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Three Essays on Energy Consumption, Economic Growth and Future Energy Mix in Myanmar

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Sei Thu Kyaw Kyaw

Graduate School of Seoul National University
Technology Management, Economics, and Policy Program

Three Essays on Energy Consumption, Economic Growth and Future Energy Mix in Myanmar

지도교수 허은녕

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Sei Thu Kyaw Kyaw

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부위원장 허은녕 (인)

위 원 김진수 (인)

위 원 구윤모 (인)

위 원 부경진 (인)

Abstract

Three Essays on Energy Consumption, Economic Growth and Future Energy Mix in Myanmar

Sei Thu Kyaw Kyaw
Technology Management, Economics and Policy Program
College of Engineering
Seoul National University

The Republic of the Union of Myanmar has attained significantly economic growth, as GDP growth rates have been 7% on average since 2010. High economic growth brings needs for a new set of new energy policy to meet the increasing demand. Government need to put efforts to achieve the goal efficiently and effectively. This study performs three quatitative analyses on Myanmar energy situation and decision-making process in order to provide academic results to support effective energy policy in Myanmar.

The first essay analyze the long run relations and causality relations aming economic growth GDP, crude oil consumption, natural gas consumption, electricity consumption, and coal consumption of Myanmar over the period of 1990-2017. Time series data of the variables have been analyzed via unit root test, Johansen cointegration test, Vector Error Correction Model (VECM) or Vector Autoregression Model (VAR), and Granger Causality test to evaluate the direction of causality among variables.

The second research is about the role of sectoral energy consumption in Myanmar's economic growth. This research employs a panel data set for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017 to explore the causal relationship between energy consumption and economic growth taking into account other factors as CO_2 emission.

The third analysis is to establish a multicriteria hierarchy for the selection of energy resources among decision makers in the sustainable energy mix in Myanmar. The study demonstrated choices of government officials from three ministries via AHP method as it has flexibility and simplicity for the analysis to prioritize criteria, subcriteria and alternatives.

Based on the analysis results of the examination, this study reveals the fact that high energy consumption leads to economic growth GDP in Myanmar, though there are many other factors contributing to economic growth, and energy consumption is only one of such factors. Natural gas consumption shows the highest contribution to Myanmar's economic growth. Also, energy alternative options were defined as 41.5% for Natural Gas to be the best option, followed by renewable (34%), petroleum (17.6%) and coal (6.8%). However, electricity consumption is not effect to economic growth in Myanmar at the same period.

Regarding the selection of energy resources in the sustainable energy mix in Myanmar, the most important criterion to be considered in the energy decision making process is the technology criterion. It followed by economic criteria, socio-political criteria and environmental criteria. In the sub-criteria, the highest global priority goes to the technology subcriteria of availability of local expert, asking policies to enhance education and development of energy technology.

Keywords: (Energy Consumption, Economic Growth, AHP, Causality, Myanmar)
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1 Introduction

1.1 Motivation and problem statement

The Republic of the Union of Myanmar has attained significantly economic growth. According to the ASEAN statistical year book 2018, Myanmar gross domestic product (GDP) growth rate was 7% since 2010 to 2017. This growth rate was the third-highest economic growth rate among the ASEAN member countries. Myanmar real GDP per capital was 1,229 USD in 2017 (ASEAN 2018).

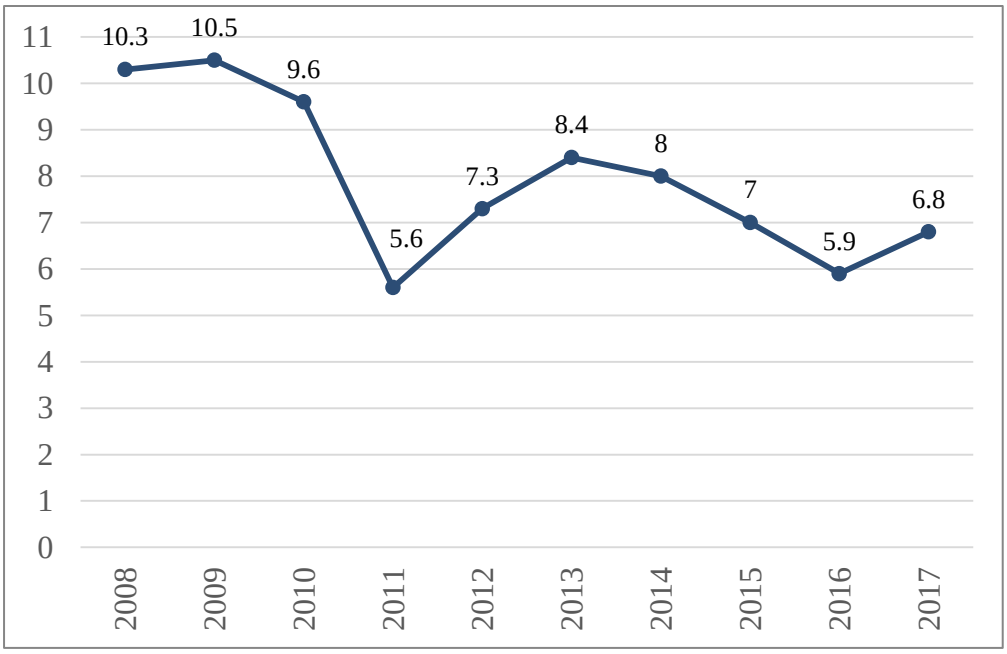


Figure 1.1. Myanmar economic growth rate (2010-2017)

(Source: ASEAN Statistical Year Book 2018)

With 53 million populations, Myanmar will require a lot of energy supply to contribute its economic development. Myanmar energy demand has increased with a significant portion of the shares is coming from the consumption of fossil fuels such as; crude oil, natural gas, coal, electricity consumption. These types of energy availability are essential in Myanmar to contribute several productive sectors such as industrial, transportation, commercial and services sectors as well as residential sector.

High economic growth also brings a new risk that crude oil, natural gas, electricity, coal availability might not be able to fulfill the growing demand. Myanmar, ASEAN member state, will require a lot of crude oil from the other area through import activity (Behmiri and Pires Manso 2014). It will also create an environmental issue with the increase of energy-related emissions and may cause a problem to public health. The transportation sector has a dominant effect on crude oil consumption compare with the building and industrial sectors.

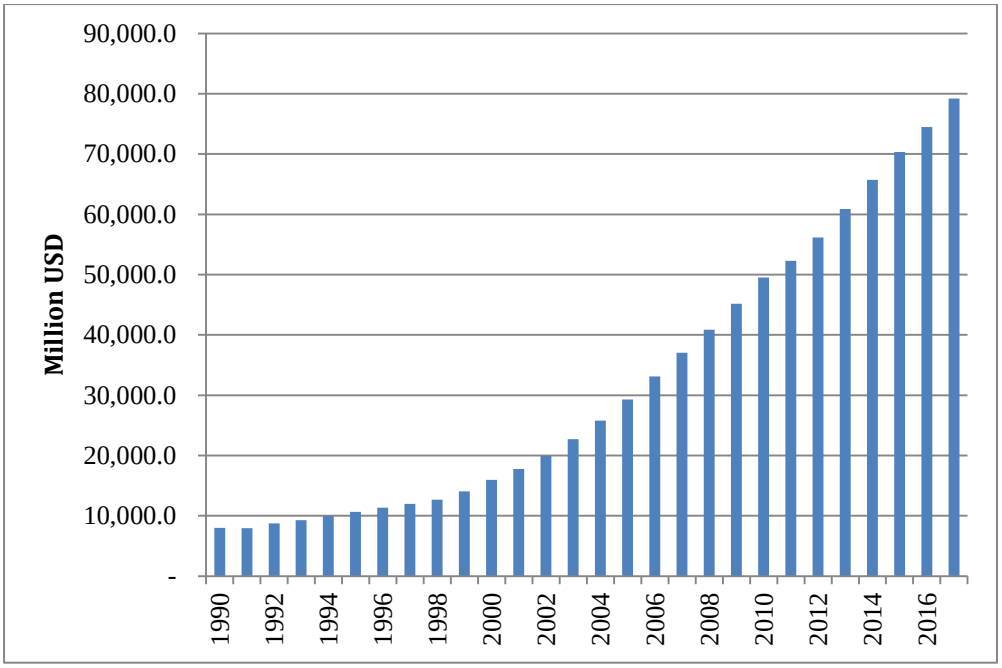


Figure 1.2. GDP in Myanmar (Million USD)

(Source: World Bank)

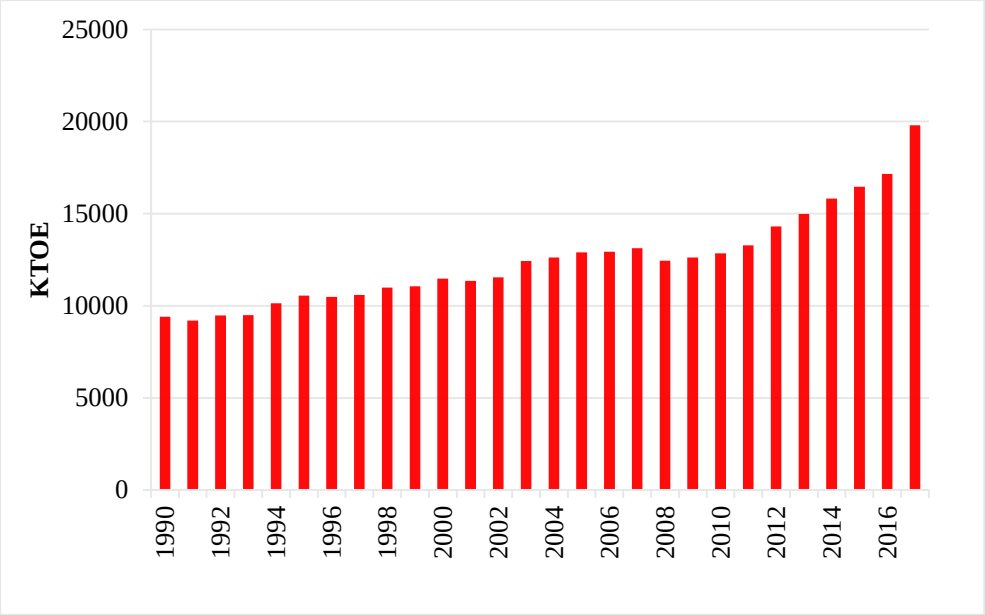


Figure 1.3. Myanmar Total Final Energy Consumption (ktoe) 1990-2017 (Source: ASEAN Statistical Year Book 2018)

Figure 1.3 shows that the Myanmar energy consumption (ktoe) from 1990 to 2017 (Asia 2018). According to that figure, Myanmar has increased energy consumption from 9,400 ktoe in 1990 to 19,000 ktoe in 2017. It can be seen that energy consumption has been increased 2 times in 27 years. Figure 1.4 shows that Myanmar energy consumption (ktoe) by type from 1990 to 2017 ("Southeast Asia Energy Outlook 2017" 2017). According to that figure, among five types of energy, coal, oil product, natural gas, electricity and biofuel and waste, biofuel takes large portion of the Myanmar energy consumption. Myanmar energy consumption has increased oil products from 400 ktoe in 1990 to 6600 ktoe in 2017. Similarly, although electricity consumption, natural gas consumption and coal consumption have

been promoted, there are no significant increases in total energy consumption of Myanmar.

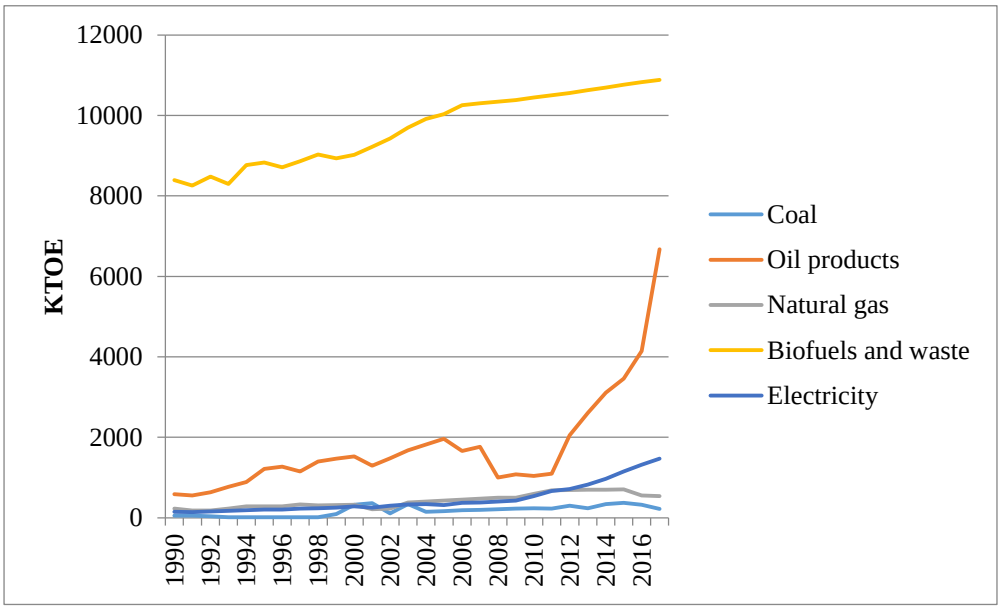


Figure 1.4. Myanmar Energy Consumption (ktoe) by type from 1990 to 2017 (Source: International Energy Agency IEA)

Figure 1.5 shows that the average energy consumption growth rate of the total final energy consumption (TFEC) of Myanmar increased around 3.8% from 2010 to 2017. Unfortunately, biofuels and waste take large portion of the Myanmar energy consumption. At that time, oil products grew the fastest at a rate of 15.8% per year and electricity, natural gas, coal consumption have been increased but not significant.

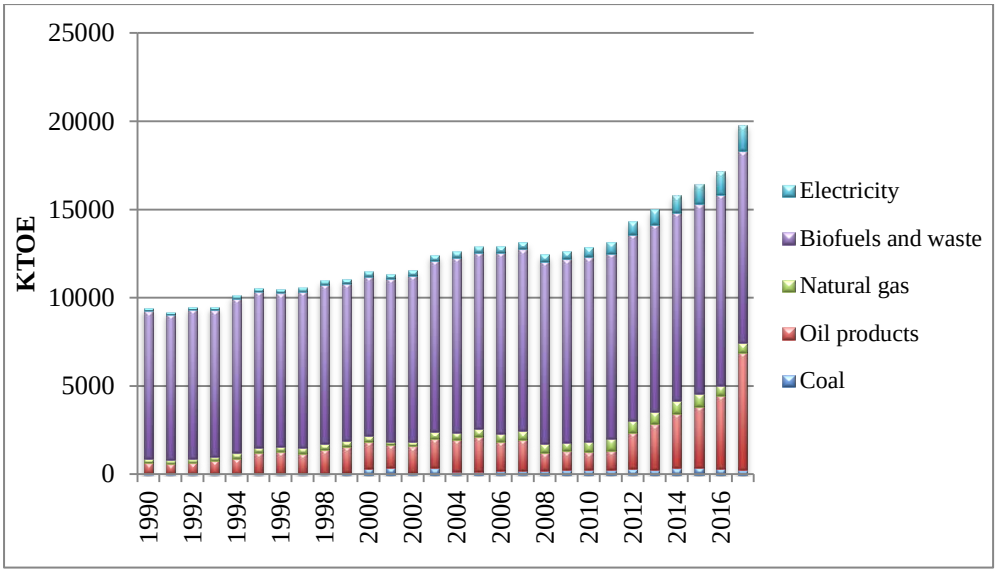


Figure 1.5. Myanmar Final Energy Consumption (ktoe) by type

(Source: International Energy Agency IEA)

At the present, Energy is the most important role of the country to be stable developed in every sector such as political, social and economic and also driving to develop in Myanmar. First of all, there is needed to attempt to be filled with the needs of energy of the country it is important to explore, drilling and produce systematically in energy sources such as oil, gas, electricity, coal and renewable energy. In accordance with the national energy policy and guidelines, government have need to effort to get the goals something like that to fill with extremely enough the needs of energy in short term and long term expectations for country after produced natural resource systematically, to be full of energy, to be strong infrastructure in every energy sector and to change high value energy products.

The current major challenges in Myanmar's energy sector, and also future energy scenario, as the starting base for policy improvement in order to establish a proper energy planning system. It was proposed that the participation of Myanmar's energy experts in this study would be the key factor in collecting different perspectives in determining the criteria and factors that should be taken into account for energy planning in Myanmar.

Even though the fact that Myanmar is endowed with abundant energy resources, but this country is still not able to cope with the issue of electricity shortage, long term contract issues and high dependence on energy imports. The absence of comprehensive decision-making process in Myanmar's energy planning system makes the energy sustainability concept as the idea that is difficult to be realized by the Government. According to the Ministry of Electricity and Energy, Energy Consumption Per Capital of Myanmar is just about 0.21 ton of oil equivalent. At the same time, Malaysia 2.7 toe, China 1.8 toe, Thailand 1.6 toe, Indonesia 0.9 toe, Vietnam 0.8 toe, India 0.6 toe and Sri Lanka 0.5 toe respectively. There is a little bit of energy consumption in Myanmar in comparison with other neighboring Asian countries. According to these numbers fire wood and charcoal are widely used in Myanmar as the energy consumption but per capital energy consumption is a small amount because of the requirement of technology, funding, resources management and proficient in rich energy resource country Myanmar.

In accordance with the national goals of new government to be stable develop in every aspects of political, social and economic, energy is the most important need and it is essential to fill in the requirement of energy sector of Myanmar. There is a submission about the situation that whether sufficient

or insufficient of energy in Myanmar at the present and in the future after studying the effort of Ministry of Electricity and Energy and each of other related ministry and the energy sectors in each of related ministry with it.

1.2 Research Objectives

As the country is developing, the domestic energy demand is certainly enormous so far. To build a well-disciplined and developed democracy country, the government has simultaneously undertaken economic, political and educational reforms and has been recognized by international circles because of the dramatic changes in Myanmar. Moreover, foreign companies are interested in a huge investment because economic sanctions imposed by the US and the European countries for two decades have been lifted. Increasing investment in Myanmar can create job opportunities and the economy of the country will be booming, needless to say. It is certain that filling the energy consumption which kept abreast of the country development has played a vital role. The relevant ministries are undertaking long-term and short-term plans to meet the domestic energy demand which are essential for the country development.

The main objective of this study is to examine the causal relationship between economic growth and energy consumption by fuel type such as; crude oil consumption, natural gas consumption, electricity consumption and coal consumption in Myanmar by using Vector Auto-Regression Monde (VAR) and Vector Error Correction Model (VECM). Similarly, this study is also to analyze the relationship between energy consumption and economic growth in Myanmar in the sectoral aspects (Industry, Transportation, Commercial and Public Services, Agriculture) by using Panel Data Analysis by using data from 1990 to 2017. Moreover, in order to fulfill increasing

energy consumption, the study will evaluate for sustainable energy mix of Myanmar by using Analytical Hierarchy Process (AHP) model.

- To investigate the causal relationship between economic growth and energy consumption by fuel type and sector.
- To prioritize energy resources to be adopted in the Energy Mix.
- To propose the appropriate policies to the government and policy makers to achieve the goals of sustainable development.

1.3 Research Questions

In order to obtain the research objectives, this study have to answer the following research questions:

(1) Does long-term equilibrium exit between economic growth Oil Consumption, Natural Gas Consumption, and Electricity Consumption in Myanmar?

(2) What kind of energy type support to be developed economy for Myanmar?

(3) What is the relationship between Energy Consumption and Economic Growth by sectors?

(4) Which energy resources are more preferable to be adopted for future Energy Mix?

(5) Which criteria and sub-criteria should be paid more attention to, in the decision making process for choosing energy resources for energy mix?

(6) What policies and strategies are required to be implemented in the Myanmar National Energy Policy?

1.4 Research Outlines

This study is composed of six chapters. Chapter 1 is an introduction, which covers research background, research objectives, research questions, as well as thesis structure. Chapter 2 provides information on the energy status of Myanmar, the energy security situation and resources potential.

Chapter 3 presents the first research of this dissertation: Does Energy Consumption drive Economic Growth in Myanmar? Evidence from fuel types to examine the causal relationship between economic growth and energy consumption by fuel type such as; crude oil consumption, natural gas consumption, electricity consumption and coal consumption in Myanmar. It consists of the status of economic growth and energy consumption by type, VAR and VECM model, previous studies, and empirical results for this chapter.

Chapter 4 states the second research of this dissertation: What Is The Role of Sectoral Energy Consumption in Economic Growth? The Case of Myanmar to examine the causal relationship between economic growth and energy consumption by sector such as; industrial sector, transportation sector, agricultural sector, and commercial and public service sector in Myanmar. It consists of the status of energy and economic growth by sector, previous studies, Panel Data Analysis and empirical results for this chapter.

Chapter 5 is the third research of this dissertation: What Is The Most Appropriate Energy Combination In Myanmar: A Multi-criteria Approch, consists previous studies, Multi-Criteria Decision Analysis (MCDA) in the energy sector, Analytical Hierarchy Process (AHP) methodology, empirical results of this research. Lastly, chapter 6 concludes the general conclusion and policy implementation.

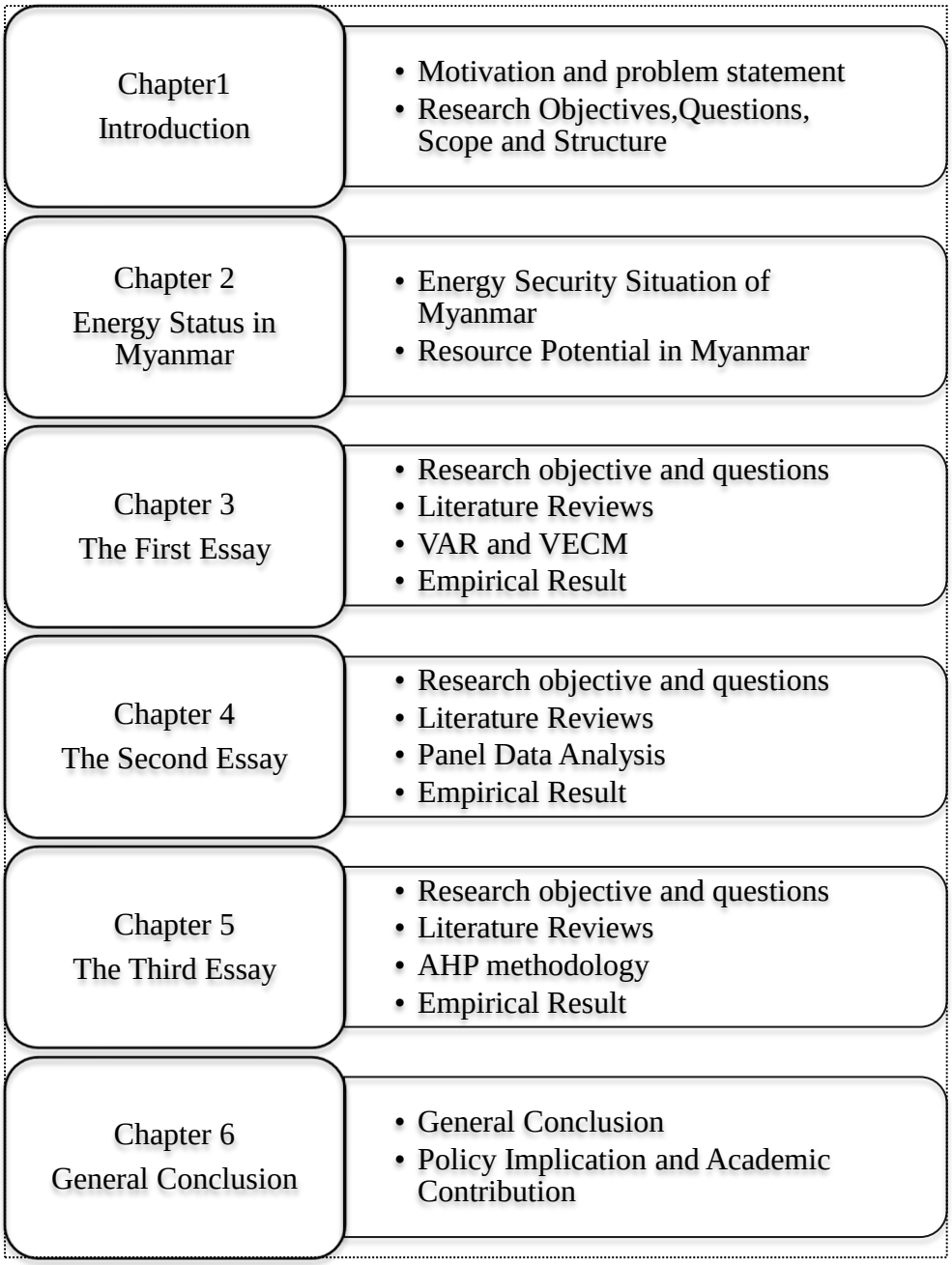


Figure 1.6. Thesis Outline

2 Energy Status in Myanmar

2.1 Energy Security Situations in Myanmar

2.1.1 Today Energy Consumption in Myanmar

Myanmar is rich in natural resources such as oil and gas, hydroelectric and renewable energy. Fire wood, charcoal, oil, gas, electricity and coal are primarily used as energy in Myanmar and the following figure is the ratio of various kinds of energy consumption in Myanmar.

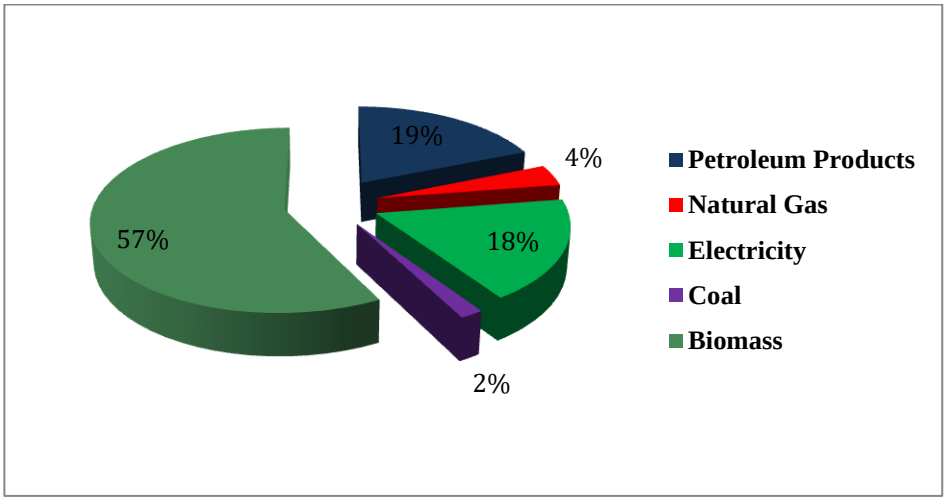


Figure 2.1. Total Primary Energy Consumption in Myanmar (2014-2015)
(Source: Myanmar National Energy Policy)

As above calculated Figure 2.1, energy consumption of 53% for the whole country is Traditional Energy such as fire wood and charcoal and followedy by oil (19%), electricity (18%), natural gas (4%) and coal (2%) respectively.

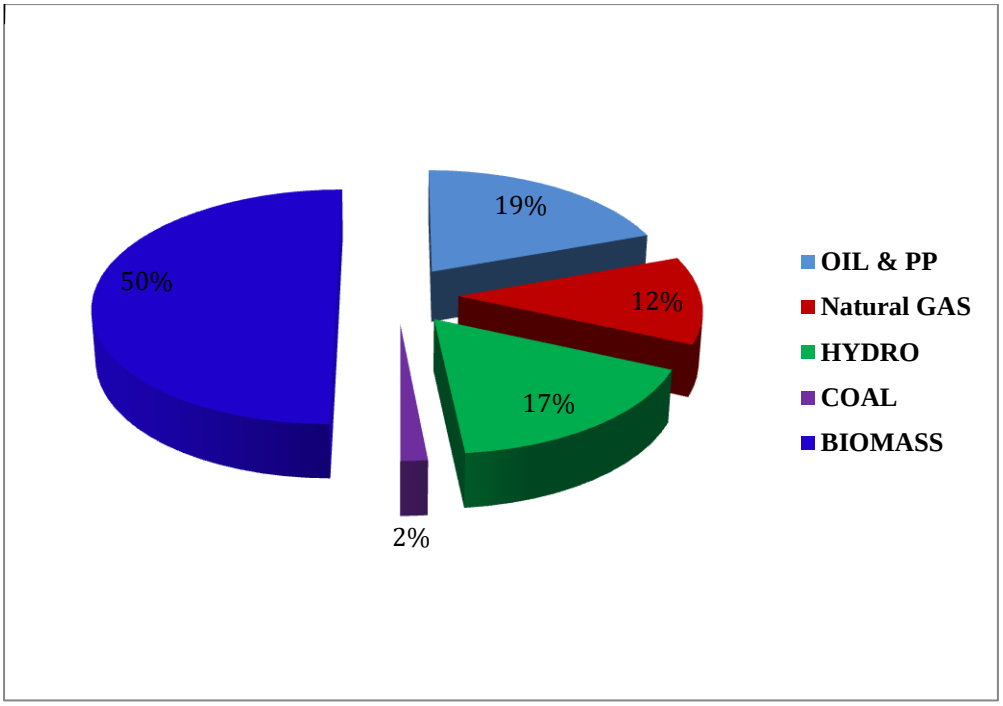


Figure 2.2. Total Primary Energy Supply (2014-2015)

(Source: Myanmar National Energy Policy)

Figure 2.2 shows about the total primary energy supply of Myanmar. In that figure, biomass energy is largest portion in Myanmar TPES, and followed by oil, hydropower, natural gas and coal, respectively (Energy and Committee 2014).

