growth of 2.3% has been considered in the study.

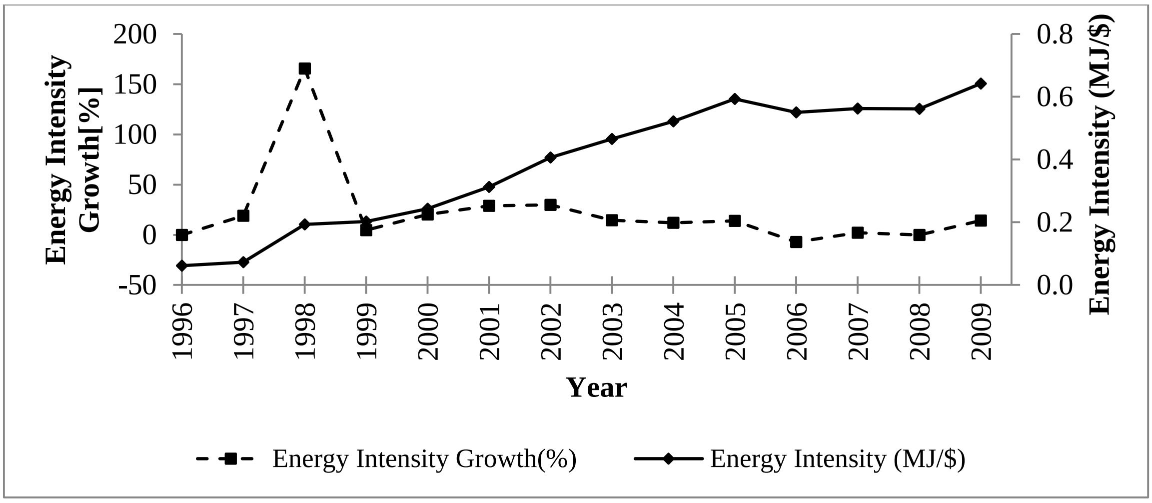


Figure A.13: LPG Intensity and Intensity Growth

(Source: Computed; WECS, 2010, WB, 2012)

Appendix-4: Selected Parameters for Transport Model

Source: Bajracharya et al. (2013), Shakya et al. (2011), Bidya et al. (2009)

Parameters	Bus	HDV	LDV	2Wheeler	3Wheeler	M. Vehicle	P.Tailor
α	2.3	2.29	2	1.99	1.94	2.29	2.29
T	14	12	12	8.5	10	12	12

Appendix-5: Future Projection of Vehicles

The projections of the number of vehicles have been carried out based on the annual registration data of the vehicles from the year 1990 to the year 2012. Although, the total number of vehicles has been increased exponentially, but within the total vehicle the contributing shares of different types of vehicles have been varied. The cumulative number of registered vehicles till 2013 has been illustrated in Figure A.14.

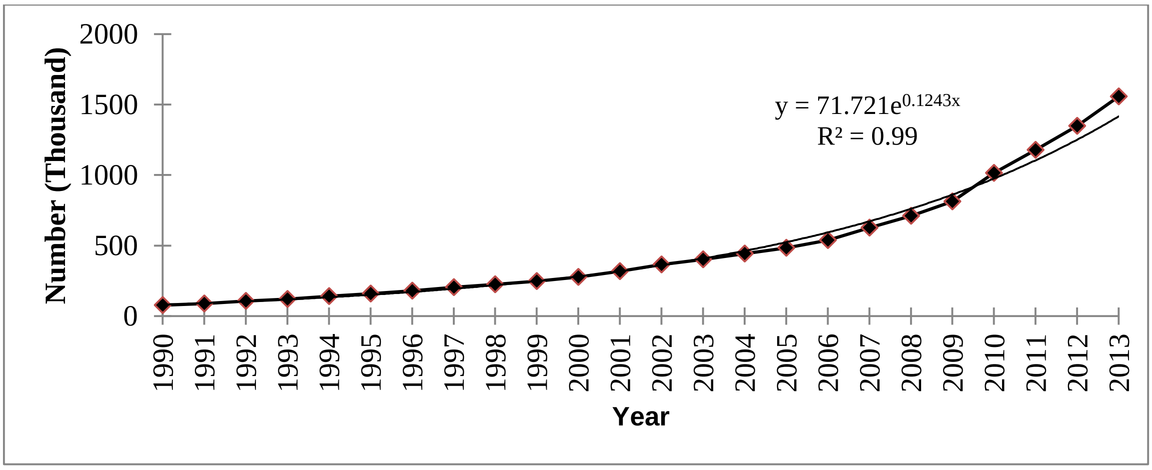


Figure A.14: Cumulative Number of Total Registered Vehicles

(Source: Computed; DoTM, 2012)

The historical sales trends have illustrated that the trends of some vehicles have been increased, where as the trends of others have been decreased. Additionally, for some vehicles the trends have been observed up and down annually. Therefore, a separate analysis has been carried out for projecting each type of vehicles in the study as follows:

1. Bus

Figure A.15 shows the historical trend of annually registered buses across the country. Although there are up and down in the number of the vehicles, but the trend has been increased. For further projections of the vehicles, a linear model has been selected.