2.2 Oil and Natural Gas

At inland regions of Myanmar, crude oil and natural gas can be found from mature and immature sedimentary rocks transportation that are occurred the potential oil and gas resources as like as sedimentary basins. There are fourteen sedimentary basins as follows;

(a) Rakhine Sedimentary Basin

(b) Huekaung Sedimentary Basin

(c) Chindwin Sedimentary Basin

(d) Shwe Bo-Monywa Sedimentary Basin

(e) Central Myanmar Sedimentary Basin

(f) Pyay Embayment Sedimentary Basin

(g) Ayeyarwaddy Delta Sedimentary Basin

(h) Bago Yoma Sedimentary Basin

(i) Sittaung Sedimentary Basin

(j) Maepale Sedimentary Basin

(k) Mawlamyine Sedimentary Basin

(l) Nanthmyaw Sedimentary Basin

(m) Hsipaw-Larshio Sedimentary Basin

(n) Kalaw Sedimentary Basin

Among these basins, Central Myanmar, Pyay and Ayeyarwaddy Delta, Bago Yoma and Chindwin sedimentary basins are exploring, drilling and producing and the other basins have a potential situation to be produced commercially and there have also restricted to get seismic data detail.

Ministry of Electricity and Energy are cooperating with international oil and gas companies to explore, drill and produce oil and gas at the potential reservoirs of Rakhine, Moattama and Tanitharyi offshore sedimentary basins. Estimated of useable oil and gas amount at offshore and onshore regions of Myanmar are as follow Table 2.1.

Table 2.1. Oil and Natural Gas reserve of Myanmar

Resource		**Reserve**
Crude Oil	Onshore	102 mmbbl (proven)
	Offshore	43 mmbbl (proven)
Natural Gas	Onshore	5.6 TCF (proven)
	Offshore	11 TCF (proven)

(Source: Myanmar National Energy Policy)

Ministry of Electricity and Energy has been serving exploration and production activities in Myanmar with self-investment and self-knowledge to fill with the need of domestic oil and gas along the economy of a developing country and MOEE is serving as their activities to explore new oil and gas blocks and to be maximum oil and gas production from the active wells. Moreover, Ministry of Electricity and Energy is serving more to fill with the need of domestic energy for the country by cooperating with international oil companies by signing a contract to the other side of interest with the help of modern technology and materials and good investment.

As Myanmar also created a market economic system after amended foreign investment law in 1989, MOEE has cooperated with foreign oil companies to explore, drilling and production in onshore and offshore blocks of Myanmar. MOEE is serving with self-investment and self-education to drilling and production in onshore oil and gas fields such as Kyaukkhwet–Letpando, Ayadaw, Kyauk-Lanywa, Yae Nan Gyaung, Man, Htaukshabin, Kan Ni, Pet Pal, Htan Kaing, Dahukpin, Yae Nan Ma, Pyay, Pyart Yi, Myan Aung, Shwe Pyi Tar, Ah Pyayk, Nyaungdon, Meaubin. Oil and gas can be produced in these field barrels of oil 7500 per day and 65 million standard cubic feet per day like that.

There are currently being produced 12,000 barrels of light of crude oil (condensate) per day and about 3 trillion cubic feet per day from offshore operation according to Production Sharing Contract (PSC) with the cooperation of foreign oil companies. Among these gas production 1.5 trillion cubic feet are sold to Thai and China and 0.5 trillion cubic feet is distributed for domestic. The situation of each offshore block's activities will show as follow;

(a) **Yetagun Project:** Ministry of Electricity and Energy has cooperated with Petronas Company limited from Malaysia to do oil and gas exploration and production with Production Sharing Contract (PSC) in Tanintharyi Offshore blocks M-13, M-14 and M-12 of Yetagun Project at 1990. In 1997, natural gas from the production of Yetagun Project was exported to Thailand as per the gas sale agreement and 460 million standard cubic feet from Yetagun Project was exported to Thailand with 24 inches production pipeline at 2000. Moreover, 12000 barrels of light of crude oil (condensate) are producing per day from Yetagun Project.

(b) **Yadana Project:** MOEE has cooperated with Total E&P Myanmar Limited from French and the Production Sharing Contracts (PSC) were signed for the blocks M-5 and M-6 of Yadana Project in 1992. In 1995, natural gas from the production of Yadana Project was exported to Thailand as per the gas sale agreement and 700 million standard cubic feet from Yadana Project was exported to Thailand with 36 inches production pipeline at 1998. Natural gas from the production of Yadana Project was used for domestic such as 250 million cubic feet was

transported with 24 inches pipeline from Yadana Project to Yangon and 20 inches to Kanbauk-Myainkalay respectively by day.

(c) **Shwe Project:** Ministry of Electricity and Energy has cooperated with Daewoo International Coperated from Korea and the Production Sharing Contracts (PSC) were signed for the blocks A-1 and A-3 of Shwe Project in November, 2003 and in the reservoir of this project, the total reserve of gas initial in place (GIIP) was identified as much as 4.532 TCF. In 24th December 2008, Myanma Oil and Gas Enterprise, Daewoo International Corporation and China National Petroleum Corporation (CNPC) had made a contract as Export Gas Sale and Purchase Agreement (EGSPA) to export natural gas from the production of Shwe Project to China. To export natural gas from Shwe Project to the Republic of China, there is constructed 32 inch sub-sea pipeline of 110 km long from Shwe Platform to Kyaukphyu and 40 inch onshore pipeline of 760 km long and the gas was transported into pipes both for domestic use 100 million cubic feet and for export 400 million cubic feet just at present. 500 million cubic feet of natural gas are producing from Shwe Project by day.

(d) **Zawtika Project:** Ministry of Electricity and Energy has cooperated with PTTEP Co., Ltd from Thailand and the Production Sharing Contract (PSC) was signed for the block M-9 of Shwe Project in April, 2005 and 4821 km2 at the eastern part of the block M-9 was declared the Commerciality area. The recoverable gas reserve was estimated as much as 2.285 TCF at Zawtika Project according to Geological situation. Myanma Oil

and Gas Enterprise and PTT had signed the agreements such as Export Gas Sale Agreement (EGSA) and Domestic Gas Sale Agreement (DGSA), Supplementary Agreement to Gas Terms (SAGT), Export Gas Transportation Agreement (EGTA) and Pipeline Right Agreement (PRA) to export the natural gas of Zawtika Project to Thailand in July, 2010. The natural gas of Zawtika Project is currently producing 300 mmscfd and 200 mmscfd was transported to Thailand for export and 100 mmscfd for domestic.

(e) **Moattama Offshore Block M-3:** In 2011, Aung Sin Kha well 2 was drilled in Moattama Offshore Block M-3 and that block was expected to undertake for development process of country and have to distribute as domestic use by production of natural gas. The period from a commercial stage to production typically last for 5-6 years according to the regular show in offshore projects. At the present, drilling appraisal well and drawing development plan are making to calculate the volume of block M-3 reservoir and it is estimated to produce natural gas from this block in 2019. PTTEP Co., Ltd from Thailand has been operating the activities of production in block M-3 as an operator.

2.2.1 Myanmar's natural gas demand and supply

Myanmar Natural gas industry is one of major roles in country economic development and which is directly related to the industrialization, electrification etc. Even though, natural gas utilization for domestic sector is limited by the domestic gas quota and natural decline of onshore production. In fossil fuel supply sources, the natural gas fuel emission amount is the

lowest rather than crude oil, oil product and coal. In this connection, natural gas is one of alternative fuel as CO2 emission issues. In particular, natural gas is used as not only fuel but also raw material as non-energy industry sector, such as making fertilizer, lubricant etc. In the year of 2014, the world natural gas production was 3543 BCM (Billion Cubic Meter) and Asia region production was 452 BCM . On the other hand, the 3539 BCM and 669 BCM amount of natural gas was consumed in the world and Asia region respectively.

Obviously, Myanmar is one of the natural gas rich countries in the South East Asia Region and which produces 12776.514 ktoe(kilo tons of oil equivalent) in 2014. Among them, (1543.885 ktoe, 12%) of natural gas are transformed to electricity generation for domestic utilization and utilizes in domestic industry sector (374.657ktoe,3%), transport sector (172.565,1%), non-energy sector (132.314,1%) and the rest of (83%) exported to the neighboring countries (Kobayashi 2018).

Moreover, Myanmar natural gas utilization is dramatically increased year by year since 1971 (55.401 ktoe) and 2014 (2109.738 ktoe), which is 38 times relatively larger in 48 years. In fact, electricity generating sources by natural gas is significantly higher in 48 times in 48 years. In which, very big demand in natural gas fuel sources for electricity transformation is one of the alternative fuel issue and energy mix scenario in Myanmar. Moreover, the fuel mix for electricity generating by 2030 natural gas scenario is 20% which is equivalent to the 4.758 GW installed capacity. Therefore, the natural gas demand will be about 1100 mmscfd which is about 2.5 times of current situation .

The BP Statistical Review of World Energy June 2016, natural gas proved reserve is 18.7 TCF. Moreover, new offshore gas field discovery is found in western part of Myanmar (Block A-6) and Deep Sea (Block AD-7). Therefore, the potential of natural gas discovery will be a good chance to support country economic development. In the meantime, natural gas production, distribution and electricity generating industry are going to increase for country development. Currently, Economic policy is achieved to develop by industrial sector, such as developing into the three special economic zones. For the long term plan, natural gas demanding for industrial sector will be developed too. The Gross Domestic Product (GDP) is the economic indicator of countries economic growth rate and annual growth rate is 8% by 2014.

Ministry of Electricity and Energy has been producing about 65 million cubic feet gas per day of onshore natural and 2,000 million cubic feet of offshore gas per day, exporting about 1,500 million cubic feet of natural gas from offshore through pipelines to China and Thailand. However, the amount of natural gas needed for domestic consumption is about 760 million cubic feet per day, and at present it is only 520 million cubic feet, which can supply only 68% of the national demand.

The Ministry of Electricity and Energy has set policies to prioritize future natural gas for domestic consumption and to produce petrochemicals as a value-added product rather than selling raw materials in excess. The Ministry of Electricity and Energy distributes 61% of the country's natural gas to natural gas-fired power plants; 7% to the transportation sector; 32% is distributed to raw materials and industries. At present, 20% of the electricity used in Myanmar is generated by natural gas-fired power plants.

2.2.2 Efforts to meet crude oil demand

In addition, the Ministry of Electricity and Energy will use chemicals to remove oil-clogged wells to maintain existing oil and gas production to meet domestic energy needs. Sand gun expansion; clean the bottom of the pit; Re-testing of wells that were closed due to low oil production; Expansion of pennies is underway.

The Ministry of Electricity and Energy is connecting pipelines to supply natural gas to gas-fired factories and gas-powered vehicles in Myanmar, and is working to meet domestic demand for natural gas. The Ministry of Electricity and Energy has already drawn up a natural gas strategic plan for the replacement of pipes in the existing pipeline network. New pipelines are being constructed for distribution from the pipeline network to the required parts.

In addition, the Myanmar-China gas pipeline is already exporting natural gas, which will provide 100 million cubic feet of natural gas per day for domestic use in four locations. Similarly, the Myanmar-China crude oil pipeline plans to purchase 3.5 million metric tons of crude oil a year for domestic use. Moreover, MOEE had planned to fill with energy security of country on the other side through has been bought 3.5 million tons of crude oil from “Myanmar crude oil pipeline” to refine and produce raw materials after the construction of oil refinery had finished.

2.2.3 Distribution of Petroleum Products from Oil Refinery

Crude oil from onshore production and condensate from offshore production are refined by three oil refineries of Ministry of Electricity and Energy. Moreover, MOEE is planning to construct new oil refinery to refine

the optimal ratio of crude oil 56000 barrels per day to crude oil 2 million tons in one year through Myanmar-China pipeline. In addition, MOEE imported petroleum materials from other abroad and distributed them to fill with the need of domestic energy consumption. Within financial year 2011-2012, 126.264 million gallons of gasoline, 469.446 million gallons of diesel, 11.107 million gallons of jet fuel and 12.060 million gallons of lamp oil had produced and distributed by refining 84.353 million gallons of crude oil from domestic production and 126.954 million gallons of condensate from Yetagon Project. MOEE has built the industries and distributed the products from those industries as follow to fill with the need of liquefied petroleum gas for domestic use.

(a) **Liquefied Petroleum Gas (LPG) Extraction Plant (Minbu):** No.(1) LPG Industry (Ministry of Energy) was built in Man Oil Field and producing liquefied petroleum gas are producing and distributing from it. This industry can produce with more efficient use but there is depending on received into Associated Gas and producing just only about 30%-40%. The efficiently refinement of that industry running is 24 million cubic feet per day.

(b) **Liquefied Petroleum Gas (Nyaungdon):** It is situated in Nyaungdon Township, Ayeyarwaddy Region and Mixed LPG (C3 + C4) (10.5 ton/day) and (Naphtha) (9.06 ton/ton) are producing from it. The efficiency at factory can produce about 10 tons of LPG and 10 MMCF-16 MMCF are used for running at factory. Propane (C3), Butane (C4) and Naphtha are produced by using natural gas from Nyaungdon Oil and Gas Field and distributing with Gas Bowser to Myanmar Petro-Chemical

Enterprise (Yangon) and LPG shops and gasoline to No.1 Oil Refinery (Thanlyin).

(c) **Liquefied Petroleum Gas (Kyung Chaung):** It is situated near the Natural Gas Power Plant (Kyung Chaung), Pakoku Thownship, Magway Region and can produce 0.7 ton per day. Mix LPG and Naphtha are producing by refining the natural gas from the production of Oil and Gas fields such as Kyung Chaung, Ayadaw, Thargyitaung and Kyaukkhwet.

(d) **Methanol Plant (Saetar):** It was closed in 24-4-2000 because there is not enough the natural gas to refine and is situated near Saetar, Kyan Khinn township, Ayeyarwaddy region. The efficiency to refine for AA Grade Methanol is 450 metric ton (MT) per day. There is planning to produce low-density polyethylene (LDPE) from Methanol after the construction projects Methanol to Olefin Plant (MTO Plant) and Low Density Polyethylene Plant (LDPE Plant) have been finished yet by reforming.

Oil and oil materials have been distributing around the country by crude oil, associated oil materials, associated liquefied petroleum gas, methanol, associated goods, oil tankers and river-going vessels. Moreover, Myanma Petrolium Product Enterprise are distributing gasoline with 12 petrol shops respectively by 4 Distribution Departments, 8 Branch of Distribution Departments for grade-1 and grade-2 for 16, 1 Camp for storage and distribution, 2 Aircraft Fuel Departments, 5 sections and 4 camps. Gasoline are transported from Distribution Departments to Sub-Distribution Departments by various types of tankship include costal oil tanker, river going tanker, train oil tanker and rail tanker cars and then distributed by

Sub-Distribution Departments. Myanmar has opened 46 compressed national gas (CNG) filling stations and selling without any day off to be replaced CNG vehicles in order to minimize environmental impact and to restrict on the foreign imports of liquid fuel. At the present, over 27000 CNG vehicles have been replacing and using in Myanmar.

2.2.4 Privatization Development in Ministry of Electricity and Energy

To implement the economic reforms towards in the market-oriented economy, Myanma Petroleum Product Enterprise under Ministry of Electricity and Energy has made 261 Filling Stations in total privatization as of June 2010. License of storage, sale and distribution have been issuing in line with rules and regulations. New 1300 private Petro stations which have been proposed for selling more and more in respective Regions and Divisions have licensed. In addition, MPE is undertaking to determine and issues the licenses to the rest.

2.2.5 Future of Oil and Gas Sector

The minimum demand per day of Myanmar's crude oil consumption is around 60000 barrels. However, Myanmar produces around 20000 barrels-one third of 60000 barrels. To meet the country-wide demand, 40000 barrels have to be imported. Although nature gas consumption is 760 million cubic feet per day, nature gas production and distribution is 450 million cubic feet per day, which is 58% of the nationwide demand. Thus, Ministry of Electricity and Energy has negotiated with PTT Company which bought the gas from Yadana Project to get domestic gas increasingly. As a result, additional 50 million cubic feet per day than 200 million cubic feet per day in line with PSC will be allocated to domestic network. Distributing 500

million cubic feet per day has just been enough 65% of Myanmar's domestic needs. In addition, it has planned to make of offtake points at Saku and Natogyi Townships to take off and refine 40000 barrels per day from 32-inches diameter pipeline with 741 km in length in supplying the domestic energy demand of the country. Consequently, it is considered that there are good prospects to narrow the gap between demand and supply of oil and gas the whole country.

Myanama Oil and Gas Enterpise under Ministry of Electricity and Energy is increasingly undertaking to collaborate with foreign companies which are available for capital, technology, foreign technicians, much experience and a long-term investment. The international bidding rounds are being sought at the moment in transparency although foreign companies directly proposed, negotiated, signed agreements and operated with Myanmar Oil and Gas Enterprise in the past. Terms and conditions in Producing Sharing Contracts have been amended to attract a huge foreign investment in offshore and onshore blocks. Then international tenders for oil and gas exploration, drilling and producing activities in unoccupied offshore and onshore blocks have been invited. As a result, 22 onshore blocks and 20 offshore blocks have been awarded in second tender round and in first tender round respectively.

Moreover, oil shale, one of energy resources in Myanmar, is used to produce oil, gas and petroleum coke with modern technology. It has been used in production of engine oil, lubricant, wax and paraffin by retorting and refining. Mapale Basin of Myanmar is located at 60 miles off from the northeast of Mawlamyine, between Dawna Range and Thai-Myanmar border near Moei River. Although most of the area of Mae Sot and Falu Shale oil

basins are situated in Thailand, 20 square miles in Mae Sot Basins and 5 square miles in Falu are in the north of Moei River within Mynamr. It is considered that shale oil production can meet in needs of the domestic energy. The amount of crude oil can be produced as follows:

Table 2.2. Available Amount of Shale Oil in Myanmar

Sr.no	Basin	Square Miles	Prospects of Shale Oil			
			Reserve	Prospects	Possibility	Total
1	Mapale	40	720	1800	1080	3600
2	Mae Sot	20	-	-	1800	1800
3	Falu	5	-	-	450	450
	Total	65	720	1800	3330	5850

(Source- Myanmar National Energy Policy)

It has been considered that drilling exploration wells, appraisal wells, and development wells in new fault blocks of oilfields made oil production increase. Thus, the following oilfields may appear and provide the domestic energy's needs.

Table 2.3. Promising Oilfields of Myanmar

Sr.no	Year	New Oilfields	Basin
1	2011-2012	Myinkakone/Maubin	Irrawaddy
2	2013-2014	Pakon	Irrawaddy
3	2014-2015	Pidaukoin/Naukmi/Pyayi	Pyi
4	2015-2016	Moenatkone	Pyi
5	2016-2017	Thongwa/kanaungto/Katonepaw	Irrawaddy
6	2018-2019	Twantay/Sapargyisan/Natsinkone	Irrawaddy
7	2021-2022	Dedaye/Kyunnyogyi/Ahmar	Irrawaddy
8	2023-2024	Pathein/Myaungmya	Irrawaddy
9	2026-2027	Bogale/Kamarchaink	Irrawaddy

(Source- Myanmar National Energy Policy)

Daily production in the respective projects from 2011-2012 fiscal year to 2015-2016 fiscal year are as follows:

Table 2.4. Daily Production of Oil (2011-2016) (Thousand Barrels)

Oilfields	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Kyauk Khwet	9.332	11.0	12	14	16
Letpanto	0.150	3.000	5.000	8.000	11.000
Ayadaw	2.400	2.300	2.300	2.300	2.345
Thar Gyi Taung	11.000	12.000	12.500	15.000	15.481
Sapal	0	0	0	0	0
Chauk	.200	2.000	4.000	5.000	5.000
Yenanchaung	.300	.300	.300	1.000	3.500
Man	3.667	5.000	7.000	9.000	9.000
Htauk Shar Pin	.100	2.400	4.000	5.000	7.000
Kanni	0	0	0	0	0
Pah Pae	.550	.400	.150	.150	.150
Pyayi	1.500	1.400	2.500	5.300	5.500
Pyi	12.000	18.000	20.000	25.000	30.000
Myanaung	.100	.120	.120	.120	.120
Shwe Pyi Thar	.400	.300	.060	.060	.060
Ahpauk-Zalun	6.800	7.400	7.500	7.600	8.000
Ahpauk(Taikkyi)	0.700	.600	.500	.400	0
Nyaungdon	41.500	30.000	20.000	10.000	5.000
Maubin	5.000	5.200	5.200	5.200	5.200
In Pin	0	15.00	3.000	3.000	3.000
Kyunnyokyee	0	0	2.000	5.000	6.000
Moenatkone	0	0	0	0	2.500
Block-D	0	0	15.000	45.000	75.000
Total (Onshore)	95.699	102.920	123.130	166.130	209.793
Total (Offshore)	1146	1165	1849	1961	1959
Total Blocks	1241.699	1267.920	1972.130	2127.130	2168.793
Domestic(Offshore)	200	200	336.82	355.81	354.15
Total Domestic	295.65	302.91	450.95	521.94	563.943

(Source – Myanmar National Energy Policy)

In addition, Ministry of Electricity and Energy are undertaking preliminary investigation to foreign companies which are interested in cooperation with Thanlyin Oil Refinery Industry under Myanma Petroleum Enterprise. Then they are being invited to submit proposals for a slate of joint venture. Similarly, for meeting the domestic market demand in enough, the application of the local business partners interesting in distribution of LPG gas for LPG license has been analyzed in line with the rules and regulations of Myanmar Petroleum Enterprise and then exportation, distribution and storage license will have been issued.

Therefore it is concluded that the oil production will be low on and on until the discovery of the fresh oilfields as the old oilfield production are decline. Electricity and Energy are setting up to increase the oil production as well as to discover the next oilfields. Consequently, international tenders have been invited for 18 onshore blocks in 2011, for 14 onshore blocks in 2013 and 20 of 30 offshore blocks in 2014. Producing Sharing Contracts (PSC) have been contracted for 22 onshore blocks and 20 offshore blocks. Now they are being operated. Signing PSC agreement in cooperation with foreign companies aims to explore the fresh oilfields, no doubt.

As Ministry of Electricity and Energy are encouraging to reduce the impacts of oil and gas exploration, drilling and production activities, PSC agreements state that oil and gas companies has to carry out Environmental Impact Assessment(EIA), Social Impact Assessment (SIA) and Mitigation Plans and to explain local people near oil and gas blocks about the activities. Besides, the government is urging the foreign companies, which has contract PCS agreement with and operated, to conduct EIA, SIA and Mitigation Plans.

Ministry of Electricity and Energy is intended to produced 9280 barrels and 104 million cubic feet per day in onshore blocks after thirty-year project. To implement the above objective, Myanma Oil and Gas Enterprise is required to buy and invest petroleum equipment, drilling machines, drilling pipes, gas pipelines etc. All in all, it is found that domestic energy market is much in demand whether there are limitations from cooperative blocks with foreign companies and yet-to-come blocks.

2.3 Coal

Coal has mainly found in Ayeyarwaddy, Chindwin sedimentary basin and south regions of Myanmar. Seismic data acquisitions were carried out at Sagaing, Magway, Tanintharyi district and Shan state since 1965. Various kinds of coal in Myanmar are Lignite and Sub-bituminous.

2.3.1 Coal Production Sector

Myanmar have held 5.22 million tons (MMst) of proven coal reserves and consumed 1.3 million tons (MMst) to the utmost in 2006-2007 financial year. Currently, Ministry of Natural Resources and Environmental Conservation is laying down policies of technical and financial cooperation with foreign companies to produce coal more and more ranging from 5 hundred thousand tons to 7 hundred thousand tons per year. The government is taking into account to fill the power gap in our country building clean coal power plants and to analyze the risk of the environmental effects using coal plants. In Myanmar, coal is mainly used as energy source in electrical power station, steel industry, cement industry, other industries as well as briquette in households. The condition of coal consumption, annual coal production and consumption and exportation can be found as follow.

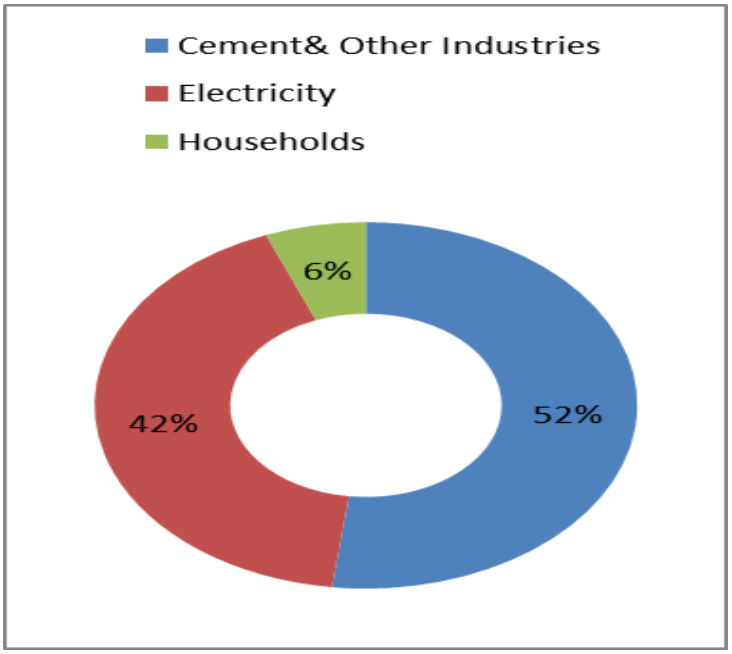


Figure 2.3. Coal consumption in Myanmar

(Source: Myanmar National Energy Policy)

Table 2.5. Coal reserve of Myanmar (Million Tons)

Positive Ore Reserve	4.615
Probable Reserve	228.399
Possible Ore Reserve	143.339
Potential Ore Reserve	146.602
Total	**522.955**

(Source: Myanmar National Energy Policy)

It was recorded that primary coal production was 19.35 tons during the reign of ancient Myanmar Dynasty from 1855 to 1863, 154.35 tons under British colonies from 1890 to 1948, 527 tons in the course of Parliament Democracy from 1949 to 1988, 9465 tons under the military government from 1988 to 2011, 732.52 tons in the financial year 2011-2012 of the current government. The 120 megawatt coal-fired power plant was built in Tigyit village, Pinlaung Township in 2004 to fill the gap in developing electricity sector. Licenses to produce coal increasingly were granted to local Private companies. They have been permitted to drill around 732 tons in total. It can be found that ASEAN Plan of Action for Energy Cooperation including ASEAN Coal Database, Clean Coal Technology (CCT) and Carbon Capture Storage (CCS) and so on gave new technologies and much experience as well as it was secure domestic energy supply in other words.

2.3.2 Future of Coal Sector

In coal sector, the government is taking tentative plan to produce up to 40% per year as the objective of annual coal production has been laid down in accordance with thirty-year plan. There are a lot of prospects supplying electricity demand of the country owing to being rich in raw materials of the coal-fired plants.

2.4 The Role of Electricity

According to geological situation of Myanmar, the World Bank estimated to produce electrical power (10,8000 MW) from the resources of hydropower at 1995. Ministry of Electricity and Energy has also estimated to produce electrical power (46,100 MW) from those sources of hydropower by 92 projects. Total electrical power (3,527 MW) has distributed in power grid

system of Myanmar such as electrical power (2,693 MW) from 19 Hydropower plant, electrical power (120 MW) from one Coal energy plant and electrical power (714 MW) from 10 Natural Gas Fire Power Plant. Moreover, electrical power (67 MW) has produced from small hydropower plants and Diesel engines.

Geographically, Myanmar has three main mountain ranges: the Arakan Yoma Range, the Bago Yoma Range and the Shan Yoma Range. There are five rivers in Myanmar; Irrawaddy, Chindwin, Thanlwin, Sittaung and Kaladan which are continually flowing from the west to the east. Besides, it occurs wet monsoon season because of these rivers which have hydropower potential.

Table 2.6. The places of Hydropower Potential resourses

Sr.no	State/Division	Number of Project	Installed Capacity (Megawatts)
1	Kachin	19	18744.5
2	Kayah	5	954.0
3	Kayin	9	7064.0
4	Sagaing	6	2830.0
5	Thanintharyi	7	711.0
6	Bago	8	538.0
7	Magwe	5	359.0
8	Mandalay	9	1555.0
9	Mon	2	290.0
10	Rakhine	6	764.5
11	Shan(East)	4	719.8
12	Shan (South)	8	7569.5
13	Shan (North)	5	4000.0
	Total	93	46099.3

(Source – Myanmar National Energy Policy)

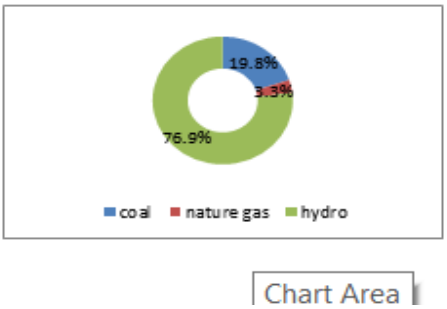
In Myanmar, Electricity is produced 2476 MW from 20 hydro power stations, 120 MW from one coal power station and 714 MW from 10 natural gas power stations. The total installed capacity is 3190 MW. In order to fill the power gap, Ministry of Electricity and Energy is undertaking in cooperation with private limited companies for building 650 MW, 300 MW and 270 MW of coal-fired plants in Yangon, 500 MW of coal-fired plant in Bokpyin Township, Tanitharyi Region and 540 MW of coal-fired plant in Irrawaddy Region. A variety of power plants which are producing and distributing to electricity supply system are as follows.

Table 2.7. producing and distributing to electricity supply system

Sr.no	Name	Installed Capacity (MW)
1	Baluchaung -1	28
2	Baluchaung-2	168
3	Yeywa	790
4	Kinda	56
5	Setawgyi	25
6	Zawgyi-1	18
7	Zawgyi-2	12
8	Thaphanseik	30
9	Mone	75
10	Paunglaung	280
11	Kabaung	30
12	Yenwe	25
13	Zaungtu	20
14	Shweli-1	600
15	Kengtaung	54
16	Shwekyin	75
17	Kun	60
18	Kyeeohn Kyeewa	74
19	Tarpein I	240
20	Thaughyekhap	120
	Total	2780

Sr.no	Name	Installed Capacity (MW)
1	Tigyit	120

Sr.no	Name	Installed Capacity (MW)
1	Kyun Chaung	54.3
2	Man	36.9
3	Shwe Taung	55.35
4	Mawlamyaing	12
5	Myanaung	34.7
6	Hlawkar	154.2
7	Ywama	70.3
8	Ahlon	154.2
9	Thaketa	92
10	Thaton	50.95
	Total	714
Total	2780	



(Source: Myanmar National Energy Policy)

Ministry of Electricity and Energy is implementing the following objectives;

- To expand transmission lines and electricity substation with shortly five-year plan.
- To gain electricity in remote villages from transmission lines by using small hydroelectricity and diesel generator
- To implement the polices and technical assistant for promoting rural electrification
- To reduce electrical power transmission and distribution losses and improve energy security
- To distribute the electricity from nature gas power plants which can be short-term production in the course of implementing the distribution of hydroelectricity
- To boost the electricity production and consumption by applying renewable energy
- To undertake joint venture between government and private sector in developing electricity production, transmission and distribution
- To produce, transmit and distribute electricity using modern technology without environment effects

According National Electricity and Energy Sector Development workshop, 505 MW hydroelectricity plant has been constructed in 2001-2006 and 1574 MW hydroelectricity plant in 2006-2011 at 2030 National Electricity Development Master Plan ranging from 2001-2002 to 2030-2031. In addition, 240 MW from Taping hydroelectricity plant has been exported to China. Despite the fact that the installed capacity is 8929.9 MW in 2012-

2013 in line with 2030 National Electricity Master Plan, 3614.9 MW is installed at the moment. It is found that 7 hydropower projects, 3 thermal power projects and 2 coal-fired power projects are unfinished in time.

The transmission lines of Power Network Development in Myanmar consist of 1982.26 miles of 230KV, 1542 miles of 132 KV and 2511 miles of 66 KV. 34 230-KV substations, 34 132-KV substations and 122 66-KV substations are delivering 3990 MVA, 1783 MVA and 2580 MVA transformer capacity respectively. As 11 hydro power plants from the northern region has produced 1714 MW in the rainy season, 1191-MW excess of the electricity consumption of Northern States and Divisions and 262 MW which will be produce after finishing Nancho, Upper Paunglaung, Balue Chaung and Upper Balue Chaung projects are added together. As a result, the power transmitted from the northern Myanmar to the southern Myanmar will be 1453.39 MW of installed generation capacity in total.

Although electricity demand was with an average annual growth of 9.6 percent between 1990 and 2011, 28.59 percent of 8.92 million households has currently installed meter and 100 KWh can be used per capita annually. It aims to supply 34 percent of the country in 2005-2006 and to progress up to 282 KWh per year.

2.4.1 Future of Electricity Sector

Myanmar's state-domestic electric power sector is facing a growing challenge to keep up with increasing demand. Based on the 1790 megwatts of peak demand in 2012, electricity demand can be expected to reach 3130 megawatts by 15 % annually from 2013 to 2016 as follows;

Table 2.8. Prediction on Electricity Demand up to 2016

Sr.no	Year	Electricity Demand (MW)	Increase Percentage
1	2012	1790	16.49%
2	2013	2060	15%
3	2014	2370	15%
4	2015	2814	15%
5	2016	3236	15%

(Source: Myanmar National Energy Policy)

Based on the GDP growth to 10.5% and population growth 1.1% in the whole country as well the GDP and population rate in Divisions and States, it is estimated that electricity power demand rise to around 13 % from 2012-2013 fiscal year to 2030-2031 fiscal year.

Table 2.9. Long-term Electricity Demand (from 2011-12 to 2030-31)

Period	Conditions by period				
	Population(million)	Consumption Load Demand		Consumption per capita (KWh	Electrification of households (%)
		Megawatts	KWh		
From 2011-12 to the current situation	60.44	1806	10444	173	27%
From 2012-13 to 2015-16	63.14	3078	17797	282	34%
From 2016-17 to 2020-21	66.69	5686	32874	493	45%
From 2021-22 to 2025-26	70.45	10400	60132	854	60%
From 2026-27 to 2030-31	74.42	19216	111100	1493	80%

(Source: Myanmar National Energy Policy)

To keep abreast of the country's electricity demand, Ministry of Electricity and Energy is having prepared to develop the 30-year Electricity Master Plan and undertaking to produce approximately 2878 megawatts from 11 gas power plants, 300 megawatts from a coal-fired plant, 50 megawatts from a solar plant and 500 megawatts from 7 hydro power plants. Moreover, it has planned to build 300-megawatts power plants in Myin Chan and Kyauk Se Townships using nature gas from Shwe project.

According President's speech on 19 July on 2012, it has been said that Ministry of Electricity and Energy need to produce electricity using energy mix besides hydro power as Ministry of Electricity and Energy's report has stated to raise the electricity production from gas and to produce 35% of hydro power, 30% of gas power and 35% of renewable energy.

It can found that Ministry of Electricity and Energy has planned to constructed and install 1760-megawatts wind power plants in Zinkyaik and Mudon Townships of Mon State, in Hpapun and Kawkareik Townships of Kayin State and in Dawei Township of Tanintharyi Division. In addition, it will keep building 270-megaawatts coal-fired plant in Yangon, 600-megawatts coal-fired plant in Kalaywa and 6-magwatts coal-fired plant in Thanintharyi Region for the target of domestic electricity.

To distribute the produced electricity, it will expand 66KV, 33KV, 11KV and 0.4 KV transmission lines and substations. Consequently, 15279 miles of total transmission lines and 16838 MVA of total stations will increase at the end of 30-year project in 2030-2031. It can be seen that the government will undertake to join ASEAN Power Grid and GMS Power Grid in the future. As it expects to require 19216 megawatts of installed capacity of Myanmar at the end of 30-year Electricity Development Master

Plan, it can concluded that Electricity Sector in Myanmar will be promising because 26095 MW of 45756-megawatts installed capacity might be produced at that time.

2.5 Renewable Energy

Myanmar has rich in solar energy, Wind power, geothermal energy, Tidal power, Biomass, Biofuel and hydropower. Especially, there is a wide gap of the electrification rate between urban and rural areas in Myanmar being rich in a lot of hydropower and biofuel. To meet the country's need, Rural Energy Supply Projects are being undertaking to study, test and produce renewable energy to a certain extent. According to Geographical indication, Myanmar has plenty resources renewable energy such as solar energy, wind energy, geothermal energy, biomass and biofuel energy. Especially, the resources of hydroelectric power and biofuel energy can get easily more and produce as follow;

(a) **Solar Energy:** The sun light can get all the whole year according to Myanmar geological indication. As the need of renewable energy in Mekong regions New Energy and Industrial Development Organization (NEDO) of Japan at 1997 estimated to produce solar potential to be (51,973 TWh) per year about the amount of solar energy in Myanmar. It is environmental compatibility of renewable energy and can collect a lot in the central tropical regions in Myanmar. It aims to generate solar energy to rural areas at first. And, photovoltaics are used for charging batteries and pumping water. With the implementation of generating solar energy resources potential, Research and Development of solar energy are being carried out in cooperation

with Scientific and Technological Research Department of Ministry of Science and Technology and the Department of Physics of Yangon Technological University. Likewise, 3-KWh solar generators are installed in technical schools and institutes which has little or no access to the central grid. MOST has planned to install off-grid electricity through solar system to the countrywide schools to promote the rural education. MOST has distributed solar PVs cheaper to meet domestic electricity demand. Mono-crystalline solar panels and BIPV are jointly produced with the private sector.

(b) **Wind Energy:** According to Myanmar has the coastal region of 2832 km strip facing Bay of Bengal and the Andaman Sea with its northwesterly and southwesterly monsoon for nine months and three months respectively. The promising areas to harness wind energy in Myanmar are the hilly regions of Chin State, Shan State, Southern and Western Costal Regions and Central Regions. There are estimated to get wind energy (365.1 TWh) per year at Myanmar according to the research of New Energy and Industrial Development Organization (NEDO) of Japan at 1997. Department of Meteorology and Hydrology Research has studied the data from 34 weather station in Myanmar. To meet the country's electricity demand, Myanmar Scientific and Technological Research Department under Ministry of Science and Technology has conduct research and development for using wind energy efficiently and effectively. The results from investigative studies to apply wind energy constructing Wind Turbines indicates that the feasible areas average wind speed of 5.6 to 7.4 meters per second

(12.5 to 16.5 miles per hour) can yield output ranging from 55 kW to 225 kW. The promising areas of wind energy are the hilly regions of Chin State, Shan State, Southern and Western Costal Regions and Central Regions. Ministry of Electricity and Energy has studied wind power density in Kayin State, Mon State and Tanintharyi Region to install wind turbine. It is undertaking to build wind power stations in the future in Shan State, Kayah State and Kachin State. Kyauk Se Technological University under Ministry of Science and Technology has constructed Wind Turbine to fill the electricity gap of the country that has little or no access electricity to the central grid.

(c) **Geothermal Energy:** Myanmar is one of the countries with geothermal resources that could be represented as an additional source of renewable energy to fulfill the future energy requirement. Geothermal resources are hot springs, steam, fumaroles, mud pots and other phenomena. In Myanmar, hot springs can be found in Kachin State, Shan State, Kayah State, Southern part of Rakhine State in Kyaukphyu, Shwebo-Monywa Area of Central Myanmar, Mon State and Tanintharyi Division. A total of 93 hot springs have so far been recorded and identified. Preliminary investigations have been made on 43 hot springs during 1986. They are found at Thazi Township in the Mandalay Region, at Nyaung Shwe Township in Shan State, at Wetlet Township and at Yinmarbin Township in Sagaing Division, at Chauk Township and at Minbu Township in Magwe Division, at Thandaung Township in Kayin State, at Chaungson Township, at Thanbyuzayat Township and at Ye Township in Mon State and at

Launglon Township, at Dawei Township, at Kawthoung Township and at Yebyu Township in Tanintharyi Division. According to the preliminary investigations, the temperature of the hot springs is ranging from 26.7 C to 65.6 C. Myanama Oil and Gas Enterprise, Myanma Electrical Power Enterprise carry out preliminary studies with Electrical Power Development, Union Oil Company at California State and Caithnesss Resources, Inc in USA. Therefore it is necessary to produce electricity with geothermal resources and to use them as industrial heat energy.

(d) **Tidal Energy:** Ayeyarwaddy Region, Thanintharyi Region, Yangon Region and Rakhine State are closing with the ocean and have rotary tidal currents. So, there have plenty to produce tidal energy from natural situations as like as inland waterways but it is needed to scope detail for the whole country.

(e) **Biomass & Biofuels Energy:** Biomass and Biofuels Energy in Myanmar has played an important role so far due to energy for lucrative purpose. According to Myanmar Forest Resources Assessment in 2010, forest area in Myanmar as of 2006 has been 33.1 million hectare and around 46.96% of such total land area is forested. Therefore the primary energy such as firewood and charcoal can be used a lot. In addition, there are good conditions to produce Biomass and Biofuel are coming from a plenty of agriculture wastes and animals wastes in Myanmar, which is an agriculture-based country. Evergreen forest reserve and conversation areas covering 166304 sq ml (40% of total areas) have been established in 2012. Moreover, 37895 forest areas (5.6% of total areas) have been found as nature forests to preserve

and protect Biodiversity. It is undertaking to expand 1.07% of total areas for Biodiversity once again. 70% of total population in Myanmar has resided in rural areas and mainly used firewood as fuel. Annual Firewood and charcoal consumption per household in rural and urban community are estimated 2.5 cubic tons and 1.4 cubic tons severally. The urban households have mainly consumed a lot of charcoal and their firewood consumption is ranging 4% to 6%. Firewood and charcoal production in the recent years from 2008-20009 to 2012-2013 has averaged 0.3 cubic million tons and 0.2 million tons respectively. Due to the demand of the rural residents on fuels, 22 million tons of firewood is being produced from the forests. To protect degradation and deforestation, it is carrying out for reducing firewood consumption by 58% in 2020 and by 46% in 2030. On the other side, it is supplying with energy-saving cooks, agricultural residue and briquette to use energy effectively. Besides, it is setting up to distribute 2.4 million briquettes annually as 481397 energy-saving cooks, 92 million briquettes have been provided. A variety of agricultural products, sawdust, rice husks, rice stalks, stubbles, coconut shells, crop residues, cow pat etc. are being used for biomass energy production. Rice husks and sugarcane bagasse are being applied as Biomass energy resources in Myanmar. 151 Biogas plants with 100/50/25 cubic meters have been built in Mandalay Division, Sagaing Division, Magwe Division and Shan State as of 2002. Consequently, they are being run for 4-hour lighting Monasteries and road constructions at night. 100 cubic meter biogas plant, moreover, has been constructed at Dairy Farm in Mandalay

Division in 2008 to produce in need of electricity, to cut feeds and to perform milk operations. Besides, Sin Min Cement Industry has built Solid-Waste Biogas plant for cooking. Waste and disposal water form that plant is used as organic fertilizer in agriculture. 33 family-size biogas plants in 2009 and 177 family-size biogas plants in 2012 having been installed and operated in Nay Pyi Taw, Yangon, Mandalay, Irrawaddy Division and Shan State. Biogas Research Department is distributing the electricity to rural residents for cooking and lighting by 2 hp generators. Now that the investment expense to build biogas plant is high for rural community although a lot of Biomass and Biofuel energy resources occurs in Myanmar, it is found the low amount of biogas consumption in the country. As it is setting up to use alternative fuels an increase of 8% in transportation sector in 2020, Bioethanol is currently used as a substitute in transportation. It is observed that biodiesel has been distributed and sold from private sector in Yangon, Bago, Mandalay, Nay Pyi Taw and Sagaing Regions and the biofuel plants will be built in the future.

2.5.1 Future of Renewable Energy Sector

Renewable energy such as wind energy, solar energy, geothermal, biomass, biofuels, which will have vital role in Myanmar's energy sector, has being carried out preliminary investigations so far. It is necessary to widely promote the development of these projects with technical and assistance and loan for sustainability in the future. It has to implement Renewable Energy Policy which has been laid down after being developed National Energy Policy. Renewable Energy Policy aims to expand energy

production based on renewable energy resources, to collaborate between Ministries and departments, to promote private cooperation and to provide the livelihood opportunities to the rural poor technically.

2.6 Current Energy Policies in Myanmar

2.6.1 National Energy Policy

Myanmar have formulated 11 points of Integrated National Energy Policy (Energy and Committee 2014) for all energy sectors and the main objective is to fulfill our domestic needs by means of exploring all available energy resources by promoting international engagements and private participation.

1. In extraction and utilization of natural resources in order to fulfill the nation's energy needs, the following measures will be taken;
   - To minimize the environmental impacts
   - To include a utilization plan for future generations
   - To invite the local and foreign investments
   - To adopt prioritized plans on Energy Efficiency and Conservation
   - To continuously carry out Corporate Social Responsibility (CSR) activities.
2. In defining the energy pricing according to the market oriented economy, the necessary laws and regulations for following measures shall be promulgated by observing the ASEAN and international energy pricing policy;
   - To maintain the stability of energy prices

- To guarantee the economic benefits for both energy producers and energy users
- To ensure fair energy price for the people
- To set up an energy support fund

3. To follow energy standards and specifications which are appropriate for the situations of the nation and which are also in conformity with ASEAN and international practices.
4. To encourage more cooperation with private sector according to the State's economic policy for thriving of the State-owned Enterprises (SOEs) or privatization of the SOEs
5. To lay down the short term and long term plans for not only renewable energy and hydropower projects but also feasible utilization of Liquefied Natural Gas (LNG) in thermal power plants to generate more electricity supply in order to meet the increased demand which will accompany the growth of the nation’s GDP.
6. To plan and implement for the share of renewable energy in power generation mix to reach 23% by 2020 in compliance with ASEAN target.
7. To participate in regional energy trading (such as electric power, crude oil and natural gas) by expanding the power grid and pipeline network to neighboring countries including ASEAN nations.
8. To implement the following short term and long term plans in order to get power generation stability;
   - Conserving the water catchment areas of hydropower dams and the reservoirs

- Rehabilitating the aged plants and constructing the new ones in the grid system
- Replacing the ineffective transmission lines, constructing new lines, expanding the existing lines and building substations in the national grid system.

9. To prioritize the use of solar, wind, hydro, biomass and other renewable energy resources in fulfilling the electricity demand of off-grid areas.
10. To draw and implement power distribution plans after conducting and analyzing yearly electricity demand surveys for Special Economic Zones, Industrial Zones, Businesses and Rural and Urban Areas.
11. To formulate a plan on civilian use of nuclear energy for future energy security.

3 First Essay

Does Energy Consumption drive Economic Growth in Myanmar? Evidence from fuel types.

3.1 Introduction

High economic growth also brings a new risk that crude oil, natural gas, electricity, and coal availability might not be able to fulfill the growing demand. Myanmar, ASEAN member state, will require a lot of crude oil from the other area through import activity. It will also create an environmental issue with the increase of energy-related emissions and may cause a problem to public health. The transportation sector has a dominant effect on crude oil consumption compare with the building and industrial sectors. This section will analysis between qualitative and quantitative analysis using data and evidence related with the energy resources and economy development in Myanmar. This research will also effort to observe empirical analysis for energy consumption by fuel type and economic growth relationship including unit root test, cointegration test, Vector Auto Regression (VAR), Vector Error Correction Model (VECM), Granger Causality test to progress the causal relationship between economic growth and energy consumption by fuel type in Myanmar.

The research started with data collection process during 1990 to 2017, where Myanmar economic growth will be described by the Gross Domestic Product (GDP) from Central Statistic Organization (CSO) Myanmar and the data of crude oil consumption, natural gas consumption, electricity consumption and coal consumption will be collected from

International Energy Agency (Kevin Lane 2018). This research will be analyzed by using EViews software.

3.1.1 Research Objectives

This research efforts to examine the causal relationship between economic growth and energy consumption by fuel type such as; crude oil consumption, natural gas consumption, electricity consumption and coal consumption in Myanmar. It will employ to analysis indication of this relationship: no causality, unidirectional causality or bidirectional causality between economic growth and energy consumption in Myanmar by using data from 1990 to 2017.

3.1.2 Research Questions

In order to analyze the relationship between economic growth and energy consumption, this study will solve the following research questions:

1. Does long-term equilibrium exit between economic growth Oil Consumption, Natural Gas Consumption, and Electricity Consumption in Myanmar?
2. What kind of energy type support to be developed economy for Myanmar?
3. What policies and strategies are required to be implemented in the Myanmar National Energy Policy?

3.1.3 Oil products

According to the International Energy Agency (IEA) statistics, Myanmar oil production consumption has increased stably 2,301 ktoe in 2010 and increased to 6,427 ktoe in 2017, which is an average annual growth rate of about 16%. Myanmar is a crude oil production country from onshore and offshore. Unfortunately, Myanmar oil production declined by 7.1% per year and refinery products declined by 13% per year within 2010 to 2017 (Asia 2018). The total petroleum products supply of Myanmar is from domestic oil production and import. Petroleum products were mainly utilized by industrial sector, transportation sector, commercial and services sector, residential sector and other, as well as for electricity generation and own use.

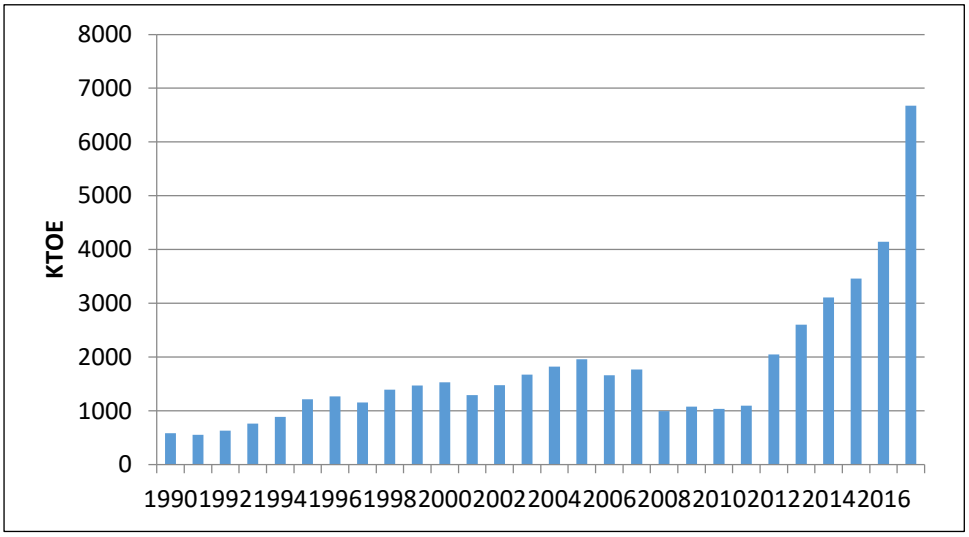


Figure 3.1. Myanmar Oil products consumption (ktoe) 1990-2017

(Source: International Energy Agency IEA)

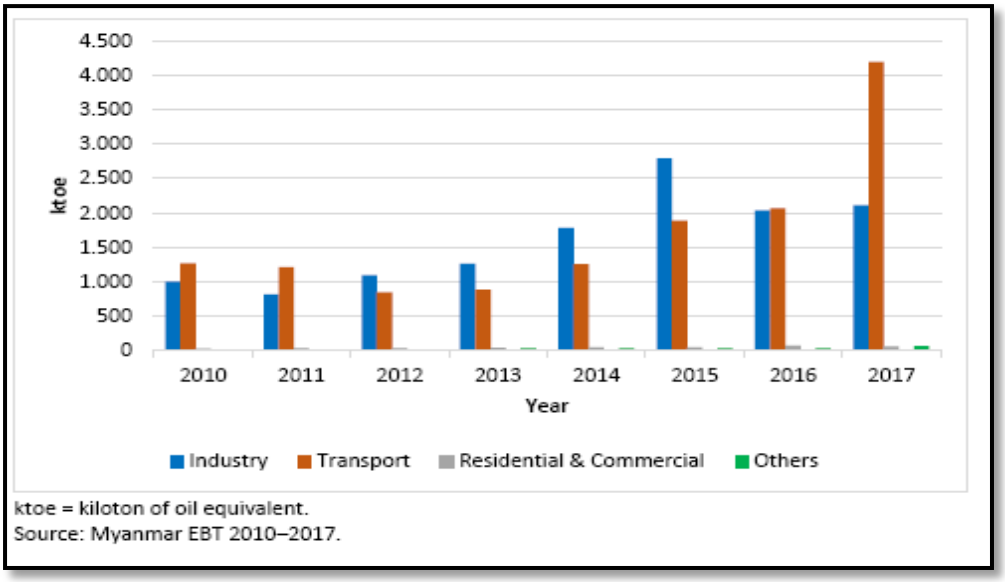


Figure 3.2. Petroleum Consumption by Sector (ktoe) 2010-2017

(Source: Myanmar National Energy Policy)

3.1.4 Natural Gas

Myanmar is natural gas production and exporting country. The 80% of the natural gas was exported to the neighboring countries, Thailand and China. The 20% amount of natural gas production was used for domestic usage. Most of the natural gas for domestic are using at electricity generation. Natural gas produced from both onshore and offshore area increased 6.5% per year within 2010-2017 (ASEAN 2018). At the same time natural gas exports also promoted by 5.5% per year.

Meanwhile, the natural gas supply in the total primary energy supply (TPES) increased by 10.5% per year from 2010 to 2017. In 2010-2017, natural gas consumption for power generation raised yearly by 16.3%,

industrial sector consume decreased by 8.8% per year, and transportation sector use increased yearly by 0.3% (Asia 2018).

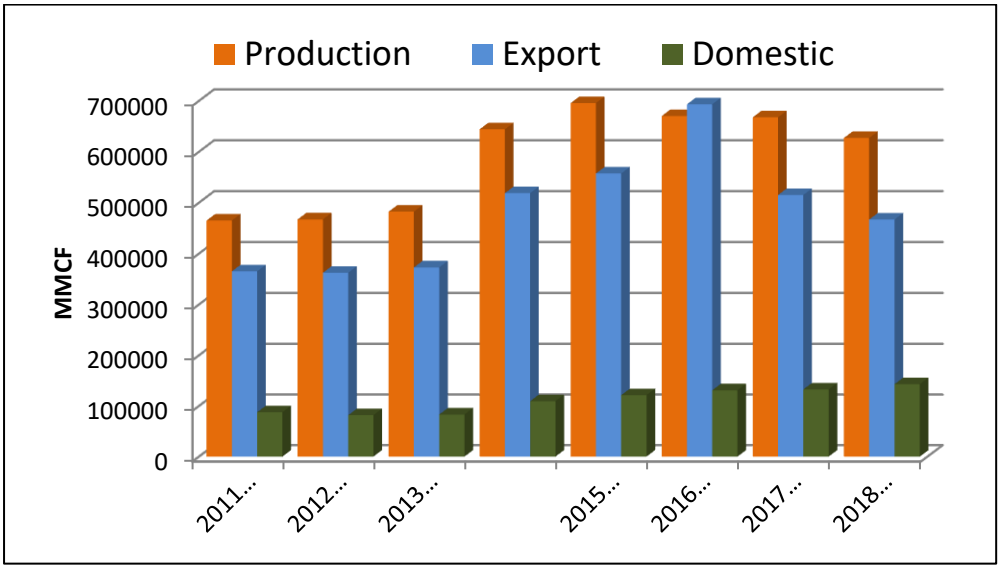
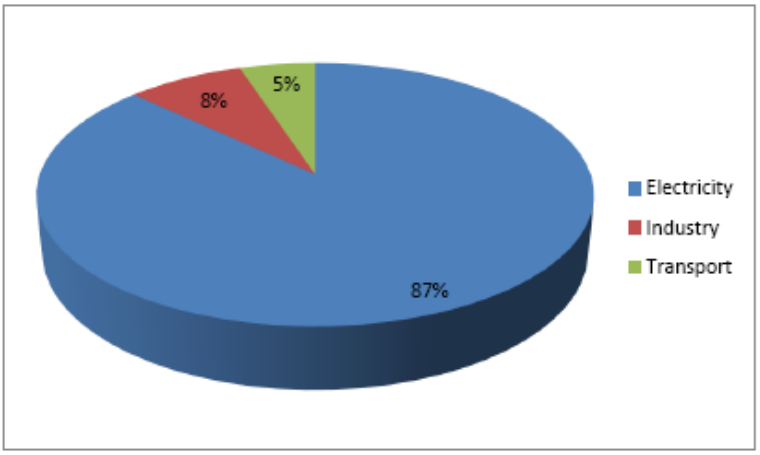


Figure 3.3. Natural Gas production, export and domestic utilization 2011-2018

(Source: Myanmar National Energy Policy)



Source: Myanmar EBT 2010–2017.

Figure 3.4. Natural Gas consumption by sector

(Source: Myanmar National Energy Policy)

3.1.5 Electricity

According to the Ministry of Electricity and Energy (MOEE) (Energy and Committee 2014), out of 10.877 million households in 2019, 50% of total households have access to grid-based electricity services. Figure 3.5 shows that the ratio of electricity consumption by sector. In 2017, the household sector is consumed to be the largest portion using 6,674.658 kWh (49.26%) of the electricity supply. Similarly, industrial sector uses for 4.120.768 kWh (30.41%), the commercial and services sector for 2,506.079 kWh (18.49%) and the other sector accounts for 248.762 kWh (1.84%) of the electricity consumption.

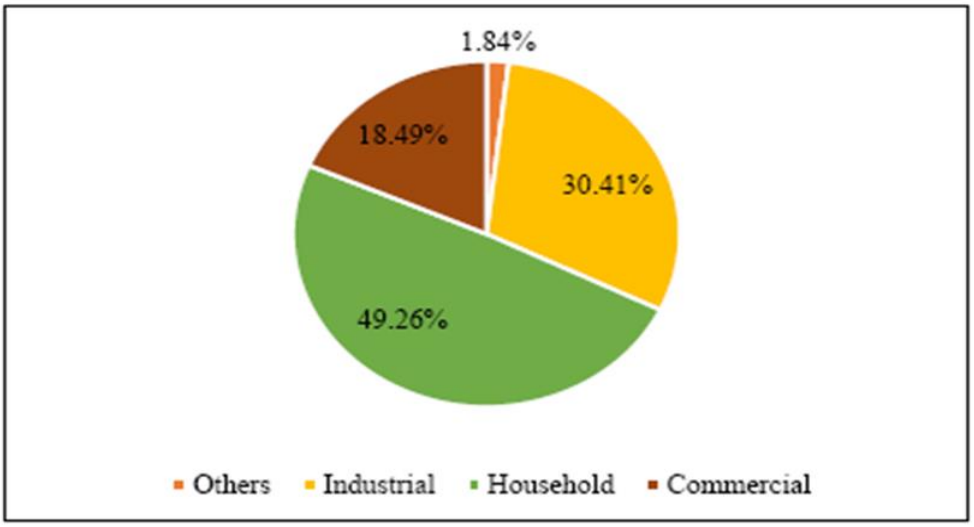


Figure 3.5. Electricity Consumption by sector

(Source: Myanmar National Energy Policy)

Figure 3.5 descripts that the total electricity consumption in Myanmar from 2010 to 2017, the total electricity demand has more than 2 times from 6,467 GWh in 2010 to 15,355 GWh in 2017, annually growth rate of electricity consumption by 14.41% in the same period. Myanmar electricity demand was estimated 48,639 – 77,730 GWh in 2030 by JICA. (JICA, NEWJEC Inc., and The Kansai Electric Power 2015).