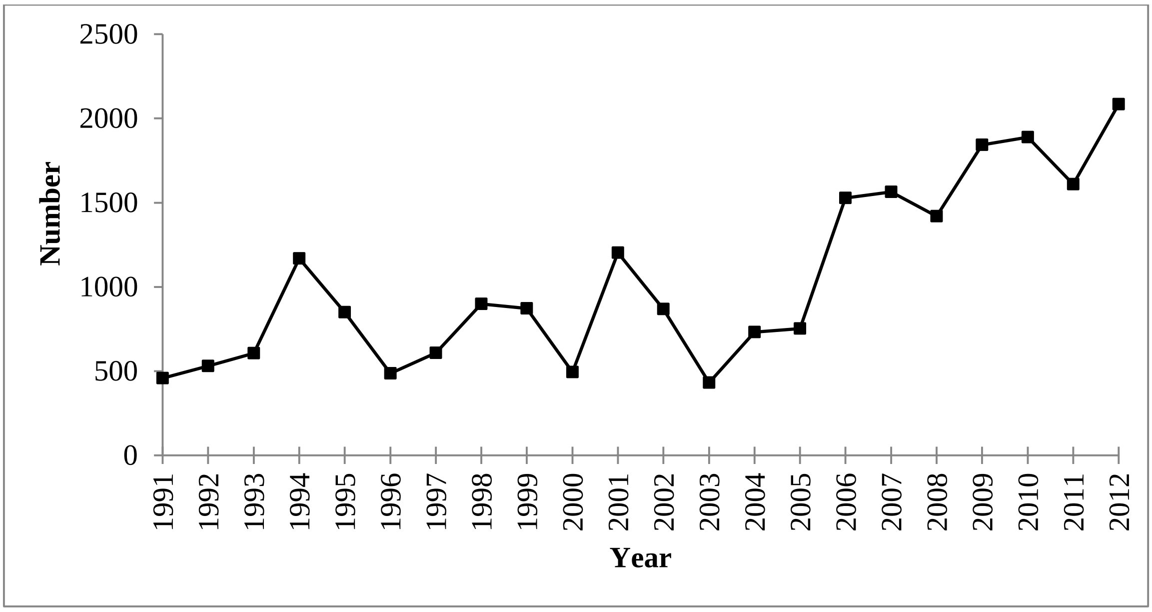


Figure A.15: Annual Registration of Bus (Source: Computed; DoTM, 2012)

$$No.of\ Bus = 63.17x + 314.29 \qquad (A.1)$$
$$R^2 = 0.62$$

2. Mini Vehicle

Mini bus and mini truck are included under this category. Figure A.16 shows the historical trend of their registration. Although, there was annually variation of the registered vehicles, but the average trend has been increased as shown in the figure. For projection of the number of vehicles for coming years following equation has been considered.

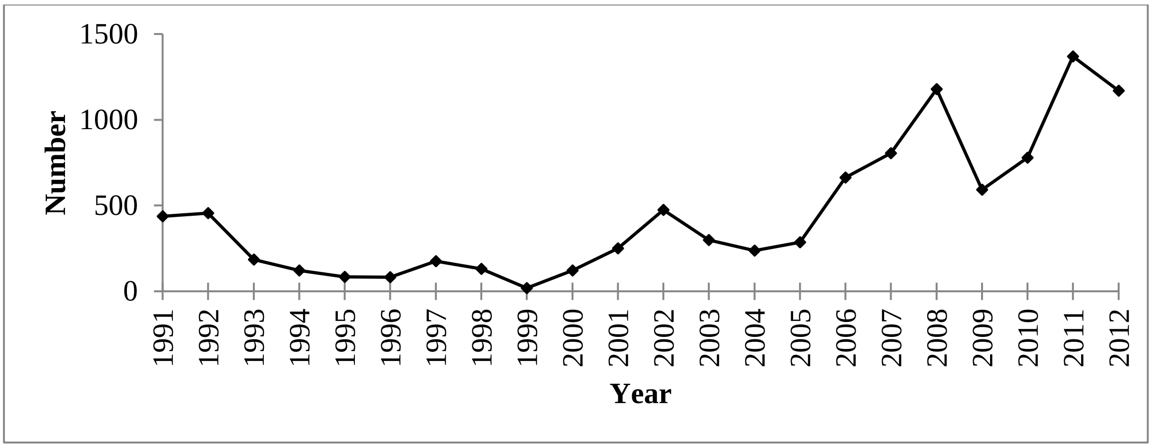


Figure A.16: Annual Registration of Mini Vehicle (Source: Computed; DoTM, 2012)

$$No.of\ Minin\ Vehicles = -5932.22 + 264.99\ \times Populaiton(in\ Million) \qquad (A.2)$$
$$(t - stat) \qquad (-5.039) \qquad (5.584)$$
$$R^2 = 0.74$$

3. Heavy Duty Vehicle

Figure A.17 shows the historical growth pattern of the Vehicle. For projection of the vehicle following equation has been considered in the study.