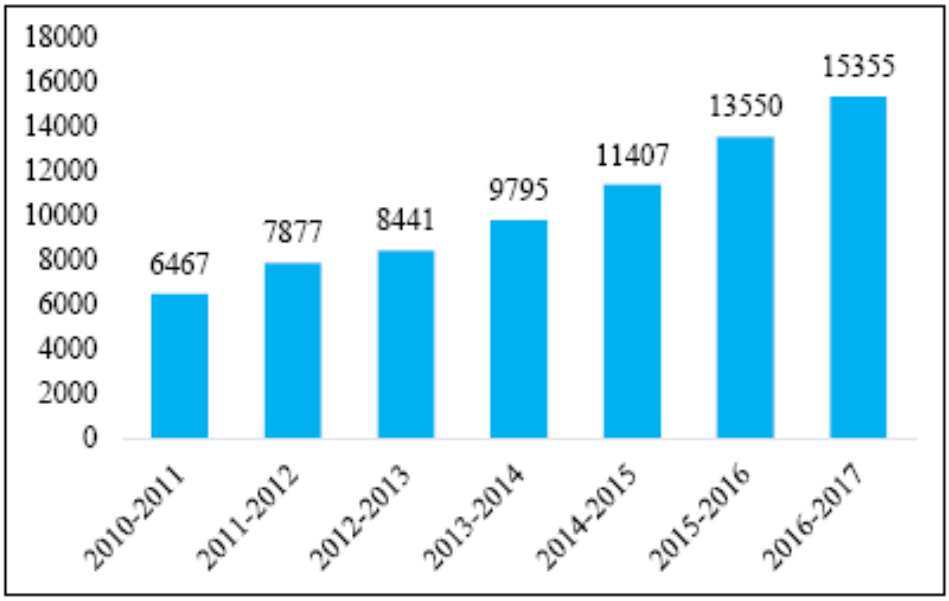


Figure 3.6 Total Electricity Consumption in Myanmar (2020-2017)

(Source: Myanmar National Energy Policy)

3.1.6 Coal

In Myanmar, coal is mainly used as energy source in electrical power station, steel industry, cement industry, other industries as well as briquette in households. The Ministry of Mines (MOM), which has been reformed as the Ministry of Natural Resources and Environmental Conservation (MONREC) estimated that the amount of coal resources in Myanmar is nearly 540 million tons and that these resources are found in 565 locations within the country. It is forecasted that there will be increased demand for coal in the coming years, which will require the extraction of up to 5 million tons of coal per year by 2030.

3.2 Literature Reviews

The connection between energy consumption and economic growth was ongoing in 1970-1980 where the international energy crisis happened due to the growing of energy prices. Many researchers have placed their consideration in how energy consumption in one country can take significant effect to the economy development or vice versa. Higher energy consumption especially by consuming internal energy resources will take negative impact to environment. Every country shall consider whether their energy consumption has taken effective and positive impact to the economic development than the negative impact to the environment. If energy consumption is not inspiring economy development, then it will better for the government to endorse energy conservation and optimize the energy consumption to minimize environmental issues. It is vital to understand the causal relationship between these two variables. Different countries will cause different causal relationship result and give an impact to the policy implication that need to be lead. These difference caused by several factors including indigenous energy supplies mix, political orientation, economic history, institutional arrangement, culture and energy policy of each country (Chen, Kuo, and Chen 2007). Some cases in developing countries where the economic data is not available or lack of knowledge in data collection progression make the result of the analysis is not reliable enough as the input for energy policymaker (Karanfil 2008).

The way of causal relationship between energy consumption and economy growth classified into four categories (Apergis et al. 2010) (Prakash et al. 2015) (S. H. Yoo 2006) (Chen, Kuo, and Chen 2007) (Mozumder and Marathe 2007) (Squalli 2007) (Shiu and Lam 2008). First,

no causality means that energy consumption has no correlation with economic growth or recognized as neutrality hypothesis. The change in the energy policy will only take an impact to the energy consumption and no impact to the economy growth. The second, unidirectional causality from economy growth to energy consumption means that there is only one causal relationship where the increases of economy growth may give an increase in the energy consumption. However, the change in energy consumption still carry no impact to economy growth. This situation known as conservation hypothesis and happened in a less-energy dependent economy. Third, unidirectional causality from energy consumption to economy growth means that the energy consumption in one country will bring significant impact to economy growth. This causal relationship known as growth hypothesis. The country with this situation shall be alert to the energy consumption because restricted or shortage in energy consumption will give negative impact to economy growth. Fourth, bidirectional causality means that there are two directions in the relationship between energy consumption and economy growth or known as feedback hypothesis. Both variables shall get proper attention from energy policy maker to guarantee there is no negative impact might be happened when they try to adapt new energy policies.

The common models that usually calculated by the energy policy maker is bivariate models between energy consumption and economy growth. However, some educations have advanced the causal relationship by the addition of several indicators such as capital, labor forces, and carbon dioxide emission in multivariate models (Ghali and El-Sakka 2004) (Huang, Hwang, and Yang 2008) (Apergis et al. 2010). There are a lot of studies in several countries related to causal relationship between energy consumption and economy development that has been directed by using different

methodology. Each study may calculate different result though it was done in same country case. The empirical studies on energy consumption and economic growth for the US has been conducted by (Author, Kraft, and Kraft 1978) with granger causality method for 1947-1974 period and the result shows there is one direction where GDP as economic growth indicator give an impact to energy consumption. Other studies with sims technique done by (Akarca and Long 1979) shows there is no relationship between GDP and energy consumption during 1950-1970 and 1947-1979 period respectively.

(Yu and Jin 1992) and (Benjamin S.Cheng 1999) has developed the case by conducted cointegration and granger causality in the 1947-1990 and 1974-1990 period and found that there is no causality between two variables. Rare situation also happened in the US case where recent studies conducted by (Nicholas Bowden and Payne 2009) and (Payne 2009) shows different result though they took same Toda-Yamamoto Causality test. (Nicholas Bowden and Payne 2009) shows that there is one causal relationship where energy consumption effect GDP and (Payne 2009) shows that there is no causal relationship between two variables.

It can be understood that some studies might use different time period, methodology or approach that will prove different result in same country case. In order to evade contradictory and less consistent result, it is suggested for the energy policymaker to get deeper investigation by adding several methods such as ARDL bounds test (Pesaran, Shin, and Smith 2001), two regime threshold cointegration models (Hansen and Seo 2002), Panel data approach, or multivariate models.

3.3 Methodology

This study will analysis qualitative and quantitative analysis using data and evidence related with the energy resources and economy development in Myanmar. This research will also effort to observe empirical analysis for energy consumption by fuel type and economic growth relationship including unit root test, cointegration test, Vector Auto Regression (VAR), Vector Error Correction Model (VECM), Granger Causality test to progress the causal relationship between economic growth and energy consumption by fuel type in Myanmar.

The research started with data collection process during 1990 to 2017, where Myanmar economic growth will be described by the Gross Domestic Product (GDP) from Central Statistic Organization (CSO) Myanmar and the data of crude oil consumption, natural gas consumption, electricity consumption and coal consumption will be collected from International Energy Agency (IEA 2018). This research will be analyzed by using EViews software. The variables that will be examined in this research as presented in table 1. All variables will be converted to logarithmic form to reduce heteroscedacity error and calculate it the result is easier to be interpreted.

Table 3.1 Lists of variables

Variables	Description	Unit	Source
LNGDP	The number of Gross Domestic Product (GDP) of Myanmar	Kyat (Million) (Myanmar Local Currency)	Central Statistic Organization (CSO) Myanmar
LNOC	The number of Myanmar crude oil consumption.	Kilo Ton of oil equivalent (ktoe)	International Energy Agency (IEA)
LNNGC	The number of Myanmar natural gas consumption.	Kilo Ton of oil equivalent (ktoe)	International Energy Agency (IEA)
LNEC	The number of Myanmar electricity consumption.	Kilo Ton of oil equivalent (ktoe)	International Energy Agency (IEA)
LNCC	The number of Myanmar coal consumption.	Kilo Ton of oil equivalent (ktoe)	International Energy Agency (IEA)

The rationale of threshold co-integration was presented by ("Economics Department of the University of Pennsylvania Threshold Cointegration Author (s): Nathan S . Balke and Thomas B . Fomby Source : International Economic Review , Vol . 38 , No . 3 (Aug ., 1997), Pp . 627-645 Published by : Wiley for the Econom" 2016) as a feasible means to combine both non-linearity and cointegration. As mentioned out by ("Economics Department of the University of Pennsylvania Threshold Cointegration Author (s): Nathan S . Balke and Thomas B . Fomby Source : International Economic Review , Vol . 38 , No . 3 (Aug ., 1997), Pp . 627-645 Published by : Wiley for the Econom" 2016), the concept of cointegration is used to capture the notion that non-stationary variables may nevertheless have long-run equilibrium relationships and thus, have a

tendency to move together in the long-run. According to (Engle et al. 2020), a linear combination of two or more non-stationary series, which have the same order of integration, may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long-run equilibrium relationships exist.

In order to causality testing, we must check at first hand the stationary of variables to decide whether we can apply the standard Granger causality test or not. If the data sets prove to be stationary, then we can apply the standard vector autoregressive (VAR) Granger causality test, but if they prove to be non-stationary, we work with the first differences. This step is to convert the non-stationary variables to stationary data. Next, we can check whether the variables are cointegrated. If it is revealed that the variables have a cointegrating equation, then the Granger causality test based on the vector error correction models (VECM) is used to check the causality between variables. On the other hand, if they are not cointegrated, we examine also the interrelation between them using a VAR framework in the first differences.

3.3.1 Unit Root Test

The research will be ongoing with the unit root test by using Augmented Dickey Fuller (ADF) to make sure the stationary of the data. Stationary requires the Mean, Variance and Auto-covariance of a series shall be stationary. A series will be stationary if it has constant mean and the variance of the series is not showing systematically change over time or tend to fluctuate steadily around the mean. If the first difference of a non-stationary series is stationary, then the series can be recognized as integrated I(1). If the non-stationary series shall be differenced n times, then it is

integrated of n order or I(d). Early in 1976, Dickey and Fuller have developed their method to test the stationary if time series data. Furthermore, the improved the method into Augmented DF in 1980. Augmented Dickey Fuller has known broadly as a method to examine the unit root test and stationary. The equation is time series model is explained as follows:

$$\Delta x_t = (\rho - 1)x_{t-1} + \sum_{j=1}^{\rho} \lambda_j \, \Delta x_{t-j} + \varepsilon_t \qquad \text{----------(1)}$$

Where: ε_t is the residual and then unit root test can test the null hypothesis where $H_0: \rho = 1$ that the series is non-stationary and $H_1: \rho < 1$ that the series is stationary.

3.3.2 Cointegration Test

The research will continue by directing the cointegration test. This test to show the two time-series data have their long term equilibrium between them as long as they are cointegrated. According to (Engle et al. 2020), if the two time-series data are both non-stationary, but integrated in the same order, and there is a linear combination between them which is stationary then they are cointegrated. The cointegration test that can be calculated by using Johansen Cointegration test. This test will check trace and Eigen value that has been created in the two time-series data.

Moreover, the research will also use vector auto regression (VAR) to analyze the dynamic impact of random disturbances on the system of variables. The VAR approach will use the structural modeling for every endogenous variable in the system as a function of the lagged values of all endogenous variables in the system. the equation of VAR is explained as follows:

$$y_t = A_1 y_{t-1} + \cdots + A_\rho y_{t-\rho} + B x_t (\rho - 1)x_{t-1} + \varepsilon_t \quad \text{--------(2)}$$

Where y_t is a k vector of endogenous variables, x_t is a d vector of exogenous $A_1 \dots A_\rho$ variables, and B are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with the right hand side variables. For example, if the energy consumption (EC) and economic growth (GDP) are jointly determined by a VAR and let the constant be the only exogenous variable. Then we can assume the VAR contains two lagged values of endogenous variables then the equation may be written as:

$$GDP_t = a_{11}GDP_{t-1} + a_{12}EC_{t-1} + b_{11}GDP_{t-1} + b_{12}EC_{t-1} + c_2 + \varepsilon_t \quad \text{--(3)}$$

Where a_{ij}, b_{ij}, c_i are the parameter that need to be estimated. If the cointegration result displays that two variables have cointegration equation, then the analysis shall endure with the Vector Error Correction Model (VECM) analysis. According to (Engle et al. 2020), cointegration suggests with the existence of error correction model in the following equation:

$$\Delta y_{1t} = c_1 + \alpha_{t-1}\left(y_{1,t-1} - \beta_2 y_{2,t-1}\right) + \sum_j y_{11}^j \Delta y_{1,t-j} + \sum_j y_{12}^j \Delta y_{2,t-j} + \varepsilon_{1t} \quad \text{----------(4)}$$

The error correction term will denote the long run equilibrium with the short run adjustment mechanism that shows how the variables react they deviate from the equilibrium. The causality analysis by using VECM will be able to present three types of causal path which are short run, long run and joint or strong causality. Short run causality tests the statistical significance on the two types of hypothesis in the VAR case and the long run causality test will demonstrate the short run and long run causality (Kim et al. 2013).

3.3.3 Granger Causality Test

The last test that will calculate in this study is the Granger causality test that was accepted to designate the causality between two series according to (Engle et al. 2020). If there is causality from one time-series data to the forecast of another time-series data, then the forecast can be more precisely generated. The Granger causality test shall be applied by using bivariable autoregression model as explain below:

$$y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_1 \, y_{t-1} + \sum_{i=1}^{m} \beta_1 \, x_{t-1} + \varepsilon_t \text{ ----------(5)}$$

$$x_t = \alpha_0 + \sum_{i=1}^{m} \alpha_j \, y_{t-j} + \sum_{i=1}^{m} \beta_j \, x_{t-j} + \varepsilon_t \text{ ----------(6)}$$

The research will continue the analysis with F test to test the null hypothesis $H_0: \beta_i (i = 1,2, \dots, m) = 0$, which equal to the hypothesis that x_t has no granger causality to y_t. If the null hypothesis is rejected, then x_t has granger causality to y_t. All of the procedure that will be conducted in this empirical analysis is shown in Figure 3.7.

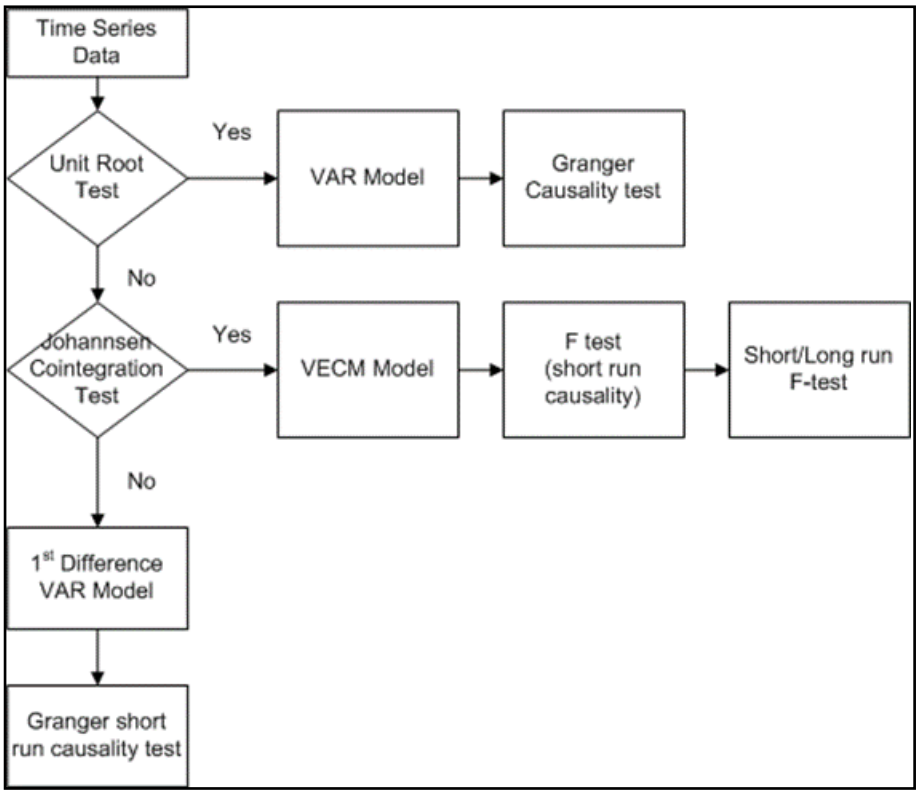


Figure 3.7. Empirical Analysis Procedure

3.4 Empirical Results

3.5 Total Primary Energy Consumption and Economic Growth

3.5.1 Data collection

This research use the time series data of gross domestic product (GDP) and Total Primary Energy Consumption (EC) in Myanmar and the Global Oil Price (OP) for the period 1990-2017. The data sets are attained from two sources where central statstical organization (CSO) Myanmar and International Energy Agency (IEA). In this study, GDP is used in Myanmar local currency unit (Kyats million) and Total Primary Energy Consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNENC respectively. Table 3.2 shows that the dedscriptive statstics of these two variables.

Table 3.2. Summary statistics of GDP and Total Primary Energy Consumption and Oil Price in Myanmar, 1990-2017

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
GDP	28	17620930	3870781	22654748	49933.30	63827919
ENC	28	2817.464	2325.000	1805.223	931.0000	8906.000
OP	28	57.64286	44.60000	32.38805	19.10000	121.2000

(Unit: Kyat million for GDP, KTOE for ENC, USD per barrel for OP)

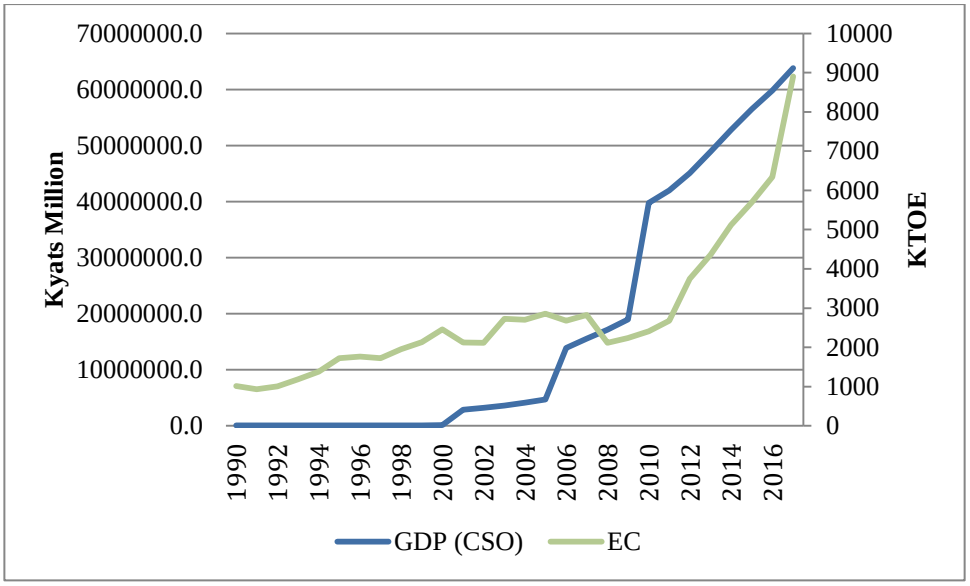


Figure 3.8. GDP and curde oil consumption of Myanmar, 1990-2017

(Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

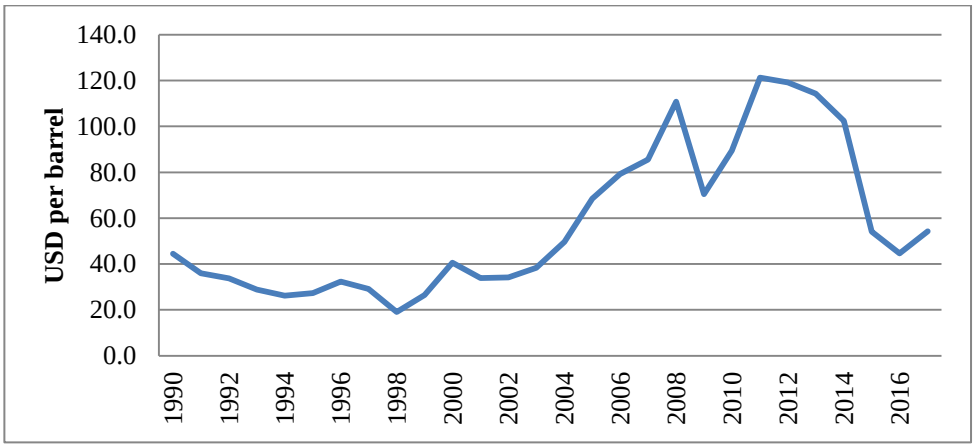


Figure 3.9. Global Oil Price (1990-2017)

(Source: BP statistic)

3.5.2 Unit Root Test

The empirical analysis starts with unit root test to the economic growth (GDP) and total primary energy consumption (EC) of Myanmar and global oil price in the period from 1990 to 2017. To find the order of integration of variables, the unit root test was analyzed by using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). These two tests were applied to calculate the robustness of the results. In general, the order of integration of a series is the minimum number of times a variable must be differenced to be sure it stationary, written by I(d) with d is number of time after differencing ("Economics Department of the University of Pennsylvania Threshold Cointegration Author (s): Nathan S . Balke and Thomas B . Fomby Source : International Economic Review , Vol . 38 , No . 3 (Aug ., 1997), Pp . 627-645 Published by : Wiley for the Econom" 2016). When checking whether to reject the null of a unit root (non-stationary), the 5% significance was used for the levels and the 10% for the first differences; disparity being based on the expectation that in general the variables will be I(0) in levels and I(1) in the first differences (Chontanawat, Hunt, and Pierse 2008). Unit root test results of five variables are as following Table 3.3.

Table 3.3. Unit Root Test result of all variables with ADF and PP.

Variables		Level		First Difference	
		ADF	PP	ADF	PP
GDP	intercept	-0.651377	-0.639915	-5.187206 ***	-5.187710 ***
	Trend and intercept	-1.953873	-2.018168	-5.085330 ***	-5.085468 ***
EC	intercept	0.736202	0.640841	-4.073612 ***	-4.068986 ***
	Trend and intercept	-0.772085	-1.122891	-4.079831 ***	-4.081814 ***
OP	intercept	-1.203248	-1.246971	-4.405922 ***	-4.359529 ***
	Trend and intercept	-1.806198	-1.806198	-4.331364 ***	-4.272987 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

All of the variables (GDP, total primary energy consumption and oil price) are non-stationary or have unit root at their original level series because their probability value (p value) are greater than 0.5% significant level. However, the first difference results of all variables show that all of the variables are stationary or have not unit root in the first difference because their probability values (p values) are less than 0.5% significant level. It means that all of the variables are separately integrated to order 1 of I(1). Based on the unit root test results, both of ADF and PP tests are seen to be first-difference-stationary.

As the results of the unit root test, all variables of Myanmar are separately integrated to the order 1 or I(1), the study will continue Johansen Cointegration Test to check whether a cointegration among the variables or existent long-run relationship. If the variables are shown to be cointegrated, the non-standard Granger causality test based on VECM model can be used; otherwise, if the variables are shown that two variables are not cointegrated, the non-standard Granger causality test based on VAR model can be used.

3.5.3 Johansen cointegration test between EC, GDP and OP

The Johansen cointegration test is used with a lag length interval 2 in the first difference for each pair of time series data sets. Two test statistics that approximation the number of cointegrating vectors in Johansen's cointegration process are used in this research. These are the maximum eigenvalue test and the trace statistic test (Johansen 1988).

The trace statistic test works to examine the number of cointegration vectors among the variables by checking the null hypothesis $H_0: r = 0$ against the alternative hypothesis $H_1: r > 0 \; or \; r \leq 1$ (r equals the number of cointegrating vectors).

The maximum eigenvalue test examine the null hypothesis that $H_0: r_0 = r$, and the alternate hypothesis $H_1: r_0 > r$. If likelihood ratio value is larger than the critical values at a given significant level, the null hypothesis $H_0: r = 0$ is rejected in favor of the alternatives.

Table.3.4. Johansen Cointegration Test Results between GDP, EC, and OP

No. of Cointegration	**Eiganvalue**	**Trace Test**			**Maximum Eigenvalue Test**		
		Trace statistic	5% critical value	Prob.	Max. Eigen statistic	5% critical value	Prob.
Null ($r = 0$)	0.548359	23.07674	29.79707	0.2423	20.66653	21.13162	0.0580
$r \leq 1$	0.081592	1.194648	15.49471	0.9873	2.212955	14.26460	0.9850
$r \leq 2$	0.007558	0.197248	3.841466	0.6569	0.197248	3.841466	0.6569

Table.3.4 shows Johansen cointegration test results between economic growth (GDP), total primary energy consumption (EC) and oil price (OP). The results table shows that both of trace statistic and maximum eigenvalue statistic values are smaller than their 5% critical values. Moreover, probability values (p values) of both test are greater than 0.05. Therefore, the null hypothesis of no cointegration ($H_0: r = 0$) cannot be rejected applying both the trace test and maximum eigenvalue test at 5% significant level. This means that there is no cointegrated between economic growth (GDP), total primary energy consumption (EC) and oil price (OP) for Myanmar, and maximum rank =0. Hence, VECM cannot be used, and thus, the study continues with unrestricted Vector Autoregression (VAR) models.

3.5.4 Vector Autoregression Model (VAR)

According to the Johansen cointegration test results, the relationship between economic growth (GDP) and total primary energy consumption of Myanmar has no cointegrated. Thus, the study continues with Vector Autoregression Model to determine causal relationship between two variables. The results of this VAR model as follows:

Equation (1)

LNGDP = EN(1)*LNGDP(-1) + EN(2)*LNGDP(-2) + EN(3)*LNEC(-1) + EN(4)*LNEC(-2) + EN(5)*LNOP(-1) + EN(6)*LNOP(-2) + EN(7)

Equation (2)

LNEC = EN(8)*LNGDP(-1) + EN(9)*LNGDP(-2) + EN(10)*LNEC(-1) + EN(11)*LNEC(-2) + EN(12)*LNOP(-1) + EN(13)*LNOP(-2) + EN(14)

Equation (3)

LNOP = EN(15)*LNGDP(-1) + EN(16)*LNGDP(-2) + EN(17)*LNEC(-1) + EN(18)*LNEC(-2) + EN(19)*LNOP(-1) + EN(20)*LNOP(-2) + EN(21)

Table.3.5. VAR coefficient values and p values of GDP, EC and OP

	Coefficient	**P-value**
EN(1)	0.840441	0.0006
EN(2)	0.123479	0.5924
EN(3)	0.065729	0.0403***
EN(4)	0.039652	0.0242***
EN(5)	0.016914	0.0397***
EN(6)	0.065033	0.0402***
EN(7)	2.609525	0.1253
EN(8)	0.034030	0.0449***
EN(9)	0.056474	0.0499***
EN(10)	0.980424	0.0002
EN(11)	0.120964	0.6414
EN(12)	0.199046	0.1096
EN(13)	0.038455	0.7585
EN(14)	0.453136	0.2073
EN(15)	0.153093	0.0501
EN(16)	0.025809	0.7348
EN(17)	0.304908	0.4217
EN(18)	0.756524	0.0657
EN(19)	0.795384	0.0001
EN(20)	0.503921	0.0120
EN(21)	1.586189	0.0059

Table.3.5 illustrates the coefficient values, standard errors, t-statistics, and probability p values of the relationship between GDP, total primary energy consumption EC and oil price OC of Myanmar.

In equation (1), the GDP is as the dependent variable, total primary energy consumption EC is as independent variable, and oil price OP is as control variable. The VAR result shows that the independent variable total primary energy consumption (EC) significantly effects to the dependent variable economic growth (GDP) because the probability p values of the coefficients of total primary energy consumption EN(3) and EN(4) are smaller than 5%. It means that there is long run causality from total primary energy consumption EC to economic growth GDP, when energy consumption increases 1%, economic growth will increase 0.65%, in Myanmar in the period 1990-2017. Similarly, the control variable oil price (OP) significantly effects to the dependent variable economic growth (GDP) because the probability p values of the coefficients of oil price EN(5) and EN(6) are smaller than 5%. It means that there is long run causality from oil price OP to economic growth GDP, when oil price increases 1%, economic growth will increase 0.16%.

In equation (2), the total primary energy consumption EC is as the dependent variable, GDP is as independent variable and oil price is as control variable. The VAR model result shows that the independent variable economic growth (GDP) also significantly effects to the dependent variable total primary energy consumption (EC) because the probability p values of the coefficients of GDP EN(8) and EN(9) are less than 5%. It means that there is long run causality from economic growth GDP to total primary energy consumption EC, when economic growth increases 1%, crude oil

consumption will increase 0.34%, in Myanmar in the period 1990-2017. Nevertheless, the control variable oil price (OP) does not effects to the dependent variable total primary energy consumption (EC) because the probability p values of the coefficients of oil price EN(12) and EN(13) are greater than 5%. It means that there is no long run causality from oil price OP to total primary energy consumption EC.

In equation (3), the oil price OP is as the dependent variable, GDP and total primary energy consumption EC are as independent variables. The VAR model result shows that the independent variable economic growth (GDP) and total primary energy consumption EC do not effect to the dependent variable oil price OP because the probability p values of the coefficients of GDP EN(15), EN(16) and the coefficients of total primary energy consumption EN(17), EN(18) are more than 5%. It means that there is no long run causality from economic growth GDP and total primary energy consumption EC to oil price OP.

Therefore, there is long run causality relationship between economic growth and total primary energy consumption in Myanmar.

3.5.5 Granger Causality Test

The study continues Granger Causality test to estimate the direction of the short run causal relationship which can be bidirectional, unidirectional, and no Granger causality (neutrality).

Table.3.6. Granger Causality Test of GDP, EC and OP in Myanmar

Null Hypothesis	Obs	F-Statistic	P Value
LNEC does not Granger Cause LNGDP	26	0.82800	0.0407***
LNGDP does not Granger Cause LNEC	26	0.50297	0.0118***
LNOP does not Granger Cause LNGDP	26	1.34009	0.0233***
LNGDP does not Granger Cause LNOP	26	2.95581	0.0739
LNOP does not Granger Cause LNEC	26	0.54966	0.5852
LNEC does not Granger Cause LNOP	26	0.61040	0.5525

Table.3.6 shows the result of Granger Causality Test. The result illustrations that the null hypothesis that total primary energy consumption EC does not Granger Cause economic growth GDP can be rejected because probability p value is less than 0.5. It means that there is short run Granger Causality from total primary energy consumption EC to economic growth GDP. Similarly, the null hypothesis that economic growth GDP does not Granger Cause total primary energy consumption OC can be rejected because probability p value is less than 0.5. It means that there is short run Granger Causality from economic growth GDP to total primary energy consumption EC. The Granger Causality Test results show the existence of bidirectional Granger Causality from economic growth GDP and total primary energy consumption EC in Myanmar in the period 1990-2017.

3.6 Oil Consumption and Economic Growth

3.6.1 Data collection

This research use the time series data of gross domestic product (GDP) and crude oil consumption for the period 1990-2017 in Myanmar. The data sets are attained from two sources where central statstical organization (CSO) Myanmar and International Energy Agency (IEA). In this study, GDP is used in Myanmar local currency unit (Kyats million) and crude oil consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNOC respectively. Table 3.7 shows that the dedscriptive statstics of these two variables.

Table 3.7. Summary statistics of GDP and Oil Consumption in Myanmar, 1990-2017

Variables	Obs	Mean	Standard deviation	Minimum	Maximum
GDP	28	32175167377	23152471012	7959769716	79212697713
OC	28	1764	427	556	6677

(Unit: Kyat million for GDP, KTOE for OC)

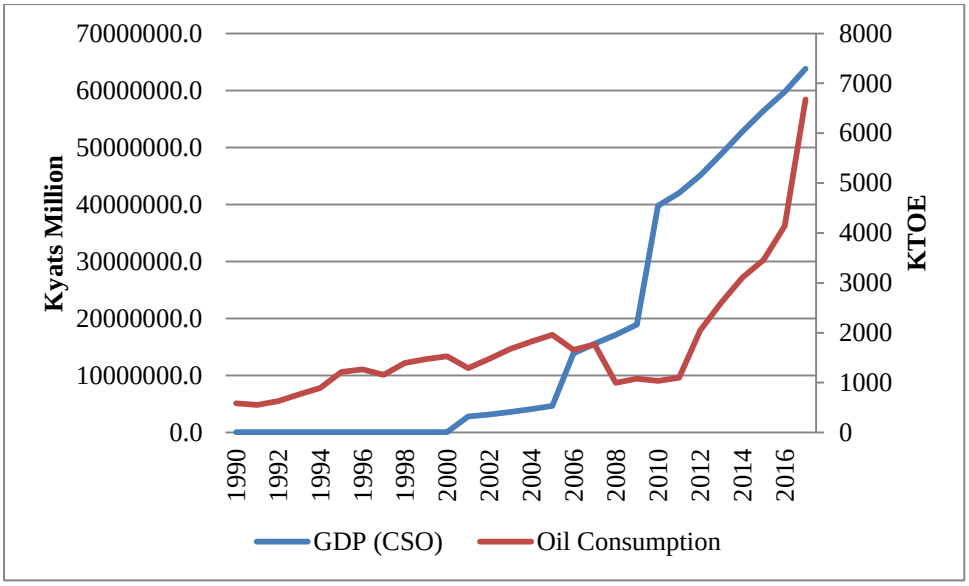


Figure 3.10. GDP and curde oil consumption of Myanmar, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Oil Consumption data from International Energy Agency IEA)

3.6.2 Unit Root Test

The empirical analysis starts with unit root test to the economic growth (GDP) and crude oil consumption (OC) of Myanmar in the period from 1990 to 2017. To find the order of integration of five variables, the unit root test was analyzed by using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). These two tests were applied to calculate the robustness of the results. In general, the order of integration of a series is the minimum number of times a variable must be differenced to be sure it stationary, written by I(d) with d is number of time after differencing ("Economics Department of the University of Pennsylvania Threshold Cointegration

Author (s): Nathan S . Balke and Thomas B . Fomby Source : International Economic Review , Vol . 38 , No . 3 (Aug ., 1997), Pp . 627-645 Published by : Wiley for the Econom" 2016). When checking whether to reject the null of a unit root (non-stationary), the 5% significance was used for the levels and the 10% for the first differences; disparity being based on the expectation that in general the variables will be I(0) in levels and I(1) in the first differences (Chontanawat, Hunt, and Pierse 2008). Unit root test results of five variables are as following Table 3.8.

Table 3.8. Unit Root Test result of all variables with ADF and PP.

Variables		Level		First Difference	
		ADF	PP	ADF	PP
GDP	intercept	-0.651377	-0.639915	-5.187206 ***	-5.187710 ***
	Trend and intercept	-1.953873	-2.018168	-5.085330 ***	-5.085468 ***
OC	intercept	0.256675	-0.039282	-3.955164 ***	-4.021824 ***
	Trend and intercept	-0.781506	-1.196045	-3.954368 ***	-4.020581 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

All of the variables (GDP, crude oil consumption) are non-stationary or have unit root at their original level series because their probability value (p value) are greater than 0.5% significant level. However, the first difference results of all variables show that all of the variables of Myanmar

are stationary or have not unit root in the first difference because their probability values (p values) are less than 0.5% significant level. It means that all of the variables are separately integrated to order 1 of I(1). Based on the unit root test results, both of ADF and PP tests are seen to be first-difference-stationary.

3.6.3 Johansen Cointegration Test and lag length selection

As the results of the unit root test, all variables of Myanmar are separately integrated to the order 1 or I(1), the study will continue Johansen Cointegration Test to check whether a cointegration among the variables or existent long-run relationship. If the variables are shown to be cointegrated, the non-standard Granger causality test based on VECM model can be used; otherwise, if the variables are shown that two variables are not cointegrated, the non-standard Granger causality test based on VAR model can be used. Before that, the study has to select the number of lag.

3.6.4 Lag length selection

The number of lags is selected by applying the model selection criteria AIC (Akaike information criterion), SC (Schwartz information criterion), and HQIC (Hannan and Quinn information criterion), which are automatic settings in the EView 10 software package, as follows:

- AIC: Akaike information criterion
- SC: Schwartz information criterion
- HQ: Hannan and Quinn information criterion

The smallest values of AIC, SC, HQ information criterion are the optimum lags. The cointegration test result bases on the number of lags.

Table 3.9. Lag selection for Johansen co-integration test

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.001098	7.374618	7.618394	7.442231
1	193.8328*	3.16e-07	-0.827110	0.635541*	-0.421433
2	33.46865	2.81e-07	-1.217728	1.463799	-0.473987
3	33.85834	1.14e-07*	-2.979766*	0.920637	-1.897960*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 3.9 shows the lag selection for Johansen cointegration test. Through the result, lag length 3 is the optimum lag because the smallest AIC value, -2.9798, is selected.

3.6.5 Johansen cointegration test between GDP and OC

The Johansen cointegration test is used with a lag length interval 2 in the first difference for each pair of time series data sets. Two test statistics that approximation the number of cointegrating vectors in Johansen's cointegration process are used in this research. These are the maximum eigenvalue test and the trace statistic test (Johansen 1988).

The trace statistic test works to examine the number of cointegration vectors among the variables by checking the null hypothesis $H_0: r = 0$ against the alternative hypothesis $H_1: r > 0 \; or \; r \leq 1$ (r equals the number of cointegrating vectors).

The maximum eigenvalue test examine the null hypothesis that $H_0: r_0 = r$, and the alternate hypothesis $H_1: r_0 > r$. If likelihood ratio value

is larger than the critical values at a given significant level, the null hypothesis $H_0: r = 0$ is rejected in favor of the alternatives.

Table 3.10. Johansen Cointegration Test Results between GDP and OC

No. of Cointegration	**Eiganvalue**	**Trace Test**			**Maximum Eigenvalue Test**		
		Trace statistic	5% critical value	Prob.	Max. Eigen statistic	5% critical value	Prob.
Null ($r = 0$)	0.144521	5.253075	15.49471	0.7814	4.058427	14.26460	.8531
$r \leq 1$	0.044908	1.194648	3.841466	0.2744	1.194648	3.841466	0.2744

Table 3.10 shows Johansen cointegration test results between economic growth (GDP) and crude oil consumption (OC) of Myanmar. The results table shows that both of trace statistic and maximum eigenvalue statistic values are smaller than their 5% critical values. Moreover, probability values (p values) of both test are greater than 0.05. Therefore, the null hypothesis of no cointegration ($H_0: r = 0$) cannot be rejected applying both the trace test and maximum eigenvalue test at 5% significant level. This means that there is no cointegrated between economic growth (GDP) and crude oil consumption (OC) for Myanmar, and maximum rank =0. Hence, VECM cannot be used, and thus, the study continues with unrestricted Vector Autoregression (VAR) models.

3.6.6 Vector Autoregression Model (VAR)

According to the Johansen cointegration test results, the relationship between economic growth (GDP) and crude oil consumption of Myanmar has no cointegrated. Thus, the study continues with Vector Autoregression Model to determine causal relationship between two variables. The results of this VAR model as follows:

Equation (1)

LNGDP = O(1)*LNGDP(-1) + O(2)*LNGDP(-2) + O(3)*LNOC(-1) + O(4)*LNOC(-2) + O(5)

Equation (2)

LNOC = O(6)*LNGDP(-1) + O(7)*LNGDP(-2) + O(8)*LNOC(-1) + O(9)*LNOC(-2) + O(10)

Table 3.11. VAR coefficient values and p values of GDP and OC relationship

	Coefficient	**P-Value**
O(1)	0.867786	0.0004
O(2)	0.054554	0.8085
O(3)	0.087967	0.0355***
O(4)	0.490473	0.0331***
O(5)	-1.473430	0.5421
O(6)	0.029673	0.0401***
O(7)	0.008998	0.0325***
O(8)	1.131350	0.0000
O(9)	-0.234760	0.3622
O(10)	0.527527	0.5040

Table 3.11 illustrates the coefficient values, standard errors, t-statistics, and probability p values of the relationship between GDP and OC of Myanmar.

In equation (1), the GDP is as the dependent variable and OC is as independent variable. The VAR result shows that the independent variable crude oil consumption (OC) significant effects to the dependent variable economic growth (GDP) because the probability p values of the coefficients of crude oil consumption O(3) and O(4) are smaller than 5%. It means that there is long run causality from crude oil consumption OC to economic growth GDP, when crude oil consumption increases 1%, economic growth will increase 0.87%, in Myanmar in the period 1990-2017.

In equation (2), the OC is as the dependent variable and GDP is as independent variable. The VAR model result shows that the independent variable economic growth (GDP) also significant effects to the dependent variable crude oil consumption (OC) because the probability p values of the coefficients of GDP O(6) and O(7) are less than 5%. It means that there is causality from economic growth GDP to crude oil consumption OC, when economic growth increases 1%, crude oil consumption will increase 0.29%, in Myanmar in the period 1990-2017.

Therefore, there is long run causality relationship between economic growth and crude oil consumption in Myanmar.

3.6.7 Granger Causality Test

The study continues Granger Causality test to estimate the direction of the short run causal relationship which can be bidirectional, unidirectional, and no Granger causality (neutrality).

Table 3.12. Granger Causality Test of GDP and crude oil consumption in Myanmar

Null Hypothesis	Obs	F-Statistic	P Value
LNOC does not Granger Cause LNGDP	26	0.53832	0.5916
LNGDP does not Granger Cause LNOC	26	0.49056	0.0191***

Table 3.12 shows the result of Granger Causality Test. The result illustrations that the null hypothesis that crude oil consumption OC does not Granger Cause economic growth GDP cannot be rejected because probability p value 0.59 is more than 0.5. It means that there is no short run Granger Causality from crude oil consumption OC to economic growth GDP.

Nevertheless, the null hypothesis that economic growth GDP does not Granger Cause crude oil consumption OC can be rejected because probability p value 0.0191 is less than 0.5. It means that there is short run Granger Causality from economic growth GDP to crude oil consumption OC. The Granger Causality Test results show the existence of unidirectional Granger Causality from economic growth GDP to crude oil consumption OC in Myanmar in the period 1990-2017.

3.7 Natural Gas Consumption and Economic Growth

3.7.1 Data collection and unit root test

This research use the time series data of gross domestic product (GDP) and natural gas consumption (NGC) for the period 1990-2017 in Myanmar. The data sets are attained from two sources where central statstics organization (CSO) Myanmar and International Energy Agency (IEA). In this study, GDP is used in Myanmar local currency unit (Kyats million) and natural gas consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNNGC respectively. Table 3.13 shows that the dedscriptive statstics of these two variables.

Table 3.13. Summary statistics of GDP (Kyats Million) and Natural Gas Consumption (ktoe) in Myanmar, 1990-2017

Variables	Obs	Mean	Standard deviation	Minimum	Maximum
GDP	28	32175167377	23152471012	7959769716	79212697713
NGC	28	417	175	180	707

(Unit: Kyat million for GDP, KTOE for NGC)

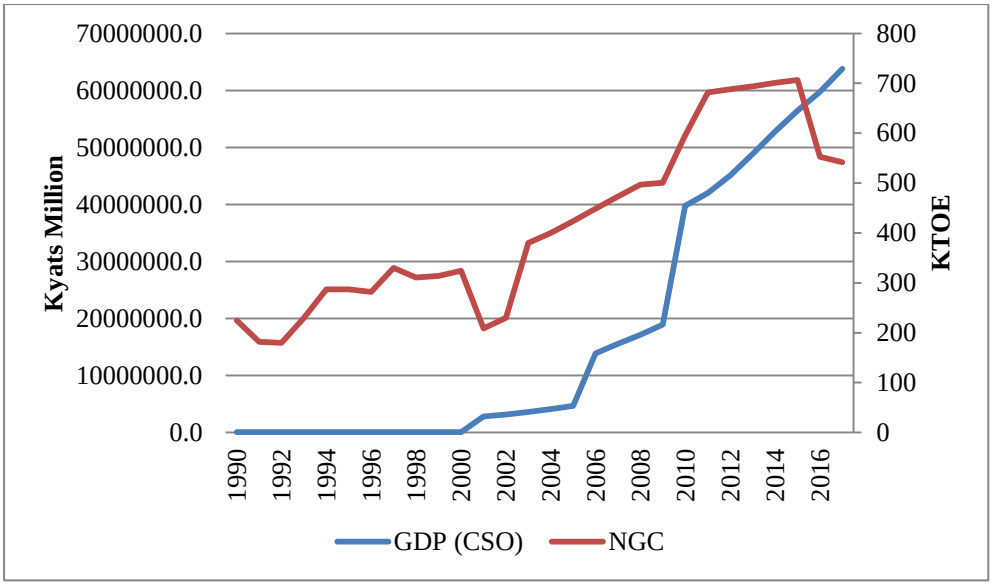


Figure 3.11. GDP and Natural Gas consumption of Myanmar, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Natural Gas Consumption data from International Energy Agency IEA)

Figure 3.11 shows the situation of economic growth GDP and natural gas consumption NGC in Myanmar in the period 1990-2017.

The empirical analysis starts with unit root test to the economic growth (GDP) and natural gas consumption (NGC) in Myanmar from 1990 to 2017 to examine the order of integration of each variables concerned by using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). The results of unit root test are as follows:

Table 3.14. Unit Root Test result of all variables with ADF and PP

Variables		Level		First Difference	
		ADF	PP	ADF	PP
GDP	intercept	-0.651377	-0.639915	-5.187206 ***	-5.187710 ***
	Trend and intercept	-1.953873	-2.018168	-5.085330 ***	-5.085468 ***
NGC	intercept	-1.201772	-1.099335	-4.687046 ***	-4.975928 ***
	Trend and intercept	-2.352348	-2.518145	-4.706694 ***	-5.241558 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

Two variables (GDP, natural gas consumption) are non-stationary or have unit root at their original level series because their probability value (p value) are greater than 0.5% significant level in both of ADF and PP tests. However, the first difference results of two variables show that two variables of Myanmar are stationary or have not unit root in the first difference because their probability values (p values) are less than 0.5% significant level. It means that all of the variables are separately integrated to order 1 of I(1). Based on the unit root test results, both of ADF and PP tests are seen to be first-difference-stationary.

3.7.2 Lags Length Selection

The number of lags is selected by applying the model selection criteria AIC (Akaike information criterion), SC (Schwartz information criterion), and HQIC (Hannan and Quinn information criterion), which are automatic settings in the EView 10 software package, as follows:

- AIC: Akaike information criterion
- SC: Schwartz information criterionHQ: Hannan and Quinn information criterion

The smallest values of AIC, SC, HQ information criterion are the optimum lags. The cointegration test result bases on the number of lags.

Table 3.15. Lag selection for Johansen co-integration test

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.400218	4.759912	4.858083	4.785957
1	89.81755*	0.007774	0.816219	1.110732*	0.894353
2	7.523653	0.007374*	0.753570*	1.244426	0.883795*
3	1.597109	0.009582	0.992956	1.680154	1.175270
4	5.202977	0.009859	0.979424	1.862965	1.213828

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 3.15 shows the lag selection for Johansen cointegration test. Through the result, lag length 2 is the optimum lag because the smallest AIC value, -2.9798, is selected.

3.7.3 Johansen cointegration test between GDP and NGC

The Johansen cointegration test is used with a lag length interval 2 in the first difference for each pair of time series data sets. Two test statistics that approximation the number of cointegrating vectors in Johansen's cointegration process are used in this research. These are the maximum eigenvalue test and the trace statistic test (Johansen 1988).

The trace statistic test works to examine the number of cointegration vectors among the variables by checking the null hypothesis $H_0: r = 0$ against the alternative hypothesis $H_1: r > 0 \; or \; r \leq 1$ (r equals the number of cointegrating vectors).

The maximum eigenvalue test examine the null hypothesis that $H_0: r_0 = r$, and the alternate hypothesis $H_1: r_0 > r$. If likelihood ratio value is larger than the critical values at a given significant level, the null hypothesis $H_0: r = 0$ is rejected in favor of the alternatives.

Table 3.16. Johansen Cointegration Test Results between GDP and NGC

No. of Cointegration	**Eiganvalue**	**Trace Test**			**Maximum Eigenvalue Test**		
		Trace statistic	5% critical value	Prob.	Max. Eigen statistic	5% critical value	Prob.
Null ($r = 0$)	0.526255	20.19483	15.4971	0.0091 *	19.42423	14.26460	0.0070 *
$r \leq 1$	0.0292 4	0.770603	3.841466	0.3800	0.770603	3.841466	0.3800

Table 3.16 shows Johansen cointegration test results between economic growth (GDP) and natural gas consumption (NGC) of Myanmar. The results table shows that trace statistic value 20.1948 is larger than their 5% critical value 15.4947 and maximum eigenvalue statistic value 19.4242 is also larger than their 5% critical value 14.2646. Moreover, probability values (p values) of both tests 0.0070 and 0.0091 are less than 0.05. Therefore, the null hypothesis of no cointegration ($H_0: r = 0$) can be rejected applying both the trace test and maximum eigenvalue test at 5% significant level. This means that the relationship between economic growth (GDP) and natural gas consumption (NGC) is cointegrated for Myanmar in the period 1990-2017. Hence, VAR model cannot be used, and thus, the study continues with Vector Error Correction Model (VECM).

3.7.4 Vector Error Correction Model (VECM)

According to the Johansen cointegration test results, the relationship between economic growth (GDP) and natural gas consumption (NGC) of Myanmar has cointegrated. Thus, the study continues with Vector Error Correction Model (VECM) to determine causal relationship between two variables. The results of this VECM model as follows:

Equation (1)

D(LNGDP)=G(1)*(LNGDP(-1)-8.75888575208*LNNGC(-1)+
37.731003497)+G(2)*D(LNGDP(-1))+G(3)*D(LNGDP(-2))+
G(4)*D(LNNGC(-1)) +G(5)*D(LNNGC(-2)) + G(6)

Table 3.17. Coefficient result of Myanmar Natural Gas consumption to GDP

	Coefficient	P Value
G(1)	-0.053891	0.6692
G(2)	0.001138	0.9975
G(3)	-0.053465	0.8652
G(4)	0.201195	0.0473***
G(5)	0.556815	0.0369***
G(6)	0.331586	0.1748

Table 3.17 shows the coefficient of Myanmar natural gas consumption to economic growth. According to that table, G(1) coefficient value is negative in sign. Moreover, the probability values of coefficients of natural gas consumption G(4) and G(5) are smaller than 0.05 or no significant. It means that there is long run causality relationship from natural gas consumption (NGC) to economic growth (GDP), when natural gas consumption increases 1%, economic growth will increase 2%, in Myanmar it the period 1990-2017.

In order to check short run causality relationship from natural gas consumption to economic growth, we continue to run Wald test.

Table 3.18. Wald Test result from NGC to GDP Myanmar

Test statistic	Value	df	Probability
F-statistic	0.145136	(2, 19)	0.8659
Chi-square	0.290271	2	0.0349***

Table 3.18 shows the result of Wald Test from natural gas consumption to economic growth of Myanmar. In this table, the Wald Test result can be rejected null hypothesis G(4)=G(5)=0 because Chi-square p value 0.0349 is less than 0.05 or significant. It shows that there is short run causality running from natural gas consumption NGC to economic growth GDP in Myanmar in the period 1990-2017.

Additionally, as natural gas consumption is dependent variable and the economic growth (GDP) is independent variable, Vector Error Correction Model test result is as the following equation:

Equation (2)

D(LNNGC)=G(7)*(LNGDP(-1)-8.75888575208*LNNGC(-1)+ 37.731003497)+G(8)*D(LNGDP(-1))+G(9)*D(LNGDP(-2))+ G(10)*D(LNNGC(-1)) + G(11)*D(LNNGC(-2)) + G(12)

Table 3.19. The coefficient result of GDP to Natural Gas consumption

	Coefficient	P Value
G(7)	-0.060230	0.0096
G(8)	0.065292	0.0268***
G(9)	0.031838	0.0404***
G(10)	0.131965	0.4867
G(11)	-0.051834	0.7939
G(12)	0.050165	0.2209

Table 3.19 states the coefficient results of economic growth to natural gas consumption in Myanmar. According to that table, the p value of G(7) is smaller than 0.05 or significant and G(7) coefficient value is also negative in sign. Moreover, p values of coefficients of GDP G(8) and G(9) are also less

than 5% or significant. It means that there is long run causality from economic growth (GDP) to natural gas consumption (NGC), when economic growth increases 1%, natural gas consumption will increase 0.65%, in Myanmar it the period 1990-2017.

In order to check short run relationship causality from economic growth (GDP) to natural gas consumption (NGC), the study continues to run Wald test.

Table 3.20. Wald Test result from GDP to NGC of Myanmar

Test statistic	Value	df	Probability
F-statistic	1.119200	(2, 19)	0.3471
Chi-square	2.238399	2	0.0265***

Table 3.20 illustrates the result of Wald Test from economic growth GDP to natural gas consumption NGC of Myanmar. In this table, the Wald Test result can reject to null hypothesis G(8)=G(9)=0 because Chi-square p value 0.0265 is lower than 0.05 or significant. It means that there is short run causality running from economic growth (GDP) to natural gas consumption (NGC) in Myanmar in the period 1990-2017.

Consequently, there are long run causality and bidirectional short run causality between economic growth GDP and natural gas consumption NGC in Myanmar in the period 1990-2017.

3.8 Electricity Consumption and Economic Growth

3.8.1 Data collection

This research use the time series data of gross domestic product (GDP) and electricity consumption (ELC) for the period 1990-2017 in Myanmar. The data sets are obtained from two sources where central statstics organization (CSO) Myanmar and International Energy Agency (IEA). In this study, GDP is used in Myanmar local currency unit (Kyats million) and electricity consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNELC respectively. Table 3.21 shows that the dedscriptive statstics of these two variables.

Table 3.21.Summary statistics of GDP and Electricity Consumption in Myanmar, 1990-2017

Variables	Obs	Mean	Standard deviation	Minimum	Maximum
GDP	28	32175167377	23152471012	7959769716	79212697713
ELC	28	464	367	141	1466

(Unit: Kyat million for GDP, KTOE for ELC)

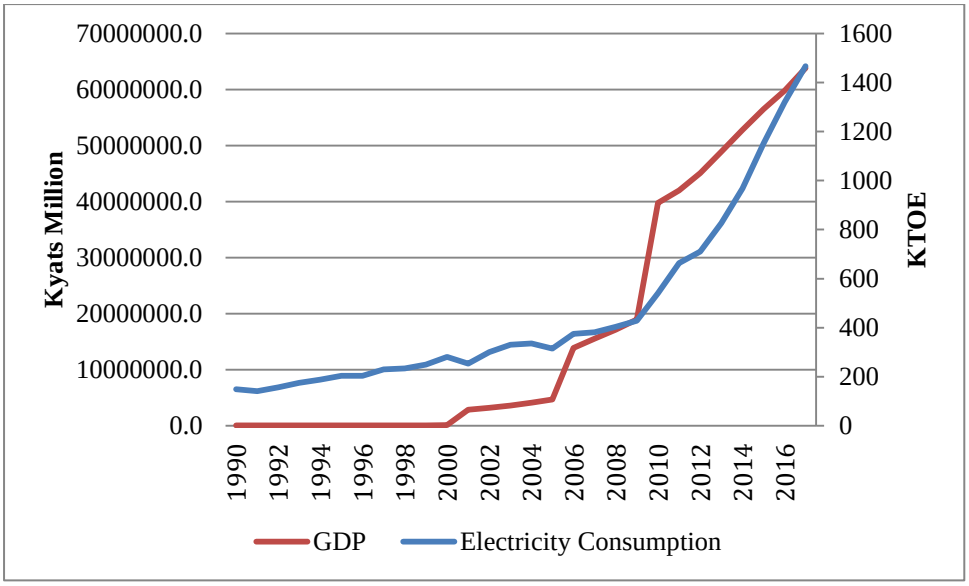


Figure 3.12. GDP and Electricity consumption of Myanmar, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Electricity Consumption data from International Energy Agency IEA)

3.8.2 Unit Root Test

The research starts with unit root test to the data sets of economic growth (GDP) and electricity consumption (ELC) in Myanmar from 1990 to 2017 to examine the order of integration of each variables concerned by using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). The results of unit root test are as follows:

Table 3.22. Unit Root Test result of all variables with ADF and PP

Variables		Level		First Difference	
		ADF	PP	ADF	PP
GDP	intercept	-0.651377	-0.639915	-5.187206 ***	-5.187710 ***
	Trend and intercept	-1.953873	-2.018168	-5.085330 ***	-5.085468 ***
ELC	intercept	2.017408	3.498460	-5.410987 ***	-5.407070 ***
	Trend and intercept	-0.628963	-0.379186	-6.093174 ***	-6.150046 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

Two variables, GDP, electricity consumption ELC are non-stationary or have unit root at their original level series because their probability value (p value) are greater than 0.5% significant level in both of ADF and PP tests. However, the first difference results of two variables show that two variables of Myanmar are stationary or have not unit root in the first difference because their probability values (p values) are less than 0.5% significant level. It means that all of the variables are separately integrated to order 1 of I(1). Based on the unit root test results, both of ADF and PP tests are seen to be first-difference-stationary. The detail results of the unit root test of two variables are shown in Table 3.22.

3.8.3 Lags Length Selection

The number of lags is selected by applying the model selection criteria AIC (Akaike information criterion), SC (Schwartz information criterion), and HQIC (Hannan and Quinn information criterion), which are automatic settings in the EView 10 software package, as follows:

- AIC: Akaike information criterion
- SC: Schwartz information criterion
- HQ: Hannan and Quinn information criterion

The smallest values of AIC, SC, HQ information criterion are the optimum lags. The cointegration test result bases on the number of lags.

Table 3.23. Lag selection for Johansen co-integration test

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.848928	5.511876	5.610048	5.537921
1	122.7652*	0.003435*	-0.000754*	0.293760*	0.077381*
2	1.567660	0.004457	0.250071	0.740927	0.380295
3	1.230297	0.005918	0.511034	1.198232	0.693348
4	2.478104	0.007301	0.679161	1.562701	0.913564

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 3.23 shows the lag selection for Johansen cointegration test. Through the result, lag length 1 is the optimum lag because the smallest AIC value, -0.00075, is selected.

3.8.4 Johansen Cointegration Test Result

The analysis continues with Johansen cointegration test for the data sets of economic growth (GDP) and electricity consumption (ELC) of Myanmar in the period 1990-2017. We employed the minimum Akaike information criterion (AIC) through the unconstrained VAR estimation to select lag interval for running the Johansen co-integration test. In the result of the lag selection, the study selects the lag interval 1 to test Johansen Cointegration.