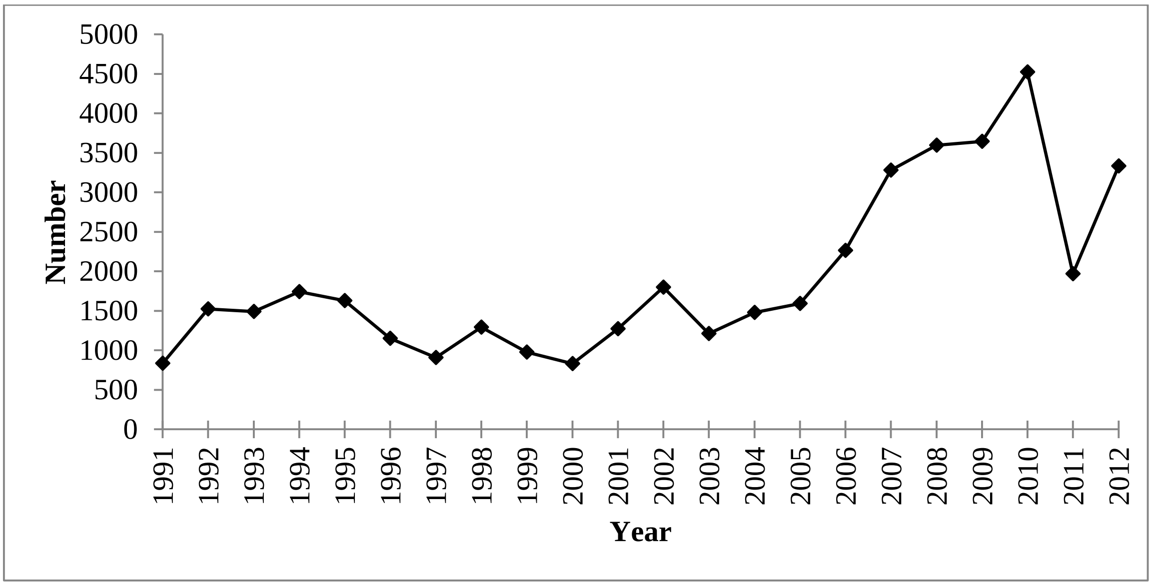


Figure A.17: Annual Registration of Heavy Duty Vehicle

(Source: Computed; DoTM, 2012)

$$No.of\ HDV = -1577.63 + 8.012\ \times GDP(in\ Billion\ NRs) \qquad (A.3)$$
$$(t - stat) \qquad (-2.297) \qquad (5.125)$$
$$R^2 = 0.58$$

4. Two Wheeler

The historical trend shows that, there has been a continuous growth of the registered two wheelers across the country as shown in Figure A.18. After the year 2006, the number of the vehicles has been sharply increased. For projection of the vehicle, following equation has been selected for the study.

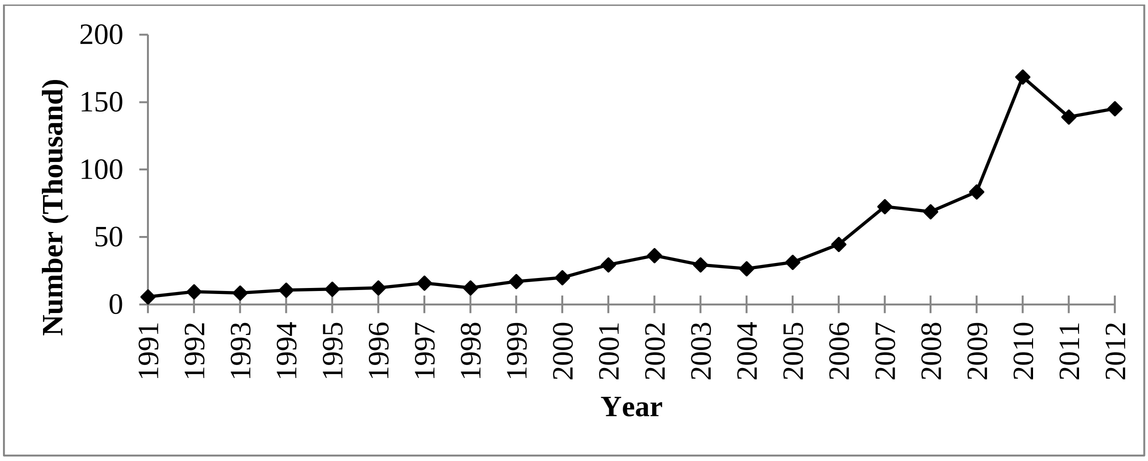


Figure A.18: Annual Registration of Two Wheeler (Source: Computed; DoTM, 2012)

$$No.\,of\ T.Wheeler = -241186 + 14924.46 \times GDP\ per\ Capita(Thousand\ NRs) \quad (A.4)$$

$$(t - stat) \qquad (-7.325) \qquad (8.795)$$

$$R^2 = 0.794$$

5. Light Duty Vehicle

Although there was varying in annual registration of the vehicles, but the trend has been increased as shown in the Figure A.19. For the study, following equation has been used for projecting the number of the vehicles in the coming years.