Table 3.24. Johansen Cointegration Test Results between GDP and ELC

No. of Cointegration	**Eiganvalue**	**Trace Test**			**Maximum Eigenvalue Test**		
		Trace statistic	5% critical value	Prob.	Max. Eigen statistic	5% critical value	Prob.
Null ($r = 0$)	0.160706	5.162108	15.49471	0.791	4.555054	14.26460	0.7966
$r \leq 1$	0.023078	0.607054	3.841466	0.4359	0.607054	3. 41466	0.4359

Table 3.24 shows Johansen cointegration test results between economic growth (GDP) and electricity consumption (ELC) of Myanmar. Johansen Cointegration Test results show that maximum eigenvalue cannot reject to null hypothesis of zero cointegrating equation r=0 at the 5% significant level because maximum eigenvalue statistic value is 4.555054, which value is smaller than its 0.05 critical value 14.26460 and p value 0.7914 is also more than 0.5% or no significant. Similarly, Trace test value also cannot reject null hypothesis of zero cointegration equation at 5%

significant level because trace statistics value 5.162108 is less than 0.05 critical value 15.49471 and p value 0.7966 is greater than 0.5% or no significant. This results show that there is no long run relationship between economic growth (GDP) and electricity consumption (ELC) in Myanmar. Therefore, the study has to continue with unrestricted Vector Autoregression (VAR) models.

3.8.5 Vector Autoregression Model Results

According to the Johansen cointegration test results, the relationship between economic growth (GDP) and electricity consumption of Myanmar has no long run relationship. Thus, the study continues with Vector Autoregression Model to determine causal relationship between two variables. The results of this VAR model as follows:

Equation (1)

LNGDP = EL(1)*LNGDP(-1) + EL(2)*LNGDP(-2) + EL(3)*LNELC(-1) + EL(4)*LNELC (-2) + EL(5)

Equation (2)

LNELC = EL(6)*LNGDP(-1) + EL(7)*LNGDP(-2) + EL(8)*LNELC(-1) + EL(9)*LNELC(-2) + EL(10)

Table 3.25. VAR coefficient values and p values of GDP and ELC relationship

	Coefficient	**P-Value**
EL(1)	0.899955	0.0003
EL(2)	0.003821	0.9874
EL(3)	-0.169318	0.9319
EL(4)	0.508406	0.8083
EL(5)	-0.277992	0.8880
EL(6)	0.020232	0.4156
EL(7)	-0.011592	0.6584
EL(8)	0.834552	0.0003
EL(9)	0.182822	0.4226
EL(10)	-0.125277	0.5591

Table 3.25 illustrates the coefficient values, standard errors, t-statistics, and probability p values of the relationship between GDP and OC.

In equation (1), the GDP is as the dependent variable and ELC is as independent variable. The VAR result shows that the independent variable electricity consumption (ELC) does not significant effect to the dependent variable economic growth (GDP) because the probability p values of the coefficient of electricity consumption EL(3) and EL(4) are larger than 5%. It means that there is no causality from electricity consumption ELC to economic growth GDP.

In equation (2), the ELC is as the dependent variable and GDP is as independent variable. The VAR model result shows that the independent variable economic growth (GDP) does not significant effect to the dependent variable electricity consumption (ELC) because the probability p values of the coefficient of GDP EL(6) and EL(7) are larger than 5%. It means that there is no causality from economic growth GDP to electricity consumption

ELC in Myanmar in the period 1990-2017. Therefore, there is no long run causality relationship between economic growth and crude oil consumption in Myanmar.

3.8.6 Granger Causality Test

By analyzing Granger Causality test, we can examine whether the GDP and electricity consumption ELC has causal relationship in the short run as displayed as follows:

Table 3.26. Granger Causality Test of GDP and electricity consumption

Null Hypothesis	Obs	F-Statistic	P Value
LNGDP does not Granger Cause LNELC	26	0.48755	0.6209
LNELC does not Granger Cause LNGDP	26	0.17368	0.8418

Table 3.26 is Granger Causality Test of economic growth (GDP) and electricity consumption (ELC) in Myanmar in the period from 1990 to 2017. This table shows that it cannot reject the null hypothesis which is electricity consumption (ELC) does not Granger Cause to economic growth (GDP) because p value 0.8418 is bigger than 0.05 or no significant. It means that electricity consumption (ELC) does not Granger Cause to economic growth (GDP) in Myanmar in the period 1990-2017. Similarly, null hypothesis which is economic growth (GDP) does not Granger Cause to electricity consumption (ELC) is not rejected because p value 0.6209 is greater than 0.05 or significant. This result also shows that economic growth (GDP) does not Granger Cause to electricity consumption (ELC) in Myanmar the period

from 1990 to 2017. Therefore, the Granger Causality Test result reveals that there is not exit short run Granger causality or neutrality between economic growth (GDP) and electricity consumption (ELC) in Myanmar in the period from 1990 to 2017.

3.9 Coal Consumption and Economic Growth

3.9.1 Data collection

This research use the time series data of gross domestic product (GDP) and coal consumption (CC) for the period 1990-2017 in Myanmar. The data sets are from two sources where central statstics organization (CSO) Myanmar and International Energy Agency (IEA). In this study, GDP is used in Myanmar local currency unit (Kyats million) and coal consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNELC respectively. Table 3.27 shows that the dedscriptive statstics of these two variables.

Table 3.27. Summary statistics of GDP and Coal Consumption in Myanmar, 1990-2017

Variables	Obs	Mean	Standard deviation	Minimum	Maximum
GDP	28	32175167377	23152471012	7959769716	79212697713
CC	28	173	126	12	375

(Unit: Kyat million for GDP, KTOE for CC)

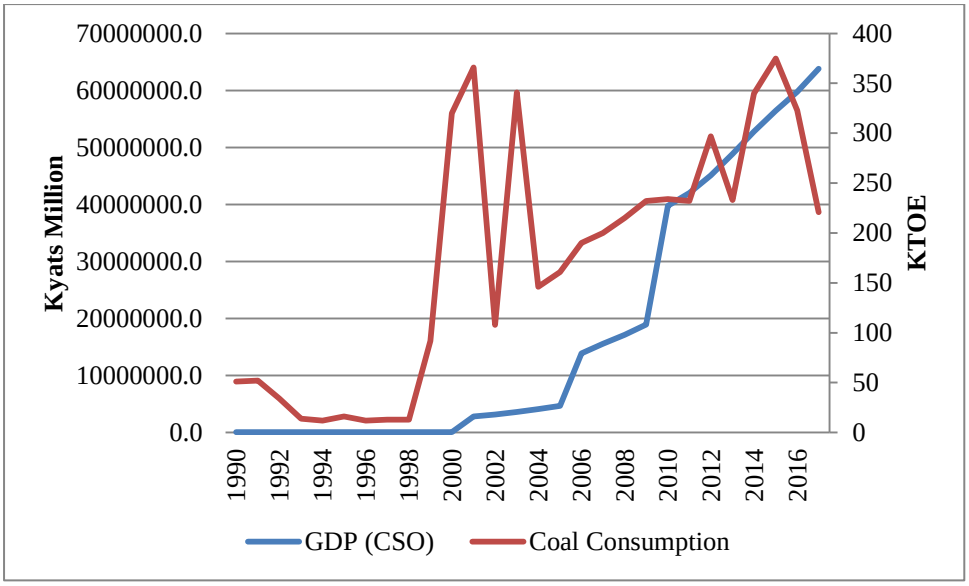


Figure 3.13. GDP and Coal consumption of Myanmar, 1990-2017

(Source: GDP data from Central Statistical Organization, Myanmar. Coal Consumption data from International Energy Agency IEA)

3.9.2 Unit Root Test

The research starts with unit root test to the data sets of economic growth (GDP) and coal consumption (CC) in Myanmar from 1990 to 2017 to examine the order of integration of each variables concerned by using the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP). The results of unit root test are as follows:

Table 3.28. Unit Root Test result of all variables with ADF and PP

Variables		Level		First Difference	
		ADF	PP	ADF	PP
GDP	intercept	-0.651377	-0.639915	-5.187206 ***	-5.187710 ***
	Trend and intercept	-1.953873	-2.018168	-5.085330 ***	-5.085468 ***
CC	intercept	-1.288891	-1.336743	-4.763163 ***	-4.763163 ***
	Trend and intercept	-2.167048	-2.267249	-4.656441 ***	-4.656441 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

Two variables, GDP, coal consumption CC are non-stationary or have unit root at their original level series because their probability value (p value) are greater than 0.5% significant level in both of ADF and PP tests. However, the first difference results of two variables show that two variables of Myanmar are stationary or have not unit root in the first difference because their probability values (p values) are less than 0.5% significant level. It means that all of the variables are separately integrated to order 1 of I(1). Based on the unit root test results, both of ADF and PP tests are seen to be first-difference-stationary. The detail results of the unit root test of two variables are shown in Table 3.28.

3.9.3 Lags Length Selection

The number of lags is selected by applying the model selection criteria AIC (Akaike information criterion), SC (Schwartz information criterion), and HQIC (Hannan and Quinn information criterion), which are automatic settings in the EView 10 software package, as follows:

- AIC: Akaike information criterion
- SC: Schwartz information criterion
- HQ: Hannan and Quinn information criterion

The smallest values of AIC, SC, HQ information criterion are the optimum lags. The cointegration test result bases on the number of lags.

Table 3.29. Lag selection for Johansen co-integration test

Lag	LR	FPE	AIC	SC	HQ
0	NA	4.324853	7.140036	7.238207	7.166081
1	81.12293*	0.127104	3.610372	3.904886*	3.688507
2	7.937423	0.117958	3.525947	4.016802	3.656171
3	9.430972	0.096679*	3.304517*	3.991715	3.486831*
4	4.013179	0.107686	3.370305	4.253845	3.604708

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 3.29 shows the lag selection for Johansen cointegration test. Through the result, lag length 3 is the optimum lag because the smallest AIC value, - 3.304517, is selected.

3.9.4 Johansen Cointegration Test Result

The analysis continues with Johansen cointegration test for the data sets of economic growth (GDP) and coal consumption (CC) of Myanmar in the period 1990-2017. We employed the minimum Akaike information criterion (AIC) through the unconstrained VAR estimation to select lag interval for running the Johansen co-integration test. In the result of the lag selection, the study selects the lag interval 3 to test Johansen Cointegration.

Table 3.30. Johansen Cointegration Test Results between GDP and CC

No. of Cointegration	**Eigenvalue**	**Trace Test**			**Maximum Eigenvalue Test**		
		Trace statistic	5% critical value	Prob.	Max. Eigen statistic	5% critical value	Prob.
Null ($r = 0$)	0.445421	15.71939	15.49471	0.0463	15.32820	14.26460	0.0338
$r \leq 1$	0.0149 3	0.391186	3.841466	0.5317	0.391186	3.841466	0.5317

Table 3.30 shows Johansen cointegration test results between economic growth (GDP) and natural gas consumption (NGC) of Myanmar. The results table shows that both of trace statistic value 15.7193 is larger than their 5% critical value 15.4947 and maximum eigenvalue statistic value 15.3282 is also larger than their 5% critical value 14.2646. Moreover, probability values (p values) of both tests 0.0463 and 0.0338 are less than 0.05. Therefore, the null hypothesis of no cointegration (H_0:r=0) can be rejected applying both the trace test and maximum eigenvalue test at 5% significant level. This means that there is long-run relationship between

economic growth (GDP) and natural gas consumption (NGC) for Myanmar in the period 1990-2017. Hence, VAR model cannot be used, and thus, the study continues with Vector Error Correction Model (VECM).

3.9.5 Vector Error Correction Model (VECM)

According to the Johansen cointegration test results, the relationship between economic growth (GDP) and natural gas consumption (NGC) of Myanmar has cointegrated. Thus, the study continues with Vector Error Correction Model (VECM) to determine causal relationship between two variables. The results of this VECM model as follows:

Equation 1

D(LNGDP)=C(1)*(LNGDP(-1)-2.61230116218*LNCC(-1)-2.45949115001)+C(2)*D(LNGDP(-1))+C(3)*D(LNGDP(-2))+ C(4)*D(LNCC(-1))+ C(5)*D(LNCC(-2)) + C(6)

Table 3.31. The coefficient result of coal consumption to GDP

	Coefficient	P Value
C(1)	-0.241413	0.0152
C(2)	-0.389721	0.0262
C(3)	-0.095750	0.5786
C(4)	0.077940	0.0449***
C(5)	0.320976	0.0180***
C(6)	0.399916	0.0056

Table 3.31 shows the coefficient of Myanmar coal consumption to economic growth. According to that table, C(1) coefficient value is negative in sign and p value of C(1) is significant and probability values of coal consumption coefficients of coal consumption C(4) and C(5) are significant. It means that there is long run causality relationship from coal consumption (CC) to economic growth (GDP), when coal consumption increases 1%, economic growth will increase 0.77%, in Myanmar it the period 1990-2017.

In order to check short run causality relationship from coal consumption to economic growth, we continue to run Wald test.

Table 3.32. Wald Test result from CC to GDP Myanmar

Test statistic	Value	df	Probability
F-statistic	1.908186	(2, 19)	0.1757
Chi-square	3.816372	2	0.0483***

Table 3.32 shows the result of Wald Test from coal consumption to economic growth of Myanmar. In this table, the Wald Test result can reject null hypothesis C(4)=C(5)=0 because Chi-square p value 0.0483 is more than 0.05 or not significant. It shows that there is short run causality running from coal consumption CC to economic growth GDP in Myanmar in the period 1990-2017.

Additionally, as coal consumption is dependent variable and the economic growth (GDP) is independent variable, Vector Error Correction Model test result is as the following equation:

Equation 2

D(LNCC)=C(7)*(LNGDP(-1)-2.61230116218*LNCC(-1)-2.45949115001) + C(8)*D(LNGDP(-1)) + C(9)*D(LNGDP(-2)) + C(10)*D(LNCC(-1)) + C(11)*D(LNCC(-2)) + C(12)

Table 3.33. The coefficient result of GDP to coal consumption

	Coefficient	P Value
C(7)	-0.264740	0.0137
C(8)	0.300770	0.0103***
C(9)	0.530275	0.0091***
C(10)	0.712805	0.0145
C(11)	0.442675	0.0497
C(12)	-0.076251	0.5864

Table 3.33 states the coefficient results of economic growth to coal consumption in Myanmar. According to that table, the p value of C(7) is smaller than 0.05 or significant and C(7) coefficient value is negative in sign. Moreover, p values of coefficients of GDP C(8) and C(9) are also less than 5% or significant. It means that there is long run causality from economic growth (GDP) to coal consumption (CC), when economic growth increases 1%, coal consumption will increase 3%, in Myanmar it the period 1990-2017.

In order to check short run relationship causality from economic growth (GDP) to coal consumption (NGC), we continue to run Wald test.

Table 3.34. Wald Test result from GDP to CC of Myanmar

Test statistic	Value	df	Probability
F-statistic	6.596173	(2, 19)	0.0067
Chi-square	13.19235	2	0.0014***

Table 3.34 illustrates the result of Wald Test from economic growth GDP to coal consumption CC of Myanmar. In this table, the Wald Test result can reject to null hypothesis C(8)=C(9)=0 because Chi-square p value 0.0014 is less than 0.05 or significant. It means that there is short run causality running from economic growth (GDP) to coal consumption (CC) in Myanmar in the period 1990-2017.

Consequently, there are long run causality and bidirectional short run causality between economic growth GDP and coal consumption CC in Myanmar in the period 1990-2017.

3.10 Conclusion

This empirical study examined the causality relationship between economic growth GDP, total primary energy consumption, crude oil consumption OC, natural gas consumption NGC, electricity consumption ELC, and coal consumption CC for the Republic of the Union of Myanmar over the period 1990-2017. Time series data of the variables have been analyzed unit root test, Johansen cointegration test, Vector Error Correction Model (VECM) or Vector Autoregression Model (VAR), and Granger Causality Test to evaluate the direction of causality among variables.

According to the unit root test result, all of the variables (GDP, TPEC, OC, NGC, ELC, and CC) have unit root or non-stationary at their original levels, but these are stationary or have not unit root at their first difference levels.

Based on the Johansen cointegration test result, since the relationships between economic growth GDP and total primary energy consumption EC was not cointegrated, the study continued with the Granger causality test which was calculated base on the VAR. The results show that there has long run causality between GDP and EC and bidirectional short run causality relationships between economic growth GDP and total primary energy consumption EC in Myanmar in the period 1990-2017.

Based on the Johansen cointegration test result, since the relationships between economic growth GDP and crude oil consumption OC was not cointegrated, the study continued with the Granger causality test which was calculated base on the VAR. The results show that there has long run causality between GDP and OC and unidirectional short run causality

relationships from economic growth GDP to crude oil consumption OC in Myanmar in the period 1990-2017.

Since, economic growth GDP and natural gas consumption NGC were cointegrated in Johansen cointegration test, the study continued with Wald causality test which was calculated base on the VECM. The result shows that there are long run causaltiy and bidirectional short run causality relationships between economic growth GDP and natural gas consumption NGC in Myanmar in the period 1990-2017.

According to the Johansen cointegration test result, since the relationships between economic growth GDP and crude electricity consumption ELC was not cointegrated. Therfore, the study continued with the Granger causality test which was calculated base on the VAR. The results show that there has no both long run and short run causality between GDP and ELC in Myanmar in the period 1990-2017.

Since, economic growth GDP and coal consumption CC were cointegrated in Johansen cointegration test, the study continued with Granger causality test which was calculated base on the VECM. The result shows that there are long run causaltiy and bidirectional short run cauaslity relationships between economic growth GDP and natural coal consumption CC in Myanmar in the period 1990-2017.

Overall, the study finding of bidirectional Granger causality between economic growth GDP and total primary energy consumption EC, bidirectional Granger causality between economic growth GDP and crude oil consumption OC, unidirection Granger causality from GDP to natural gas consumption NGC, and bidirectional Granger causality between economic growth GDP and coal consumption CC are important implications for policy

analysts and forecasters in Myanmar. The analysis reveals high energy consumption leads to economic growth GDP, though there are many other factors contributing to economic growth, and energy consumption is only one of such factors.

4 Second Essay

What Is The Role of Sectoral Energy Consumption in Economic Growth? The Case of Myanmar.

4.1 Introduction

The transport sector was the fastest-growing sector during 1990–2007, decline in 2008 and continue to grow until 2017. The government initiated economic reform aims to more investment, ease car import tax and change import policy, since 2011 and the share of this sector in the total final energy consumption was 11 percent and the industry sector was 18 percent in 2017 respectively as the industry sector was the second-fastest growing sector over the same period. The residential sector is still major contributor to total final energy consumption since 1990 to 2017. The others, commercial and agriculture sectors contribute to increase since 2014 as consequences of energy supply growth.

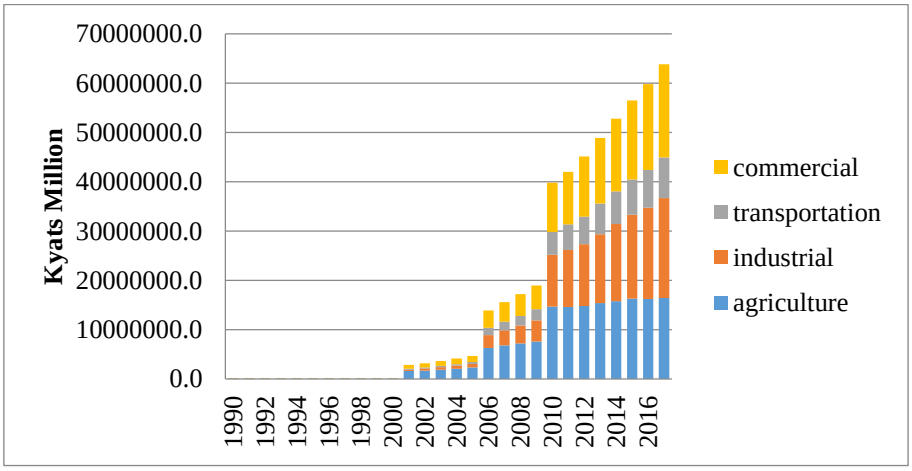


Figure 4.1. Myanmar GDP by sector 1990-2017

(Source: Central Statistical Organization, Myanmar)

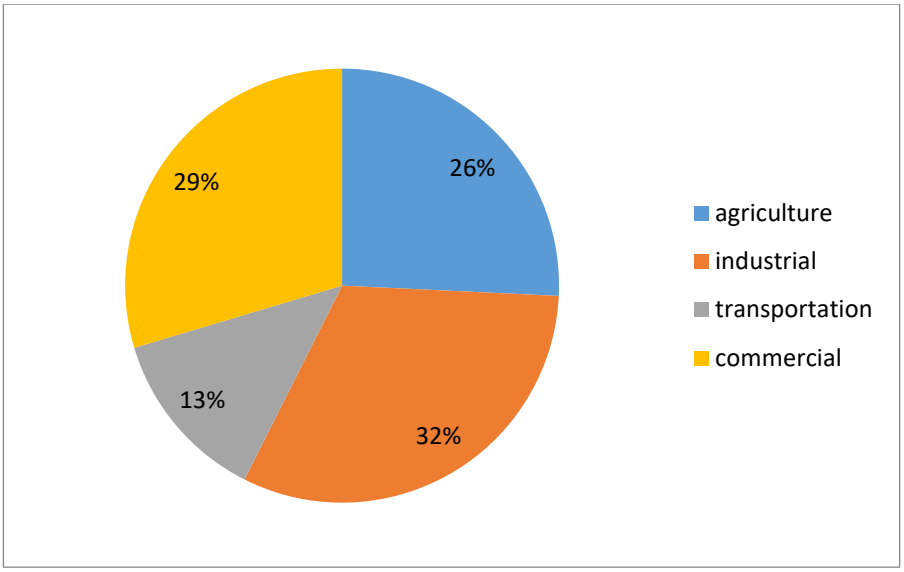


Figure 4.2. Myanmar GDP by sector 1990-2017

(Source: Central Statistical Organization, Myanmar)

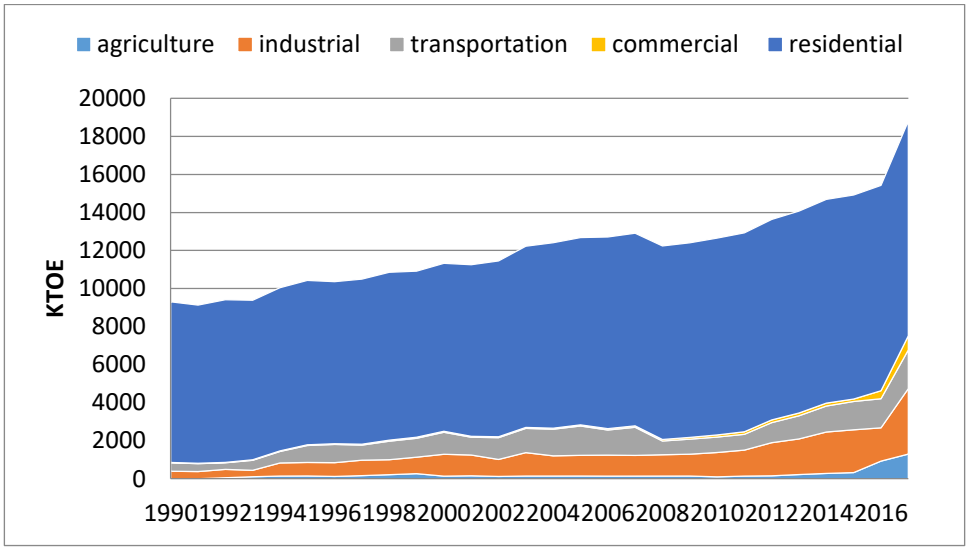


Figure 4.3. Myanmar Total Final Energy Consumption by sector 1990-2017

(Source: Internation Energy Agency IEA)

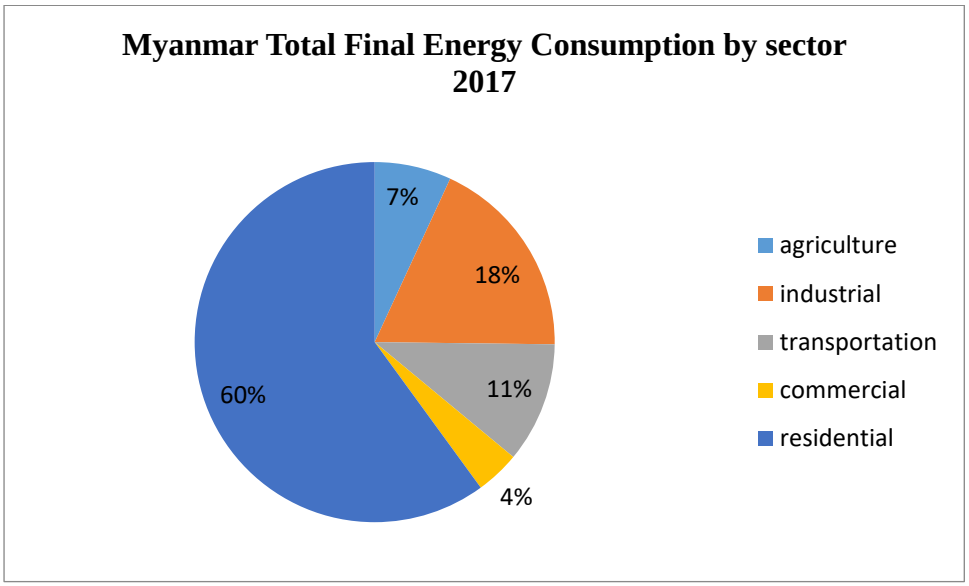


Figure 4.4. Myanmar Total Final Energy Consumption by sector 1990-2017 (Source: Internation Energy Agency IEA)

This study will use a multivariate panel framework in the annual data of the four sectors such as: industrial sector, agricultural sector, commercial and services sector, and transportation sector, from 1990 to 2017 of Myanmar. There are three variables that will be analyzed, which are energy consumption EC, CO2 emission, and economic growth GDP. CO2 emission is the exogenous variable that will be used as a control variable. After that, the study will analysis relationship between economic growth, energy consumption, and CO2 emission of Myanmar by sectoral in the whole country level by using Panel Data Analysis. This research will also effort to observe empirical analysis for energy consumption by sectoral and economic growth relationship including unit root test, panel cointegration test, FMOLS

Test, Granger Causality test to progress the causal relationship between economic growth and energy consumption by fuel type in Myanmar.

The research started with data collection process during 1990 to 2017, where Myanmar economic growth will be described by the Gross Domestic Product (GDP) from Central Statistic Organization (CSO) Myanmar and the data of crude oil consumption, natural gas consumption, electricity consumption and coal consumption will be collected from International Energy Agency (IEA 2018). This research will be analyzed by using EViews software. In this study, GDP is used in Myanmar local currency unit (Kyats million) and energy consumpiton is expressed in terms of Kilo Ton of Oil Equivalent (ktoe). All of the variables are in natural logarithms, which are called LNGDP, LNOC respectively.

4.1.1 Total Primary Energy Consumption and Economic Growth Myanmar

Table 4.1 shows that the dedscriptive statstics of two variables, total primary energy consumption and economic growth of Myanmar in the period 1990-2017.

Table 4.1.Descriptive statistics: GDP and total energy consumption

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
GDP	28	17620930	3870781	22654748	49933.00	63827919
EC	28	12479.54	12439.00	2553.054	9190.000	19792.00

(Unit: Kyats million for GDP, KTOE for EC)

From Table 4.1, maximum and minimum values of GDP are 63827919 and 49933 million Kyats, respectively. The corresponding values for total energy consumtpion are 1979.2 and 9190 ktoe, respectively. The standard deveiation shows less dispersion for energy consumption compared to GDP.

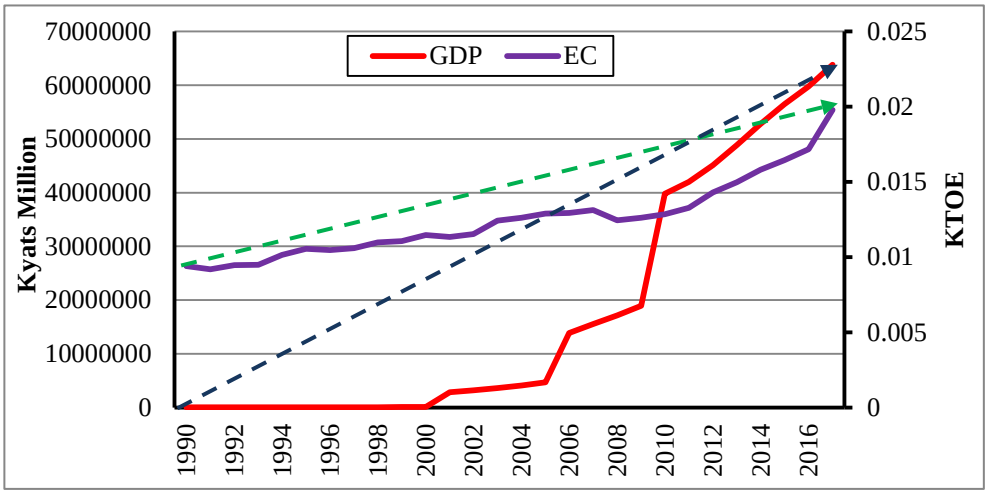


Figure 4.5. GDP and total energy consumption

(Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

Based on Figure 4.5, the high correlation between GDP and total energy consumption (90.5%) is obvious. It notes worthy to be mentioned that the Average Annual Growth Rate (AAGR) of energy consumption (2.7%) is much lower than the AAGR of GDP (29.1%). However, both time series has an upward trend.

4.1.2 Energy Consumption and Economic Growth in Industry Sector of Myanmar

Table 4.2 shows that the dedscriptive statstics of two variables, energy consumption and economic growth in industry sector of Myanmar in the period 1990-2017.

Table 4.2. Descriptive statistics: GDP and energy consumption in industry

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
INDGDP	28	4863069.	543837.5	6851791.	6583.000	20216364
INDEC	28	1178.429	1090.000	670.2492	338.0000	3441.000

(Unit: Kyats million for INDGDP, KTOE for INDEC)

According to Table 4.2, maximum and minimum values of GDP in industry are 20206364 and 6583 million Kyats, respectively. The corresponding values for energy consumtpion in this sector are 3441 and 338 ktoe, respectively. The standard deveiation confirms less dispersion for energy consumupion compared to GDP.

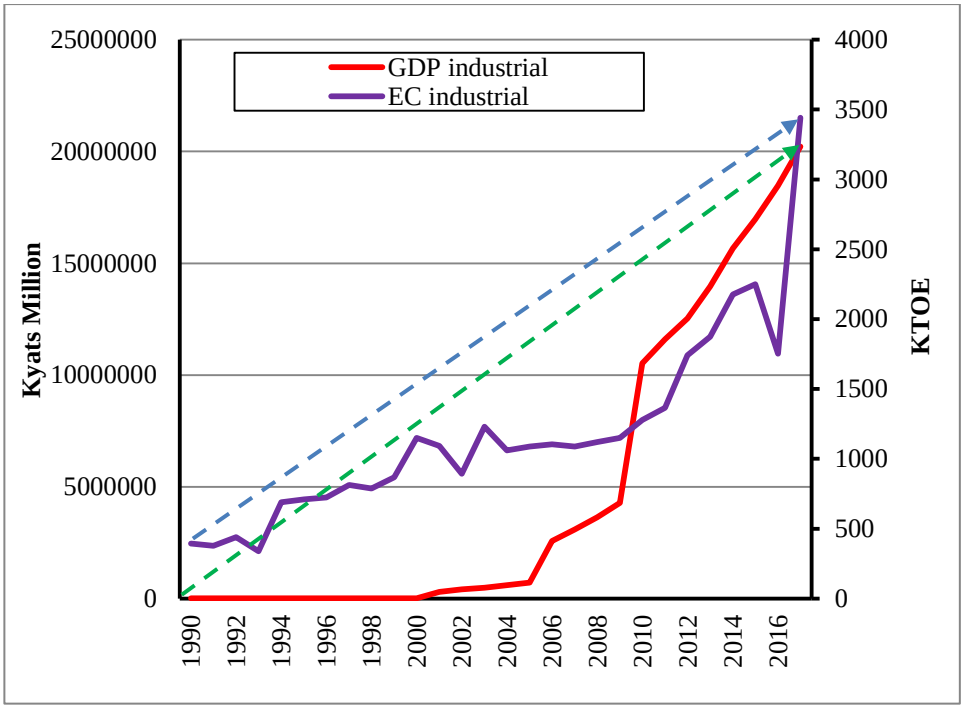


Figure 4.6. GDP and energy consumption in industry, 1990-2017

(Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

As illustrated in Figure 4.6, within studied period, GDP and energy consumption in industry experienced an upward trend. However, AAGR of GDP (33.2%) is greater than energy consumption (8%).

4.1.3 Energy Consumption and Economic Growth in Commercial Sector of Myanmar

Table 4.3 shows that the dedscriptive statstics of two variables, energy consumption and economic growth in commercial sector of Myanmar in the period 1990-2017.

Table 4.3. Descriptive statistics: GDP and energy consumption in commercial

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
COMGDP	28	4830263.	1054581.	6376937.	17749.00	18910717
COMEC	28	105.5000	55.00000	147.3729	17.00000	745.0000

(Unit: Kyats million for COMGDP, KTOE for COMEC)

According to Table 4.3, maximum and minimum values of GDP in commercial are 18910717 and 17749.00 million Kyats, respectively. The corresponding values for energy consumtpion in this sector are 745 and 17 ktoe, respectively. The standard deveiation confirms less dispersion for energy consumupion compared to GDP

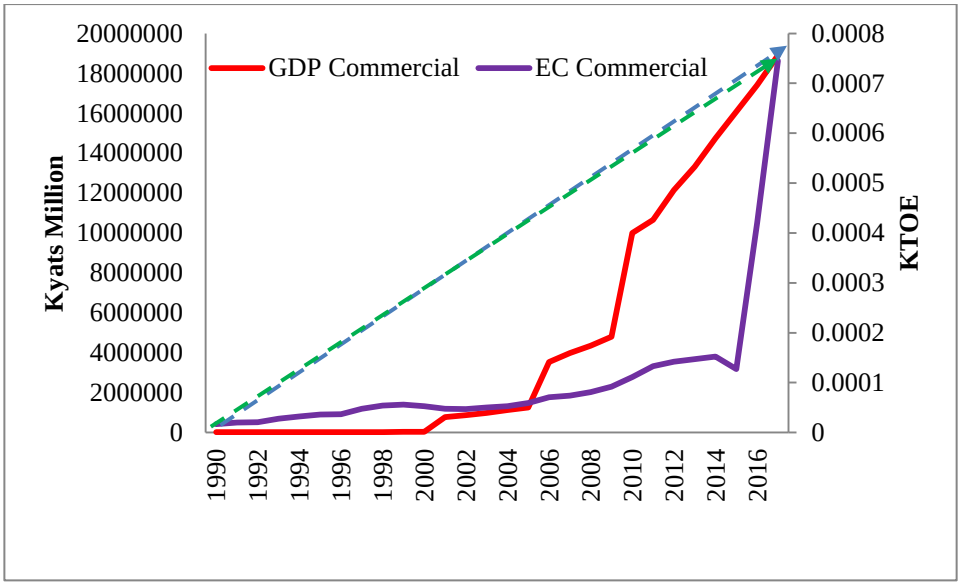


Figure 4.7. GDP and energy consumption in commercial sector, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

As illustrated in Figure 4.7, within studied period, GDP and energy consumption in commercial sector experienced an upward trend. However, AAGR of GDP (28.3%) is greater than energy consumption (14%).

4.1.4 Energy Consumption and Economic Growth in Agricultural Sector of Myanmar

Table 4.4 shows that the dedscriptive statstics of two variables, energy consumption and economic growth in commercial sector of Myanmar in the period 1990-2017.

Table 4.4. Descriptive statistics: GDP and energy consumption in Agricultural Sector

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
AGRIGDP	28	5780701	1984518	6687178	23451.00	16439257
AGRIEC	28	217.071	141.0000	265.68	22.000000	1296.000

(Unit: Kyats million for AGRIGDP, KTOE for AGRIEC)

According to Table 4.4, maximum and minimum values of GDP in agricultural sector are 16439257 and 23451 million Kyats, respectively. The corresponding values for energy consumtpion in this sector are 1296 and 22 ktoe, respectively. The standard deveiation confirms less dispersion for energy consumupion compared to GDP.

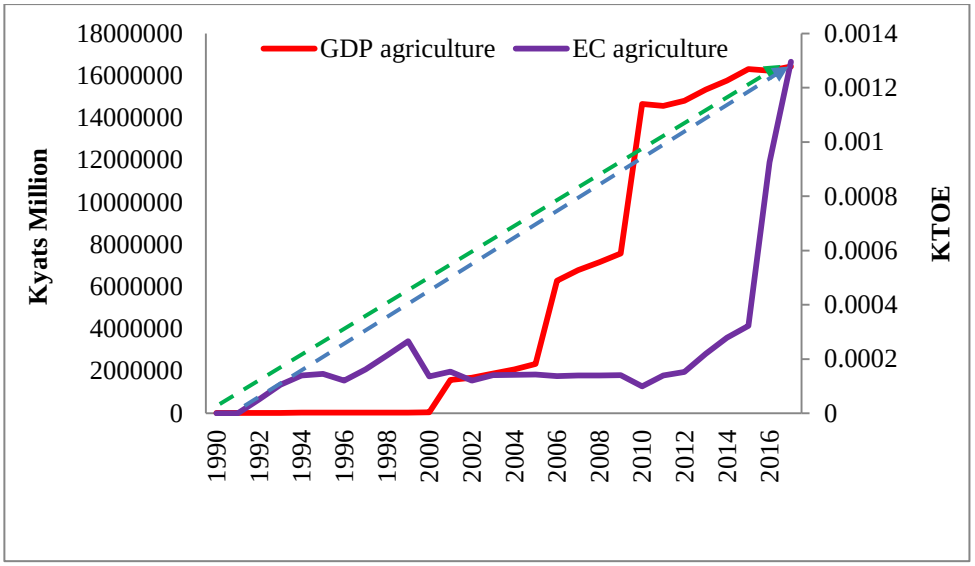


Figure 4.8. GDP and energy consumption in agricultural sector, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

As illustrated in Figure 4.8, within studied period, GDP and energy consumption in agricultural sector experienced an upward trend. However, AAGR of GDP (26.25%) is greater than energy consumption (15.67%).

4.1.5 Energy Consumption and Economic Growth in Transportation Sector of Myanmar

Table 4.5 shows that the dedscriptive statstics of two variables, energy consumption and economic growth in transportation sector of Myanmar in the period 1990-2017.

Table 4.5. Descriptive statistics: GDP and energy consumption in Transportation Sector

Variables	Obs	Mean	Median	Standard deviation	Minimum	Maximum
TRANGDP	28	2146897	287844.5	2888808	1906	8261580.
TRANEC	28	1037.64	983.00	401.408	347	2034.000

(Unit: Kyats million for TRANGDP, KTOE for TRANEC)

According to Table 4.5, maximum and minimum values of GDP in transportation sector are 8261580 and 1906 million Kyats, respectively. The corresponding values for energy consumtpion in this sector are 2034 and 347 ktoe, respectively. The standard deveiation confirms less dispersion for energy consumupion compared to GDP.

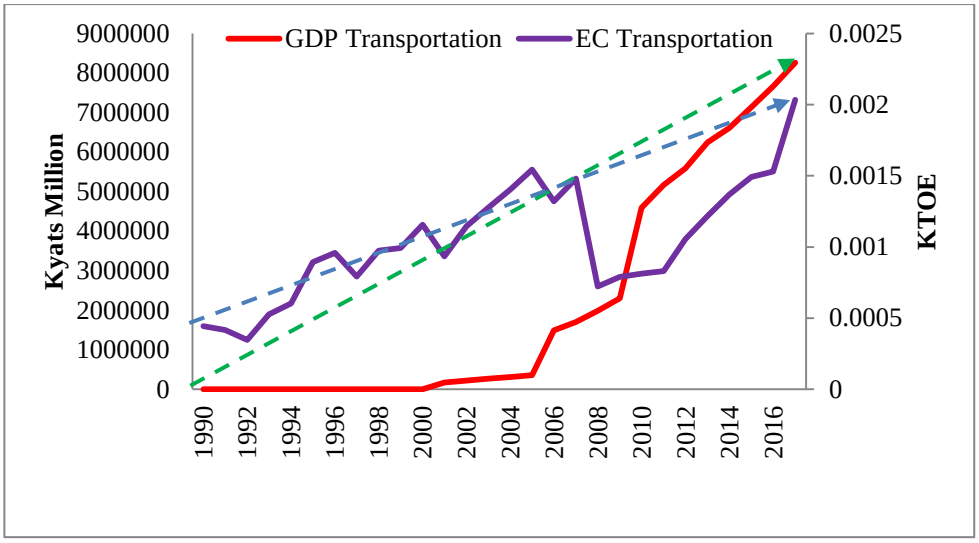


Figure 4.9. GDP and energy consumption in transportation sector, 1990-2017 (Source: GDP data from Central Statistical Organization, Myanmar. Energy Consumption data from International Energy Agency IEA)

As illustrated in Figure 4.9, within studied period, GDP and energy consumption in transportation sector experienced an upward trend. However, AAGR of GDP (34.86%) is greater than energy consumption (5.58%).

4.1.6 Research Objectives

The main objective of this study is to analyze the relationship between energy consumption and economic growth in Myanmar in the sectoral aspects (Industry, Transportation, Commercial and Public Services, Agriculture) and to propose the appropriate policies to the government and policy makers to achieve the goals of sustainable development.

4.1.7 Research Questions

In order to determine research objectives, the study aims to answer the following research questions:

1. What is the relationship between Energy Consumption and Economic Growth by sectors?
2. What policies and strategies are required to be implemented in the energy sector to achieve the goals of sustainable development?

4.2 Literature Reviews

Since the initial study by (Kraft, John kraft 1978) on the U.S. economy, the causal relationship between energy consumption and economic growth has been undertaken for a broad range of countries. An investigation of the energy consumption–growth nexus not only provides insights with respect to the role of energy consumption in economic development, but also provides a basis for discussion of energy and environmental policies.

4.2.1 Energy Consumption and Economic Growth Nexus

The literature has emphasized four possible relationships between energy consumption and economic growth: growth, conservation, neutrality,

and feedback hypotheses. The growth hypothesis suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to labor and capital. The growth hypothesis is confirmed if an increase in energy consumption causes an increase in real GDP whereby the economy is considered energy dependent. In such a scenario, conservation policies which reduce energy consumption may adversely affect real GDP. On the other hand, a number of explanationsmay be set forth if an increase in energy consumption has a negative impact on real GDP. For instance, the situation could be one inwhich a growing economy requires a decreasing amount of energy consumption as production shifts toward less energy intensive service sectors. Moreover, the negative impact of energy consumption on real GDP could be attributed to either excessive energy consumption in unproductive sectors of the economy, capacity constraints, or an inefficient energy supply (Ozcan 2013) (N. Bowden and Payne 2010).

The conservation hypothesis asserts that energy conservation policies designed to reduce energy consumption and waste will not adversely impact real GDP. The conservation hypothesis is supported if an increase in real GDP causes an increase in energy consumption. However, it is possible that a growing economy constrained by political, infrastructural, or mismanagement of resources could generate inefficiencies and the reduction in the demand for goods and services, including energy consumption (N. Bowden and Payne 2010). If such is the case, an increase in economic growth would have an adverse impact on energy consumption. The neutrality hypothesis considers energy consumption to be a small component of overall output and thus have little or no impact on real GDP. Similar to the conservation hypothesis, energy conservation policies would not adversely

impact real GDP. The neutrality hypothesis is supported by the absence of a causal relationship between energy consumption and real GDP. Finally, the feedback hypothesis suggests that energy consumption and real GDP are interrelated and may verywell serve as complements to each other. The feedback hypothesis suggests there is a bidirectional causal relationship between energy consumption and real GDP. If this is the case an energy policy oriented toward improvements in energy consumption efficiency would not adversely affect real GDP.

There are several study related to the causal relationship between crude oil consumption and economic growth in sectroal and regional area. Most of them use panel cointegration test and panel Granger Causality test to analyze the relationship from the available panel data. The study of panel framework has been conducted in Latin America region with the result shows that economic growth and crude oil consumption has not long run relationship in the Caribbean and South America region while the unidirectional causality from crude oil consumption to the economic growth has been found in Central America region (Behmiri and Pires Manso 2014). The result indicates the oil conservation policy should be carefully applied in Central America region. Another study use bootstrap panel causality test to check the nuclear energy consumption, oil consumption and economic growth in G-6 countries (Chu and Chang 2012). The result indicates that the unidirectional causality from economic growth to oil consumption is occurred in the US. The research related to this issue is also conducted in the Sub Saharan Africa region where the result shows that the crude oil consumption will have a significant impact to economic growth both in short run and long run if it is not carefully considered by the policymaker (Bashiri Behmiri and Pires Manso 2013). The other approach is conducted with the Autoregressive

Distributed Lag (ARDL) in the analysis of emerging economy group of Brazil, Russia, India, China, Turkey and South Africa with the result shows all of the country has bidirectional causality between oil consumption and economic growth (Bildirici and Bakirtas 2014).

The causal relationship between oil consumption and economic growth is also exist in individual country analysis. By conducting individual unit root test, cointegration test and granger causality test, the result shows that oil consumption and economic growth in South Korea and Malaysia has a bidirectional causality relationship (Seung Hoon Yoo 2006) (Park and Yoo 2014). The other study in China shows that the economic growth can be used as a reference for oil consumption planning in the long run. The oil consumption is also bringing a massive effect to the economic growth in this country (Herrerias, Joyeux, and Girardin 2013) (Saboori, Rasoulinezhad, and Sung 2017). The unidirectional causality from economic growth to oil consumption has been examined in Ecuador (Jin, Lim, and Yoo 2016). The other approach is conducted with the Autoregressive Distributed Lag (ARDL) in the analysis of Iran with the result shows that there is short run causality from economic growth to oil consumption.

(N. Bowden and Payne 2010) examined the causal relationship between renewable and nonrenewable energy consumption by sector and real Gross Domestic Product (GDP) in the US using annual data from 1949 to 2006 and the results indicate unidirectional causality from residential renewable energy consumption and industrial non-renewable energy consumption, respectively to and real GDP.

4.3 Methodology

This study will develop the causal relationship among the parameter of energy consumption based on the function of economic growth and CO2 emission as follows (equation 1):

$$lnEC = f(lnGDP, lnCO2) \text{ ---------- } (1)$$

The other approach is also being taken to see the impact from the different perspective when the GDP is the function of energy consumption and CO2 emission as follows (equation 2):

$$lnGDP = f(lnEC, lnCO2) \text{ ----------(2)}$$

This study will examine the EC as the energy consumption of each sector in Myanmar in the unit of ktoe. It will be the function of GDP or gross domestic product and CO2 as carbon emission. The data of energy consumption and CO2 emission are being collected from the International Energy Agency Data. The GDP data is obtained from the World Bank Database in the World Development Indicator. All the provided data is available from 1990-2017 and will be converted to the natural logarithm form to reduce the heteroscedasticity of the data.

4.3.1 Panel Unit Root Test

The methodology in this study starts with the panel unit root test. There are several kinds of panel unit root tests, and the Breitung panel unit root test is chosen to be the test in this study. This test purpose is to find the homogeneity in the unit root of time series and cross-section data. There are two hypotheses in this test where the existence of unit root or the data is not stationary is the null hypothesis, and the alternative hypothesis is indicating

the opposite result. The test starts by developing the autoregressive equation as follows:

$$y_{it} = \rho_i y_{it} + X_{it}\delta_i + \varepsilon_{it} \text{ ----------(3)}$$

This shows the panel data, which consists of $i = 1,2, \dots, n$ number of cross-sections and is the time period of the data. X_{it} is the exogenous variable, which may contain fixed-effect or individual trends. ρ_i indicates the coefficient of the autoregressive model and ε_{it} is the error terms. The value ρ_i will inform the result of the stationarity of the data. The data shows weak stationarity if the absolute value of ρ_i less than unity, and if it equals unity, then the information has a unit root. Breitung panel unit root test will consider the persistence parameters that are common across cross-sections and assess ρ_i as similar in the cross-sections data. Furthermore, this test will check the data based on the basic Augmented Dickey-Fuller (ADF) in the equation as follows:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{i=1}^{p_i} \beta_{ij}\, \Delta y_{it-j} + X_{it}^{!}\delta + \varepsilon_{it} \text{ ----------(4)}$$

Breitung test will check the value of α is the result of $\rho - 1$ to find the unit root test of the cross-section with different lag orders ρ_i. The null hypothesis will indicate that $\alpha = 0$, and the alternative hypothesis will show that $\alpha < 0$. Breitung panel unit root test will be applied to the panel data of energy consumption, GDP, and CO2 emission.

4.3.2 Panel Cointegration Test

The analysis will be continued to the panel cointegration test to see the long-run relationship among the panel data series. This study will examine the test by using the Pedroni panel cointegration test that uses

Engle-Grange two-stage cointegration test (Pedroni 1999). The test will look at the heterogeneity in the cross-section of panel data series with intercept and trend coefficients. The equation that will be used to conduct the analysis is as follows:

$$lnEC_{it} = \alpha_1 + \delta_{1t} + \beta_{1t} lnGDP_{it} + \beta_{2i} lnCO2_{it} + \varepsilon_{it} \text{ ----------(5)}$$

The equation will check whether the energy consumption as a dependent variable has a cointegration with the GDP and CO2 emission. The variable t and i represent time series period and cross-section data. α_i and β_i are indicates the intercept and time trend. Pedroni cointegration test is applicable to the stationary panel data, which means that the variable in the equation shall be in I (1). There will be two ways to check the Pedroni cointegration test by panel statistics test and group statistics test. Panel statistic test will look within the dimension test, including four approaches, which are panel v, panel ρ, panel $\rho\rho$, and panel ADF-statistics. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country in the panel. All seven tests are distributed asymptotically as standard normal. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegrationThese tests will collect the residual of the regression and check the homogeneity of the cross-sections in the panel data. On the other hand, Group statistics will look heterogeneity across the cross-sections by collecting the residual of the regression between the dimension of the panel data. If the series has a cointegration relationship, then the analysis will be continued with the Fully Modified OLS (FMOLS) to see the long-run

elasticity among the series in the panel data (Pedroni 2000). The equation that will be used in both analysis is described as follows:

$$lnEC_{it} = \alpha_{1i} + \delta_{1i}t + \beta_{11i}lnGDP_{it} + \beta_{12i}lnCO2_{it} + \varepsilon_{it}^{lnEC} \quad \text{----(6)}$$

$$lnGDP_{it} = \alpha_{2i} + \delta_{2i}t + \beta_{21i}lnEC_{it} + \beta_{22i}lnCO2_{it} + \varepsilon_{it}^{lnGDP} \quad \text{---(7)}$$

4.3.3 Panel Granger Causality

The cointegration test will show the existence of a causal relationship among the variables, but the direction of the relationship could not be explained. It is indicating there is at least one direction of causal relationship from an independent variable to the dependent variable. The analysis shall proceed to the panel Granger causality test to check the direction of each causal relationship. This test will be based on the Engle-Granger two-stage method. The Vector Error Correction Model will be used to see how the cointegrated variables can have a long-run relationship (Xiong and Wu 2008) (Zheng and Luo 2013). In the beginning, the panel FMOLS method will be conducted to check the error correction terms (ECT) of the model. ECT is a deviation of the observed values in $t-1$ the long-run equilibrium relationship. The analysis continued with the lagged ECT will be put into the VECM model to generate the dynamic error correction models in the equation as follows:

$$\Delta lnEC_{it} = \alpha_{1j} + \sum_{m=1}^{n} \theta_{11im}\, \Delta lnEC_{it-m} + \sum_{m=1}^{n} \theta_{12im}\, \Delta lnGDP_{it-m} + \sum_{m=1}^{n} \theta_{11im}\, \Delta lnCO2_{it-m} + \gamma_{1i}ECT_{it-1}^{lnEC} + u_{it} \quad \text{----------(8)}$$

$$\Delta lnGDP_{it} = \alpha_{2j} + \sum_{m=1}^{n} \theta_{21im}\, \Delta lnGDP_{it-m} + \sum_{m=1}^{n} \theta_{22im}\, \Delta lnEC_{it-m} + \sum_{m=1}^{n} \theta_{21im}\, \Delta lnCO2_{it-m} + \gamma_{2i}ECT_{it-1}^{lnGDP} + u_{it} \quad \text{----------(9)}$$

The indicates the first differences in the time series data while suggests the length of the lag. The appropriate length of the lag will be obtained from the step-down procedure. ECT result will generate long-run relationship in equation 6-7. The t-statistics of ECT will decide whether the null hypothesis in the equation 8-9 is accepted.

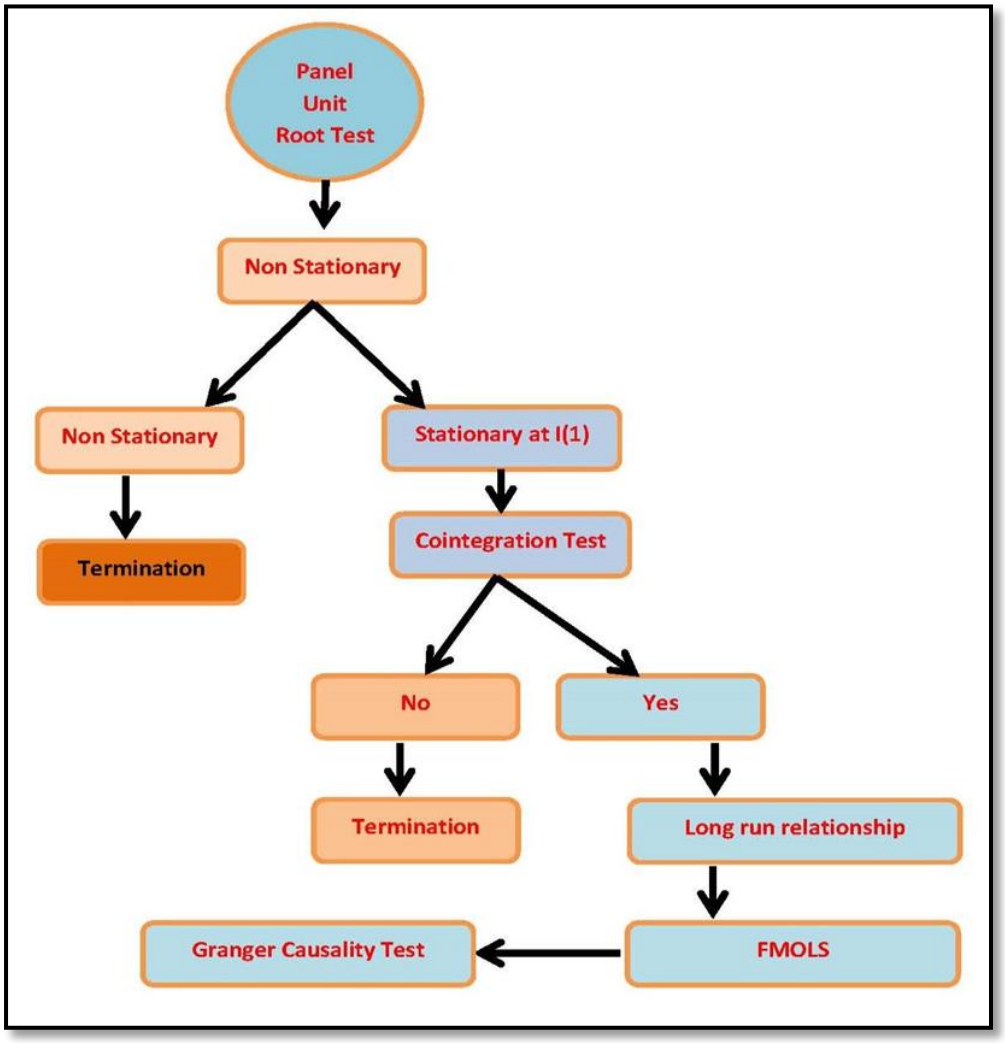


Figure 4.10. Panel Data Analysis Framework

4.4 Empirical results

4.4.1 Unit Root Test Result

The result of the panel unit root test shows that the energy consumption, economic growth, and CO2 emission in the panel data set is non-stationary or have a unit root in levels. However, the first difference of the unit root test shows that all of the datas is stationary or has no the unit root. The detail results of the panel unit root test indicate in Table 4.6.

Table 4.6. The Unit Root test in ADF and PP

Variables		Level		First Difference	
		ADF	PP	ADF	PP
LNGDP	intercept	2.38446	2.00080	53.3594 ***	95.9147 ***
	Trend and intercept	5.30606	6.54979	-5.085330 ***	35.5294 ***
LNEC	intercept	3.47013	3.13472	48.4198 ***	122.816 ***
	Trend and intercept	7.01123	16.0502	33.5488 ***	111.238 ***
LNCO2	intercept	23.7154	41.3579	89.8306 ***	145.838 ***
	Trend and intercept	27.0769	42.3897	69.9204 ***	393.014 ***

Notes: The lag lengths are selected by using Akaike Information Criterion (AIC), the number in parentheses are p value, *,**,*** mean that null hypothesis of no causality is rejected at the 10%, 5%, 1% confidence respectively.

4.4.2 Panel Cointegration Test Results

Furthermore, this study conducts the cointegration test on energy consumption and economic growth with the CO2 emission as control variable with intercept and no trend to the available panel data.

The test result shows that there is nine statistics parameter out of eleven statistics has rejected the null hypothesis in 1% significance level which means that there is cointegration among the panel data Table 4.7.

Table 4.7. Panel Cointegration Test

	Statistic	Prob.	Weighted Statistics	Prob
Within Dimension				
Panel v-statistic	2.523560*	0.0058	2.562433*	0.0052
Panel rho-statistic	-1.597716	0.0551	-2.041908*	0.0206
Panel pp-statistic	-2.351332*	0.0094	-2.869641*	0.0021
Panel ADF-statistic	-2.222995*	0.0131	-2.800303*	0.0026
Between Dimension				
Group rho-statistic	-1.118784	0.1316		
Group pp-statistic	-2.805506*	0.0025		
Group ADF-statistic	-2.636292*	0.0042		

Lag length selection is based on the Akaike Information Criterion
BU indicate the Breitung panel unit root test method
* indicates 1% significance level

According to the panel cointegration test results, there are cointegration among the panel data, economic growth, energy consumption, and CO2 emission in each group shch as; the whole country, high economic group, low economic group, high energy consumption group, and low energy consumption group of Myanmar in the period 1990-2017.

4.4.3 FMOLS Test Results

According to the panel cointegration test results, the relationship between economic growth (GDP) and energy consumption (EC), and CO2 emission in Myanmar by sector. Thus, the study continues with the Fully Modified Ordinary Lest Square (FMOLS) to find the long run elasticity among the series in the panel data.

The analysis of FMOLS indicates the elasticity of the causal relationship among energy consumption, GDP, and CO2 emission by sector for the whole country as energy consumption EC is the dependent variable, GDP is the independent variable and CO2 emission is the control variable which the result is shown in Table 4.8.