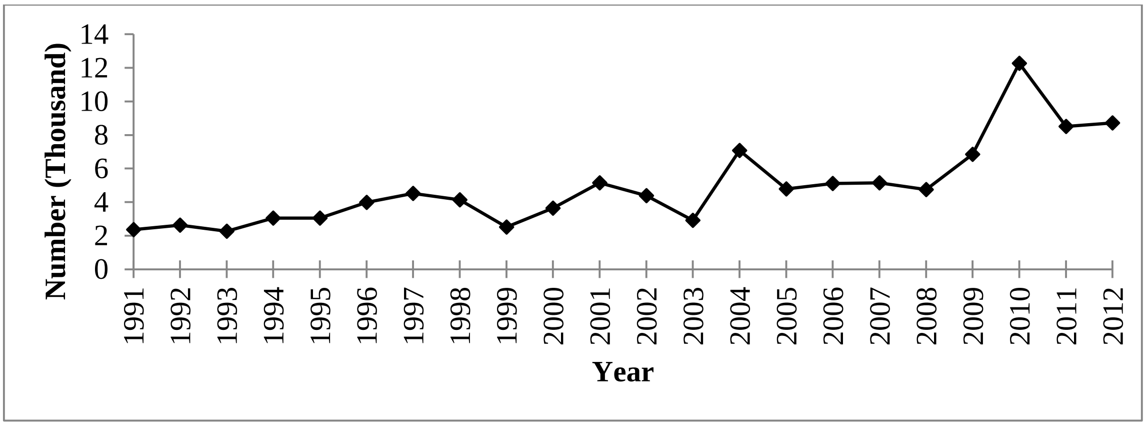


Figure A.19: Annual Registration of Light Duty Vehicle
(Source: Computed; DoTM, 2012)

$$No.\,of\ LDV = -8667.35 + 704.67\ \times GDP\ per\ Capita(in\ Thousand\ NRs) \quad \text{(A.5)}$$
$$(t - stat) \qquad (-4.377) \qquad (6.929)$$
$$R^2 = 0.71$$

6. Pick Up

The registration of the vehicles started from the year 2003 as shown in the Figure A.20. For this study, following equation has been taken for the further projection of the vehicles.

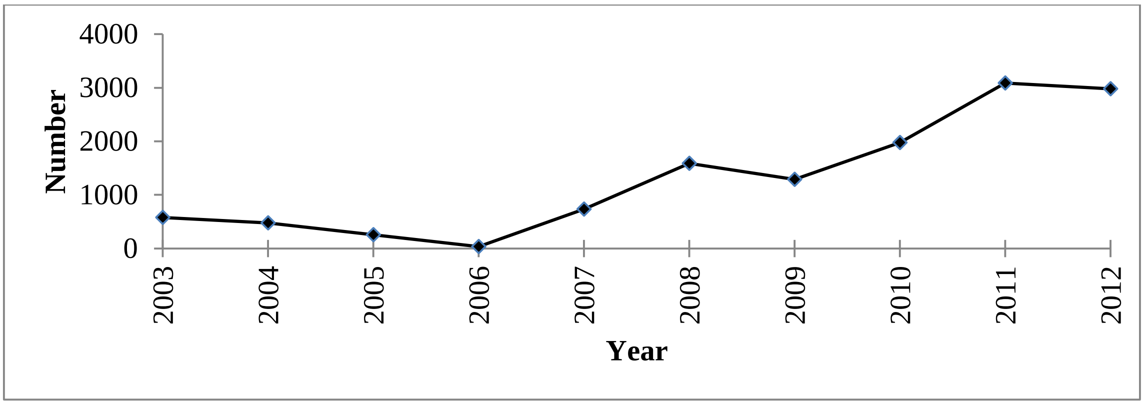


Figure A.20: Annual Registration of Pick Up (Source: Computed; DoTM, 2012)

$$No.\,of\ Pick\ Up = -6763.06 + 14.47\ \times GDP(in\ Billion\ NRs) \quad \text{(A.6)}$$
$$(t - stat) \qquad (-5.488) \qquad (6.571)$$
$$R^2 = 0.85$$

7. Micro Bus

Micro bus was introduced in the country for the public transport in 2003. Figure A.21 shows the historical annual registration scenario. In the model, it has been assumed that the annual registration of the vehicles will be the average value from the year 2006 to the year 2012.

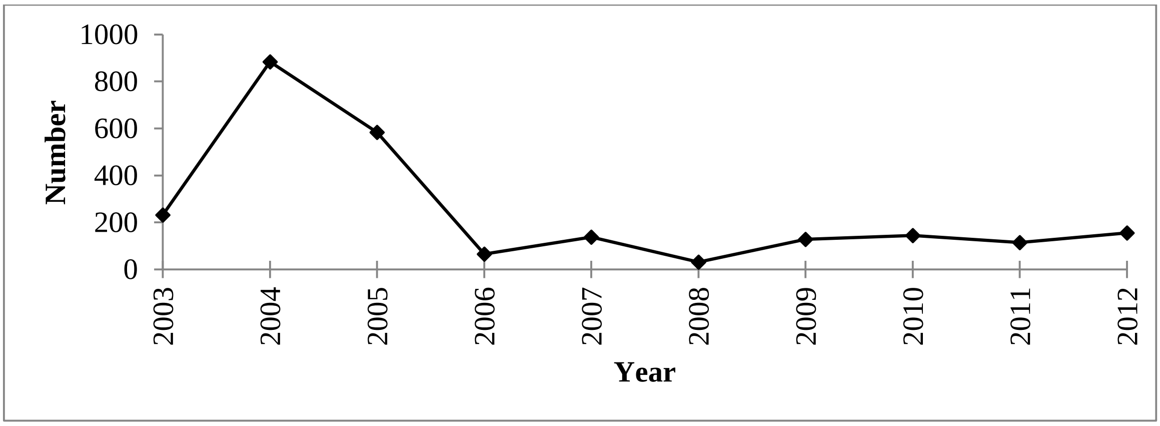


Figure A.21: Annual Registration of Micro Bus (Source: Computed; DoTM, 2014)

8. Three Wheeler

The historical pattern of annually registered three wheelers in the country has been shown in the Figure A.22. For the study, it has been assumed that the vehicle will be annually grown according to the annual average number from the year 2003 to the year 2012.

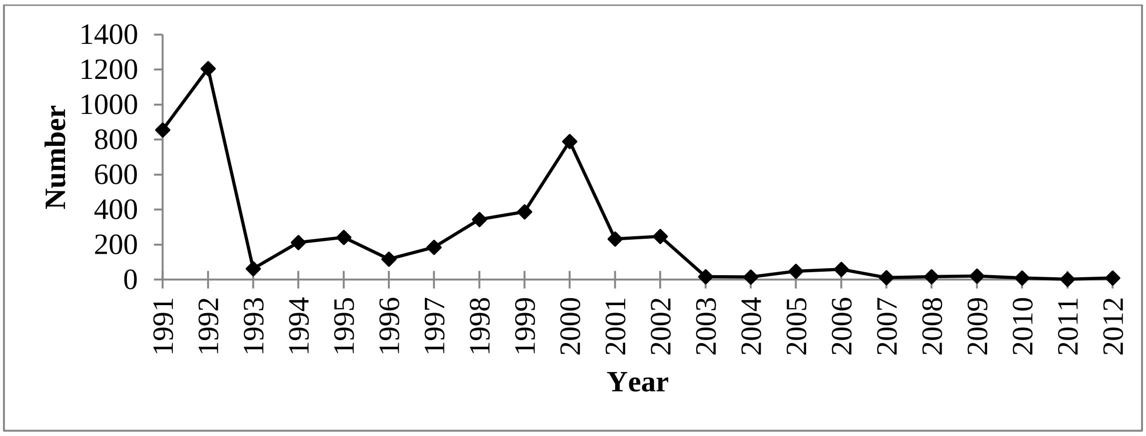


Figure A.22: Annual Registration of Three Wheeler (Source: Computed; DoTM, 2014)

9. Power Tailor

The historical trend of power tailor annual registration across the country has been shown in Figure A.23. Although the trend has been increased but, there are up and down of the numbers of annual registration of the vehicles. For the further projection of the vehicle, following equation has been selected.

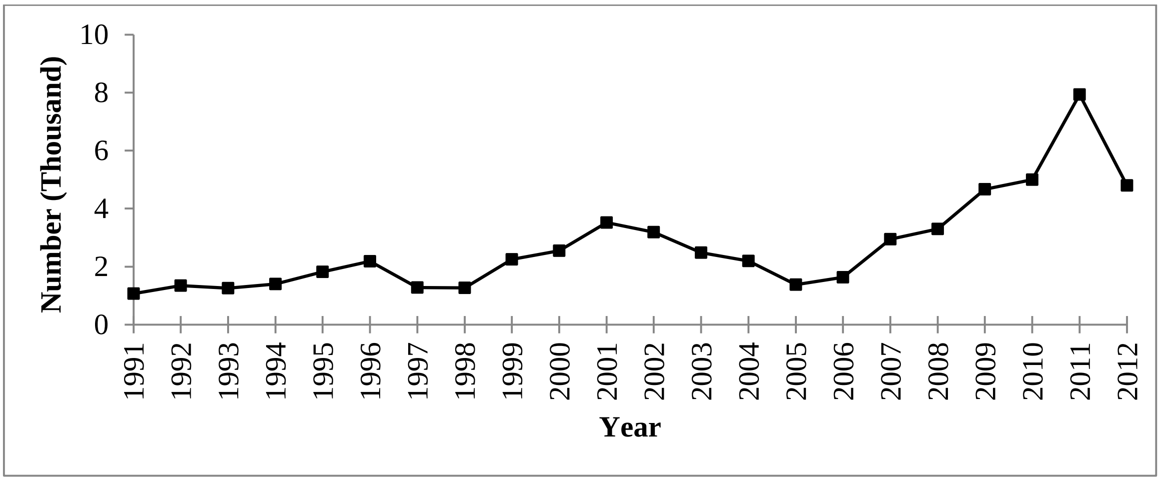


Figure A.23: Annual Registration of Power Tailor (Source: Computed; DoTM, 2014)

$$No.of\ Power\ Tactor = -2430.04 + 11.436\ \times GDP(in\ Billion\ NRs) \qquad (A.7)$$

$$(t - stat) \qquad (-2.766) \qquad (6.031)$$

$$R^2 = 0.65$$

Appendix-6: Annual Millage of Vehicles by Various Studies

Type of Vehicle	Annual Millage (Kilometer Travel by Different Studies)					
	Dhakal,S.1996	Ale,B.B,2001	DoR,2001	Bajracharya.I,2013		AEPC,2013
	City drive	City drive	Long drive	City drive	Long drive	N.Average
Bus	33522	39600	54407	44105	56826	59535
Minibus	31790	37125		43307	47500	38694
Private Car	16349			12310		
Taxi	41970	32340		25356		
Microbus	41970	37125		38520		38529
Government Vehicle	34830	37125		38520		
Battery operated 3 W	29848					
LPG 3 W	29848	32340				32679
Motorcycle(2W)	10952					9892
Truck			83654	37800	46860	23327
Mini Truck				37415		
Pick Up						14549
Car/Jeep/Van						13838

Appendix-7: Fuel Economy Values by Various Studies

Vehicle Type	Fuel Type	Fuel Consumption km/liter			
		Dhakal.S.,1996	Bajracharya.I.,2013		AEPC,2013
		City Drive	City Drive	Highway Drive	N.Average
Bus	Diesel	3	3.5	4.5	3.6
Minibus	Diesel	4.5	4	4.5	5.0
Microbus	Diesel		6.2		7.1
Truck/Tanker	Diesel		3.5	4.08	3.3
Mini Truck	Diesel		4		
Car/Jeep/Van	Diesel				12.7
Car	Gasoline	10.6	13.5		
Car	Diesel	8	8.5		
Taxi	Gasoline	10.6	12.5		
Microbus	LPG	8.4 km/kg			
Pick Up	Diesel		6.5		8.5
Motor Cycle	Gasoline	53.8	42.5		35.0
3 Wheeler	LPG	20.2 km/kg			18 km/kg
3 Wheeler	Battery	5 km/kwh DC			

Appendix-8: Energy Intensity in Agriculture Sector

The sectoral energy intensity was 0.37 MJ/$ in 1996 and reached to 1.28 MJ/$ in the year 2009. The maximum intensity 1.28 MJ/$ was observed in 2009 while minimum 0.35 MJ/$ was observed in the year 1999 respectively as shown in Figure A.24.

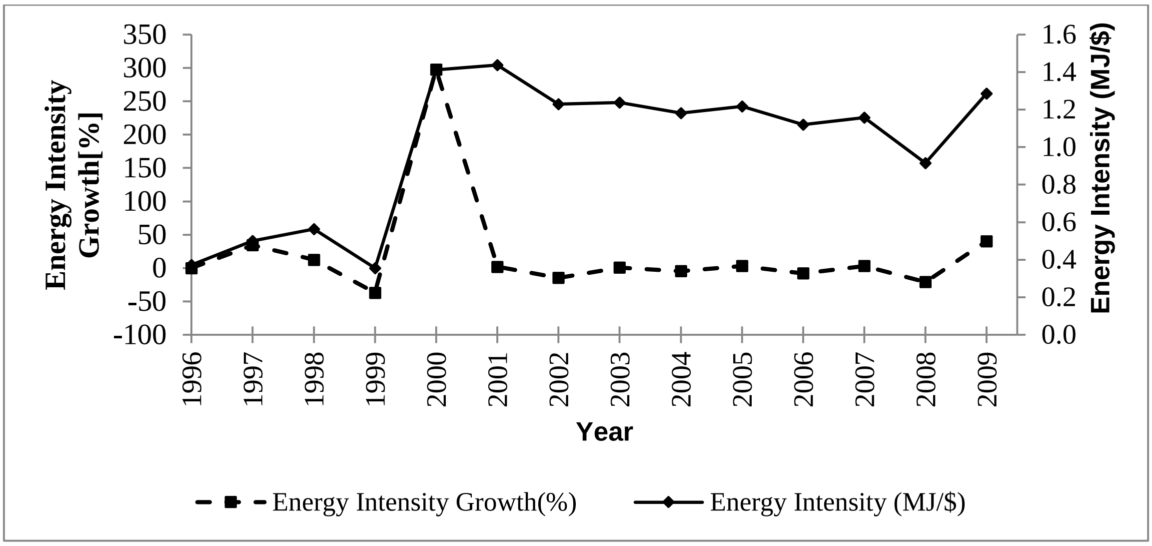


Figure A.24: Energy Intensity and Intensity Growth rate of Commercial Sector (Source: Computed; WECS, 2010, WB, 2012)

Although the share of diesel on the total energy consumption was about 87 % in 1996 but has been increased and reduced to 95.2 % in the year 2009. In 1996, its intensity was 0.32 MJ/$ and reached to 1.22 MJ/$ in 2009. The maximum intensity 1.45 MJ/$ was observed in 2001, while minimum 0.31 MJ/$ was observed in 1999. The future annual intensity has been projected based on the trend of the intensity as shown in Figure A.25.

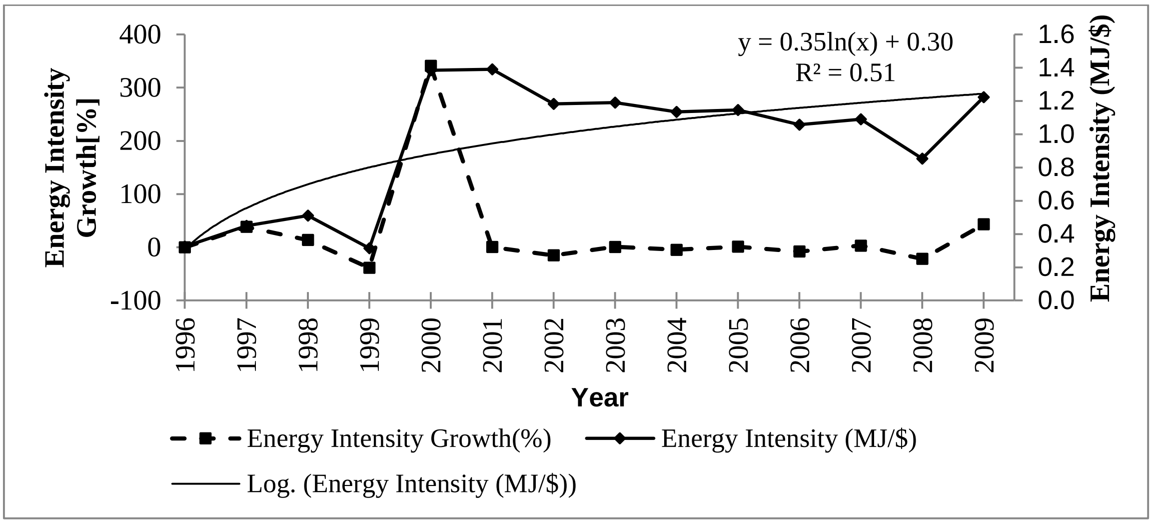


Figure A.25: Diesel Intensity in Agriculture Sector (Source: Computed; WECS, 2010, WB, 2014)

The share of electricity was 8.0% of the sectoral energy consumption in 1996 and slightly decreased to 4.8% in the year 2009. As shown in Figure A.26, the intensity had increased from 0.05 MJ/$ to 0.06 MJ/$ from 1996 to 2009. It has been found that the maximum intensity was 0.07 MJ/$ in the year 2005 while, the minimum intensity was only 0.03 MJ/$ in the year 2000.The growth of the future intensity has been projected using the average growth of the intensities during the period 2005 to 2009.

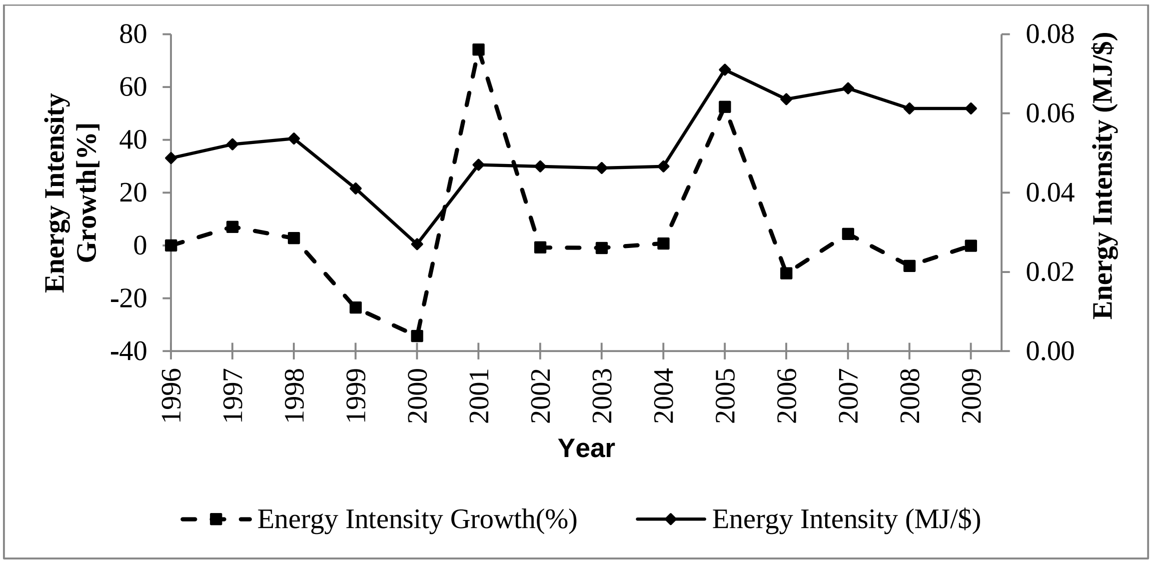


Figure A.26: Electric Intensity in Agriculture Sector

(Source: Computed; WECS, 2010, WB, 2014)

Appendix-9: Population Projections (Source: CBS, 2003, 2011 & Author)

Year	In Million		Urban (%)
	Total Population	Urban Population	
1991	18.49	1.70	9.17
1992	18.91	1.81	9.56
1993	19.34	1.93	9.97
1994	19.78	2.06	10.40
1995	20.23	2.19	10.85
1996	20.69	2.34	11.31
1997	21.16	2.50	11.79
1998	21.64	2.66	12.30
1999	22.13	2.84	12.83
2000	22.63	3.03	13.38
2001	23.15	3.23	13.94
2002	23.46	3.32	14.17
2003	23.78	3.42	14.40
2004	24.10	3.53	14.63
2005	24.43	3.63	14.87
2006	24.76	3.74	15.11
2007	25.09	3.85	15.36
2008	25.43	3.97	15.61
2009	25.77	4.09	15.87
2010	26.12	4.21	16.12
2011	26.49	4.50	16.98
2012	26.85	4.70	17.50
2013	27.21	4.90	18.00
2014	27.58	5.10	18.49
2015	27.95	5.20	18.60
2016	28.33	5.50	19.41
2017	28.71	5.70	19.85
2018	29.10	5.90	20.27
2019	29.49	6.10	20.68
2020	29.89	6.30	21.08
2021	30.30	6.50	21.45
2022	30.71	6.80	22.15
2023	31.12	7.00	22.49
2024	31.54	7.20	22.83
2025	31.97	7.50	23.46
2026	32.40	7.70	23.77
2027	32.83	8.00	24.36
2028	33.28	8.30	24.94
2029	33.73	8.50	25.20
2030	34.18	8.80	25.74

Curriculum Vitae

Family Name	:	**Bhattarai**
Name	:	Nawraj
Date of Birth	:	02 September, 1975
Marital Status	:	Married with Deewa Pokharel, 2 children
		(Son-Shaarav & Daughter- Saanvi)
Address	:	Hariwon-4, Sarlahi, Nepal
E-mail	:	bnawraj@gmail.com

Academic Qualification

- **Master of Science (M.Sc.)** in Renewable Energy Engineering from Institute of Engineering, Tribhuvan University, Nepal in 2004.
- **Bachelor of Engineering (B.E.)** in Mechanical Engineering from Institute of Engineering, Tribhuvan University, Nepal in 2000.

Job Experiences

- **Working as an Assistant Professor** since 2004 and toughed several subjects in Mechanical Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal.
- **Deputy Head** (2008-2010) in Department of Mechanical Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal.
- **Deputy Director** (2010-2011) in Centre for Energy Studies, Institute of Engineering, Tribhuvan University, Nepal.

Academic Research Supervision (M.Sc. Level)

1. 2006, Performance Study on Tabular and Compact Fluorescent Lamps used in Solar Home System in Nepal.
2. 2009, Computer Based Analysis, Design and Fabrication_of Diffuser Type Portable Wood Gasifier to Develop a Preliminary Lab Setup for Performance Test.
3. 2009, Rural Electrification Options for Kaldhar Village Nepal.
4. 2010, Study on Techno-Socio and Financial Impact of Biogas Plants in Kavre District of Nepal.
5. 2010, Wind Energy Resource Assessment and Feasibility Study of Wind Farm in Mustang of Nepal.

6. 2010, A Study on Operation and Maintenance of Electro- Mechanical Parts of Kulakhani Second Hydropower Plant of Nepal.
7. 2010, Performance Test of Residential Cook Stove and Modification of a Metal Stove.
8. 2011, Policy and Study of Grid Connected PV System in Nepal.
9. 2011, Study on Erosion Behavior of Runner and Guide Vane and its Rectification in Hydropower Station (A case of Middle Marsyangdi Hydropower Station)
10. 2012, Energy Analysis of Green Building and Setting-up Building code for Different Parts of Nepal.

Academic Publications

1. 2006, Performance Analysis of DC Tubular Lamps and Compact Fluorescents Lamps used in Solar Home System in Nepal, in first National Conference on Renewable Energy Technology for Rural Development in Kathmandu, Nepal.
2. 2006, Development of Liquid Bio-fuel out of the Traditional Biomass Resources to Generate Renewable Fuel for Rural Development in Nepal, in first National Conference on Renewable Energy Technology for Rural Development in Kathmandu, Nepal.
3. 2008, Emission of Pollutants under Different Traffic Load Condition in Kathmandu Valley, in Better Air Quality Conference, Bangkok, Thailand.
4. 2009, Knowledge Management System for Sustainable Modern Biomass Based Energy Development in Nepal, Asian Institute of Technology International Conference on Knowledge Management, Kathmandu, Nepal.
5. 2009, Relation between Air Pollution and Climate Change, in Nepal Engineer's Association 11th Convention, Kathmandu, Nepal.
6. 2009, Institutional Gasifier Stove: A Sustainable Prospect for Institutional Cooking, Journal of the Institute of Engineering, Vol 7, No, 1, 142-149.
7. 2009, Barrier for Implementation of Improved Cook Stove Program in Nepal, Institutional Gasifier Stove: A Sustainable Prospect for Institutional Cooking, Journal of the Institute of Engineering, Vol 7, No, 1, 116-120
8. 2011, Wind Energy Resource Assessment and Feasibility Study of Wind Farm in Mustang, Journal of the Institute of Engineering, Vol 8, No, 1-2, 93-104.
9. 2011, Biomethanation of Organic Waste under Psychrophilic Conditions, International Conference on Addressing Climate Change for Sustainable Development through Up-Scaling Renewable Energy Technologies, Kathmandu, Nepal.

Course Manual Writing (for International Level only)

1. 2009, Biomass and design/construction for cooking stoves, Department of Alternative Energy, Tumba College of Technology, Rwanda, Africa.