Table 4.8. Panel FMOLS long run estimates for Myanmar by sector

Dependent variable	Independent variables	Coefficient	Prob.
LNEC	LNGDP	0.117434	0.0000
	LNCO2	3.845479	0.0000
LNGDP	LNEC	5.509250	0.0000
	LNCO2	7.98046	0.0000

The result shows that the GDP has a positive long-run impact on energy consumption at a 1% significance level and CO2 emission as well because the p values are smaller than 0.05 or significant. It means that the energy consumption EC will increase by 0.12% if GDP increases by 1%. Similarly, the energy consumption will increase by 3.8% if CO2 emission rise 1%. It means that energy consumption is elastic to both of the GDP and CO2 emission.

Fathermore, the FMOLS result with the GDP as the dependent variable and EC as the independent variable. The result shows that the energy consumption EC also has a positive long run impact on economic growth GDP at a 1% significant level, CO2 emission as well because the p values of two independent variables are significant. As the results, when energy consumption EC increases by 1%, economic growth GDP will grow up 5.51%. However, if CO2 emission increase 1%, the GDP will increase 7%. It means that the GDP is elastic to both of the EC and CO2 emission.

All the coefficients are positive and statistically significant at the 1% significance level and given the variables are expressed in natural logarithms, the coefficients can be interpreted as elasticities.

4.4.4 Panel Granger Causality Test Result

According to the results, given the variables are cointegrated, a panel vector error correction model is estimated to perform Granger-causality tests to see the direction of the causal relationship among the variables in the panel data. The result of the whole country group indicates, as shown in Table 4.9.

Table 4.9. Panel causality test results

Dependent Variable	Sources of causation (Independent variables)			
	Short-run			Long-run
	LNGDP	LNEC	LNCO2	ECT
LNGDP	-	1.621(0.091) ***	0.595(0.062) ***	-0.0442 ***
LNEC	1.192(0.027) ***	-	2.797(0.264) ***	-0.356 ***
LNCO2	0.063	0.074	-	-0.018 ***

Table 4.9 the results of the short-run and long-run Grangercausality tests show that the energy consumption and CO2 emission have a positive and statistically significant impact in the short-run on economic growth GDP. An examination of the sum of the lagged coefficients on the respective variables indicates that energy consumption (0.091) has a greater impact on GDP than CO2 emission (0.062) which reiterates the importance of energy in the economic growth process. Moreover, the error correction term is statistically significant at the 1% level also denoting a relative slow speed of adjustment to long-run equilibrium.

Similarly, the GDP and CO2 emission have a positive and statistically significant impact in the short-run on energy consumption. Moreover, the error correction term is statistically significant at the 1% level also denoting a relative slow speed of adjustment to long-run equilibrium.

4.5 Conclusion

In order to draw effective energy and environmental policies, policymakers need to understand well the relationship between energy consumption and economic growth. This study employs a panel data set for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017 to explore the causal relationship between energy consumption and economic growth taking into account other factors as CO2 emission.

Pedroni heterogeneous panel cointegration test reveals there is a long-run equilibrium relationship between economic growth (GDP), energy consumption, and CO2 emission. This long-run relationship suggests that a 1% increase in energy consumption increases GDP by 5.51%; a 1% increase in CO2 emission increases GDP by 7%. Furthermore, the estimation of a

panel vector error correction model indicates the presence of both short-run and long-run Granger-causality from energy consumption to economic growth lending support for the growth hypothesis. The positive impact of energy consumption on economic growth suggests that energy consumption plays an important role in the economic growth both directly and indirectly as a complement to CO2 emission for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017.

Similarly, the GDP has a positive long-run impact on energy consumption at a 1% significance level and CO2 emission as well. The energy consumption EC will increase by 0.12% if GDP increases by 1%. Furthermore, the estimation of a panel vector error correction model indicates the presence of both short-run and long-run Granger-causality from economic growth to energy consumption lending support for the growth hypothesis. The positive impact of economic growth on energy consumption suggests that the economic growth plays an important role in energy consumption both directly and indirectly as a complement to CO2 emission for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017.

5 Third Essay

What Is The Most Appropriate Energy Combination In Myanmar: A Multi-criteria Approch

5.1 Introduction

As stated before section, the Republic of the Union of Myanmar has attained significantly economic growth. According to the ASEAN statistical year book 2018, Myanmar gross domestic product (GDP) growth rate was 7% since 2010 to 2017. This growth rate was the third-highest economic growth rate among the ASEAN member countries. Myanmar real GDP per capital was 1,229 USD in 2017. Myanmar will require a lot of energy supply to contribute its economic development. Myanmar energy demand has increased with a significant portion of the shares is coming from the consumption of fossil fuels such as; crude oil, natural gas, coal, electricity consumption. These types of energy availability are essential in Myanmar to contribute several productive sectors such as industrial, transportation, commercial and services sectors as well as residential sector.

High economic growth also brings a new risk that crude oil, natural gas, electricity, coal availability might not be able to fulfill the growing demand. Myanmar, ASEAN member state, will require a lot of crude oil from the other area through import activity. It will also create an environmental issue with the increase of energy-related emissions and may cause a problem to public health. The transportation sector has a dominant effect on crude oil consumption compare with the building and industrial sectors. Myanmar has increased energy consumption from 9.400 ktoe in 1990 to 19,000 ktoe in 2017. It can be seen that energy consumption has

been increased 2 times in 27 years. Myanmar energy consumption (ktoe) by type from 1990 to 2017. Among five types of energy, coal, oil product, natural gas, electricity and biofuel and waste, biofuel takes large portion of the Myanmar energy consumption. Myanmar energy consumption has increased oil products from 400 ktoe in 1990 to 6600 ktoe in 2017. Similarly, although electricity consumption, natural gas consumption and coal consumption have been promoted, there are no significant increases in total energy consumption of Myanmar. The average energy consumption growth rate of the total final energy consumption (TFEC) of Myanmar increased around 3.8% from 2010 to 2017. Unfortunately, biofuels and waste take large portion of the Myanmar energy consumption. At that time, oil products grew the fastest at a rate of 15.8% pre year and electricity, natural gas, coal consumption have been increased but not significant.

The current major challenges in Myanmar's energy sector, and also future energy scenario, as the starting base for policy improvement in order to establish a proper energy planning system. It was proposed that the participation of Myanmar's energy experts in this study would be the key factor in collecting different perspectives in determining the criteria and factors that should be taken into account for energy planning in Myanmar.

Even though the fact that Myanmar is endowed with abundant energy resources, but this country is still not able to cope with the issue of electricity shortage, long term contract issues and high dependence on energy imports. The absence of comprehensive decision-making process in Myanmar's energy planning system makes the energy sustainability concept as the idea that is difficult to be realized by the Government.

Based on the above energy situations, this research wants to consider that how to fulfill increasing energy consumption and to prioritiize energy resources to be evaluabed in the sustainable energy mix in Myanmar by using Analytical Hierarchy Process (AHP) method.

5.1.1 Research Objectives

The main objective of this study is to prioritiize energy resources to be evaluabed in the sustainable energy mix in Myanmar. In order to fulfil this objective, this study analyzes experts' opinions on four energy sources from a multi-dimensional point of view. It also determines the importance of the criteria and sub-criteria to be taken into account in the decision making process for the future energy mix in Myanmar.

5.1.2 Research Questions

In order to determine in the future energy mix of Myanmar from a multi-dimensional point of view, the study aims to answer the following research questions:

1 Which energy resources are more preferable to be adopted for future Energy Mix?

2 Which criteria and sub-criteria should be paid more attention to, in the decision making process for choosing energy resources for energy mix?

5.1.3 Resources Potential in Myanmar

Oil and Natural Gas

At inland regions of Myanmar, crude oil and natural gas can be found from mature and immature sedimentary rocks transportation that are occurred the potential oil and gas resources as like as sedimentary basins. Among these basins, Central Myanmar, Pyay and Ayeyarwaddy Delta, Bago Yoma and Chindwin sedimentary basins are exploring, drilling and producing and the other basins have a potential situation to be produced commercially and there have also restricted to get seismic data detail.

Ministry of Electricity and Energy are cooperating with international oil and gas companies to explore, drill and produce oil and gas at the potential reservoirs of Rakhine, Moattama and Tanitharyi offshore sedimentary basins. Estimated of useable oil and gas amount at offshore and onshore regions of Myanmar are as follow;

Table 5.1. Myanmar Oil and Gas resources

Resource		**Reserve**
Crude Oil	Onshore	102 mmbbl (proven)
	Offshore	43 mmbbl (proven)
Natural Gas	Onshore	5.6 TCF (proven)
	Offshore	11 TCF (proven)

(Source: Myanmar National Energy Policy)

Coal

Coal has mainly found in Ayeyarwaddy, Chindwin sedimentary basin and south regions of Myanmar. Seismic data acquisitions were carried out at Sagaing, Magway, Tanintharyi district and Shan state since 1965. Various kinds of coal in Myanmar are Lignite and Sub-bituminous.

Figure 5.1. Myanmar Coal Resource Potential

(Source: Myanmar National Energy Policy)

Renewable

According to Geographical indication, Myanmar has plenty resources renewable energy such as solar energy, wind energy, geothermal energy, biomass and biofuel energy. Especially, the resources of hydroelectric power and biofuel energy can get easily more and produce as follow;

Hydropower:

According to geological situation of Myanmar, the World Bank estimated to produce electrical power (10,8000 MW) from the resources of hydropower at 1995. Ministry of Electricity has also estimated to produce electrical power (46,100 MW) from those sources of hydropower by 92 projects.

Solar Energy:

The sun light can get all the whole year according to Myanmar geological indication. As the need of renewable energy in Mekong regions New Energy and Industrial Development Organization (NEDO) of Japan at 1997 estimated to produce solar potential to be (51,973 TWh) per year about the amount of solar energy in Myanmar.

Wind Energy:

The coastline of Myanmar is about 2,832 km long, and nine months are Southwest Monsoon in a year and the wind blows from the Northeast for three months in a year. There are estimated to get wind energy (365.1 TWh) per year at Myanmar according to the research of New Energy and Industrial Development Organization (NEDO) of Japan at 1997.

Geothermal Energy:

A total of 93 hot springs (geyser), the sources of geothermal energy, have recorded in Myanmar. Among those geysers, 43 geysers were initiated to assess by the cooperation of Myanma Oil and Gas Enterprise, Myanmar Electric Power Company, Electric Power Development of Japan, Union Oil Company of California and Caithness Resourses of American at 1986 but there is needed to assess more detail.

Tidal Energy:

Ayeyarwaddy Region, Thanintharyi Region, Yangon Region and Rakhine State are closing with the ocean and have rotary tidal currents. So, there have plenty to produce tidal energy from natural situations as like as inland waterways but it is needed to scope detail for the whole country.

Biomass & Biofuels Energy:

According to Forest Resources Assessment 2010 the total forest area had (33.1 million hectares) at 2016 in Myanmar. As average forest cover had (48.8%) in Myanmar traditional energy sources such as fire wood, coal, agricultural waste disposal and animal waste disposal can use plenty. These are the good situations to produce biomass and biofuels energy widely.

Table 5.2. Myanmar Renewable Energy Resources Potential

Resource	**Reserve**
Hydropower	> 100 GW (estimate)
Solar	365 TWh/year
Wind	52,000 TWh/year

(Source: Myanmar National Energy Policy)

5.2 Literature Reviews

5.2.1 Multi-Criteria Decision Analysis

Presently, multi-criteria decision analysis has been applied in complicate problems by decision makers, due to the flexiblity of such techniques to find answers to the problems of energy industry (Diaz-Balteiro, González-Pachón, and Romero 2017). The multi-criteria decision analysis has been applied in various studies with different goal and objective, such as a multi-criteria decision making approach for the urban renewal in Southern India (Manupati, Ramkumar, and Samanta 2018), multi expert and multi criteria evaluation of sectoral investments forsustainable developmet (Suganthi 2018), developing a sustainable smart city framework for developing economies in Indian (Yadav et al. 2019), holistic model to analyze and prioritize urban sustainable buildings forpublic services (Pardo-Bosch, Aguado, and Pino 2019), Off-Grid Solar PV Power Generation System in Sindh, Pakistan: A Techno-Economic Feasibility Analysis (Xu et al. 2019). Therefore, the multi-criteria decisoin analysis methods are applied as important for solving any complex decision problems. It is very difficult for decision-makers to decide on any multi-faceted decision problem because the numerous nature of uncertainties arises while analyzing the problem. These uncertainties are not only economic and technical but also social and environmental (Kassem et al. 2016) (Brand and Missaoui 2014). Thus, the multi-criteria decisoin analysis methods are significant for assessing the energy sector and choosing the optimal energy alternative. While MCDM tools have been a widely used analytics method since the energy policy and planning problems are very complicated.

There are several multi-criteria decision analysis methods, however, commonly used methodologies are Analytical Hierarchy Process (AHP), Goal Programming, Multi-Attribute Global Inference of Quality (MAGIQ), Simple Multi-Attribute Rating Technique (SMART), etc (Daim et al. 2009)(Kumar et al. 2017a)(Wang et al. 2009). This research applies Analytical Hierarchy Process (AHP) for allocating energy resources for evaluating of sustainable future energy mix in Myanmar.

5.2.2 Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a decision-making tool to answer complex problems. In AHP a hierarchy is preformed in which the problem to solve is located at the top and at the bottom are the solution alternatives. At the intermediat levels are the criteria and sub-criteria that are the basis of decision-making (Saaty 2007). In the AHP method, a hierarchy tree is founded and the objective or goal to solve is located at the top of the tree and the solution alternatives are settled at the base of the hierarchy. The criteria are remained at the intermediate leves of the hierarchy, between the goal at the top and the alternatives at the bottom (Saaty 2012). The AHP method has also been extensively used in the energy sector to formulate energy policy, select suitable power plants, select plant location, allocate energy resource, control greenhouse gas emissions, and to develop energy management systems (Amer and Daim 2011).

Similarly, the AHP method has been widely applied for the selection of the best-suited energy mix to be applied for energy resources allocation. (Malkawi, Al-Nimr, and Azizi 2017a) used AHP method for evaluating and ranking of Oil, Natural Gas, Renewable were allocated in the energy mix for Jordan and the results indicated that conventional fuels remain Jordan’s most

feasible options from a technical and financial perspective. (Ghimire and Kim 2018) applied AHP for identify the barriers, social, policy and political, technical, economic, administrative, and geographic, to developing renewable energy from the Nepalese perspective and to rank them. The results of that study showed that the two most important barrier categories are economic and policy and political. In addition, political instability and transportation problems are ranked first and second in overall barriers.

(Solangi et al. 2019) found wind energy as the most feasible RE resource for electricity generation followed by hydropower, solar, biomass, and geothermal energy by using Fuzzy AHP method and the results of this study revealed wind energy as the most feasible RE resource for electricity generation followed by hydropower, solar, biomass, and geothermal energy in Pakistan. (Daniel et al. 2010) used AHP method to identify and rank the renewable energy sources like solar, wind and biomass in India. The results showed the order of merit as Wind energy (0.501), Biomass energy (0.288), and Solar energy (0.2056) with respect to Indian policies and conditions to meet the future energy demand.

(Abdullah and Najib 2016) established a preference in the sustainable energy planning decision-making problem in Malaysia by using intuitionistic fuzzy analytic hierarchy process (IF-AHP) and the result showed that Nuclear energy has been decided as the best alternative in energy planning which provides the highest weight among all the seven alternatives. (Ishizaka, Siraj, and Nemery 2016) analysised to help policy makers in better understanding of the energy mix for United Kingdom.

(Chanchawee and Usapein 2018) analysised to prioritize renewable energy types as a guideline for targeting Thailand’s power generation plan

using an analytical hierarchy process (AHP). The results showed that solar energy had the highest ranking score, followed by biomass, small hydropower, biogas from wastewater/solid waste, wind energy, biogas from energy crops, and waste to energy.

(Heo, Kim, and Cho 2012) evaluated six hydrogen-producing methods using a fuzzy analytic hierarchy process (AHP) under benefits, opportunities, costs, and risks concepts. The results showed that achieving economic feasibility and lowering risks are very important. Therefore, considering stable natural gas prices and unconventional gas production, steam methane reforming is a promising option for hydrogen production. (Heo, Kim, and Boo 2010) established the criteria and factors and assessed the importance of each factor using the fuzzy analytical hierarchy process (AHP) method. The weights estimation results showed that four major conclusions regarding the importance of economic feasibility, the advancement of the target technology in the global market, the disagreement between the policy maker and the specialist group, and the application of the results.

(Zaw 2019) ranked five generation technologies; hydropower, natural gas, coal, solar and wind technologies from economic, technical, environmental and socio-political aspects for Myanmar by using AHP. The results showed that the best option for electricity generation in Myanmar is natural gas, followed by coal, hydropower, solar and wind technologies. (Code, n.d.) Zune Zune Htet applyed AHP to study analyzes the factors that caused major impacts and challenges for oil and gas development among five criteria (economic, social, technology, and environmental aspects) and 12 sub-criteria. The results showed that income tax, royalty, and cost recovery

are the first priority in the Oil and Gas Planning Department for the development of the oil and gas sector in Myanmar.

(Hpyo 2019) examined the assessments of energy planning among the renewable energy, natural gas and nuclear in Myanmar using AHP with four main criteria: Technological, Economic, Environmental and socio-political criteria, and 14 sub-criteria. The paper found that economic criteria is the first ranking and technological criteria is second with slight differences in Natural Gas energy and socio-political and environmental criteria is low ranking.

In summary, the literature review reveals that AHP has been widely used to identify the preferences of energy resources to be sustainable energy mix. However, no previous study has been undertaken to analyze energy mix in the case of Myanmar. The present study will be the first to undertake such an analysis and thus is well suited to provide meaningful contributions to energy planning in Myanmar.

5.3 Methodology

5.3.1 Multi-Criteria Decision Analysis

Presently, multi-criteria decision analysis has been applied in complicate problems by decision makers, due to the flexiblity of such techniques to find answers to the problems of energy industry (Diaz-Balteiro, González-Pachón, and Romero 2017). There are several multi-criteria decision analysis methods, however, commonly used methodologies are Analytical Hierarchy Process (AHP), Goal Programming, Multi-Attribute Global Inference of Quality (MAGIQ), Simple Multi-Attribute Rating Technique (SMART), etc (Daim et al. 2009)(Kumar et al. 2017a)(Wang et

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5.3.3 Steps of AHP

One of the characteristics of the AHP is that for the case of a comparison matix of $n \times n$, $\frac{n(n-1)}{2}$, judgments can be omitted. If the element a_{ij} of the matrix is known, a priori would be known of the element a_{ji}. There is a structured process of sucessfully using AHP in decision-making, which can be constructed in the following steps:

5.3.4 Step 1:Problem hierarchy

The objective or goal is located at the top of the hierarchy and at the second level are the criteria, which can be divided into sub-criteria according to the level of detail needed. Then, the alternatives are located at the bottom

of the hierarchy to satisfy the final decision. The Figure 5.2 shows example of an AHP hierarchy model with goal, criteria, sub-criteria and alternatives.

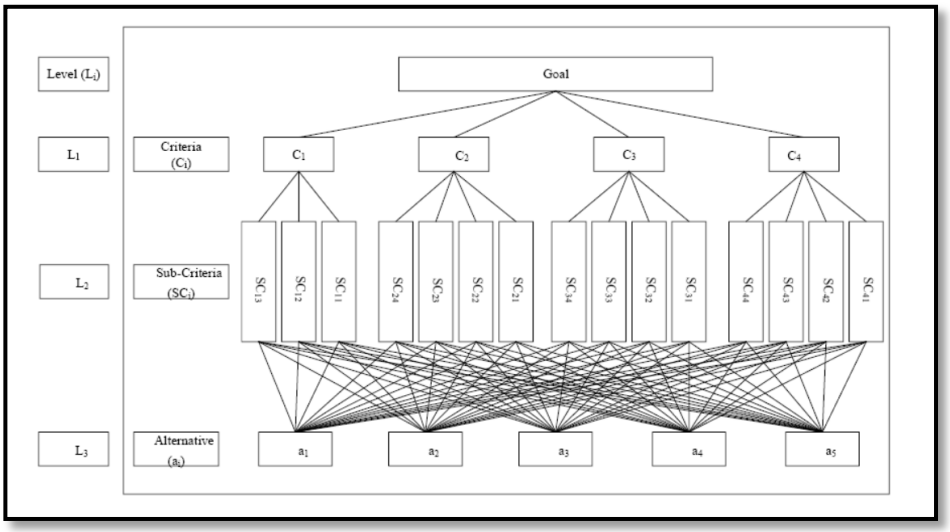

Figure 5.2. AHP hierarchy model with Goal, Criteria, Sub-Criteria and Alternatives

5.3.5 Step 2: Set priorities for criteria

A numerical value must be defined to all criteria according to the preferneces of the decision maker. The number of pairwise comparison is expressed in accordance with the total criteria n, based on the following formula (Saaty,1980).

$$\binom{n}{2} = \frac{n!}{2!(n-2)!} = \frac{n(n-2)}{2} = \frac{n^{2-n}}{2} \quad \text{----------(1)}$$

To make the pairwise comparisons, there was need to provide numerical judgment scale. In Saaty 1980 the scale presented in Table 5.3 was introduced, and its effectiveness has been validated by numerous researchers with a theorectical support related to the best scale to compare homogeneous elements. For the comparison stage, using the odd number from 1 to 9 scale is the best way for the AHP analysis. To make the matric form for the pairwise comparison, Criteria i and criteria j will be compare as A_{ij}, $i, j = 1,2, \dots, n$.

$A_{ij} = 1$ for i=j and i more than j

$A_{ij} = \frac{1}{A_{ij}}$ for i≠j, i less than j

Table 5.3. Pair-Wise comprison.

Numerical rating	**Definition**
1	i is equally important to j
3	i is slightly more important than j
5	i is strongly more important than j
7	i is very strongly more important than j
9	i is extremely more important than j
2,4,6,8	Intermediate
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.

With the scale introduced by Saaty, the decision maker must conduct the paired comparison, set priorities, and assign relative weights. A matrix A of paired comparisons must be developed where the terms $a_{ji}(W_i/W_j)$ are the result of the comparison between the elements i and j.

$$A = \left[\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & & a_{2n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}\right] \text{----------(2)}$$

$$(W_i/W_j)n \times n = A \text{ ----------(3)}$$

$$A = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & & W_2/W_n \\ \vdots & & \ddots & \vdots \\ W_n/W_1 & W_n/W_2 & \cdots & W_n/W_n \end{bmatrix} \text{----------(4)}$$

$$AW = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & & W_2/W_n \\ \vdots & & \ddots & \vdots \\ W_n/W_1 & W_n/W_2 & \cdots & W_n/W_n \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ \vdots \\ n \end{bmatrix} = \begin{bmatrix} \lambda_{max} W_1 \\ \vdots \\ \lambda_{max} W_2 \end{bmatrix} = \lambda_{max} W$$

$$\text{----------(5)}$$

The opposite values of the comparisons are placed in the aji position of A as can be seen in Equation 1.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \text{----------(6)}$$

In the case of problems of consistency with the decision maker, a matrix R is generated by performing a perturbation in the matrix A in such a way that:$R * w = \lambda_{max} * w$; where w is the auto-vector of the comparison matrix and λ_{max} is the dominant auto-value of the same matrix.

5.3.6 Step 3: Verify the Consistency of the Judgments

Consistency index (CI) is used to measure consistency, which is mathematically defined as follow:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad \text{----------(7)}$$

To verify the CI values, a comparison is conducted with the random consistency index (RI). This parameter is denoted as an average of the CIs of a large set of matrices with random inputs (Saaty 2012) Table 5.4.

Table 5.4. Random Consistency Index

n	3	4	5	6	7	8	9	10
RI	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854
RI: Random consistency index								

In addition, Saaty states the consistency ratio $(CR) = CI/RI$. If $CR \leq 0.1$, then the results are consistent. When $RC > 0.1$, the data are inconsistent and therefore the decision maker judgments must be reviewed.

5.3.7 Step 4: Define priorities for sub-criteria

In the case that sub-criteria have been determined in the decision problem, it is need to proceed as in step 3. For this objective, the paired comparisons must be conducted in order to establish the importance of the sub-criteria with respect to the higher level.

5.3.8 Step 5: Define priorities for alternatives

In this case also the procedure presented in step 3 is followed, but taking into account that a comparison must be conducted between alternatives to establish preferences according to the criteria and sub-criteria that have been defined. Finally, the global weight for the criteria, sub-criteria and alternatives is gained from the multiplication of the local weight (W_i) by the global weight of the immediately superior criterion. The sum of the global weights of the alternatives in relation to each criterion is the mechanism to attain the evaluation of all possible alternatives.

5.3.9 Sensitivity analysis

Sensitivity analysis is applied to satisfy the degree of influence of the main criteria on the overall output. In other words, it is applied to calculate how changes in the priority weights of main criteria can influence the final ranking of alternatives. After performing sensitivity analysis through a manipulation of changes in the priority weights of criteria, if the ranking does not change, the results are said to be robust. Otherwise, they are said to be sensitive (Mangla, Govindan, and Luthra 2017). In this study, nine scenarios were generated by changing the priority weights in the main criteria without changing the remainder of the AHP results.

5.3.10 Methodological Framework

Figure 5.3 presents the methodoloigcal framework for this research.

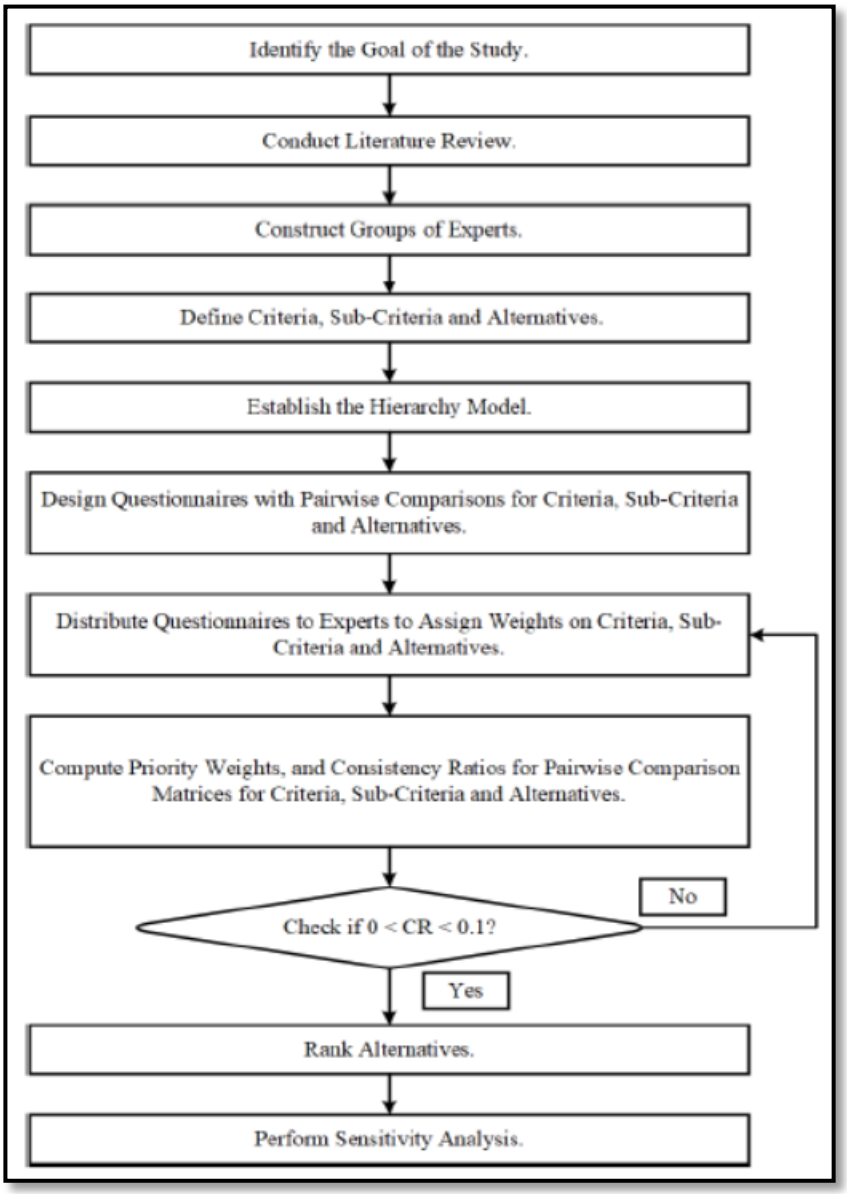

Figure 5.3. AHP Methodology Framework

As presented before, the primary objective or goal of this study is to rank the energy resources for evaluation of sustainable energy mix in Myanmar. Firstly, a thorough review of previous literatures which multi-criteria decision analysis to tackle energy policy issues was carried out. From the literature reviews related to energy planning problems using multi-criterial decision analysis was conducted in order to define the criteria and sub-criteria. In this way, a preliminary list of 16 sub-criteria was defined, grouped into four criteria: Technology, Economic, Environmental, and Socio-Political.

To finalize the list of sub-criteria, the following experts groups was defined:

1. Ministry of Electricity and Energy.
2. Ministry of Natural Resources and Environmental Conservation.
3. Ministry of Planning, Finance, and Industry.

The study was developed and answered by 25 of the 30 respondents defined. The respondents agreed to select four main criteria and sixteen sub-criteria satisfied to sustainable energy mix in Myanmar, which was the main objective of this research. This study emphasises on four energy resources as alternatives: Oil, Natural Gas, Renewable, and Coal, which were recommended by the Myanmar National Energy Policy to be obtained sustainable energy development in Mynamar. As shown in Figure 5.4, four criteria, sixteen sub-criteria, and four alternatives are applied for this research. Technology, Economic, Environmental, and Socio-Political criteria are selected in ranking energy resources for sustainable energy mix in Myanmar. In Table 5.5, detailed description for each sub-criteria.

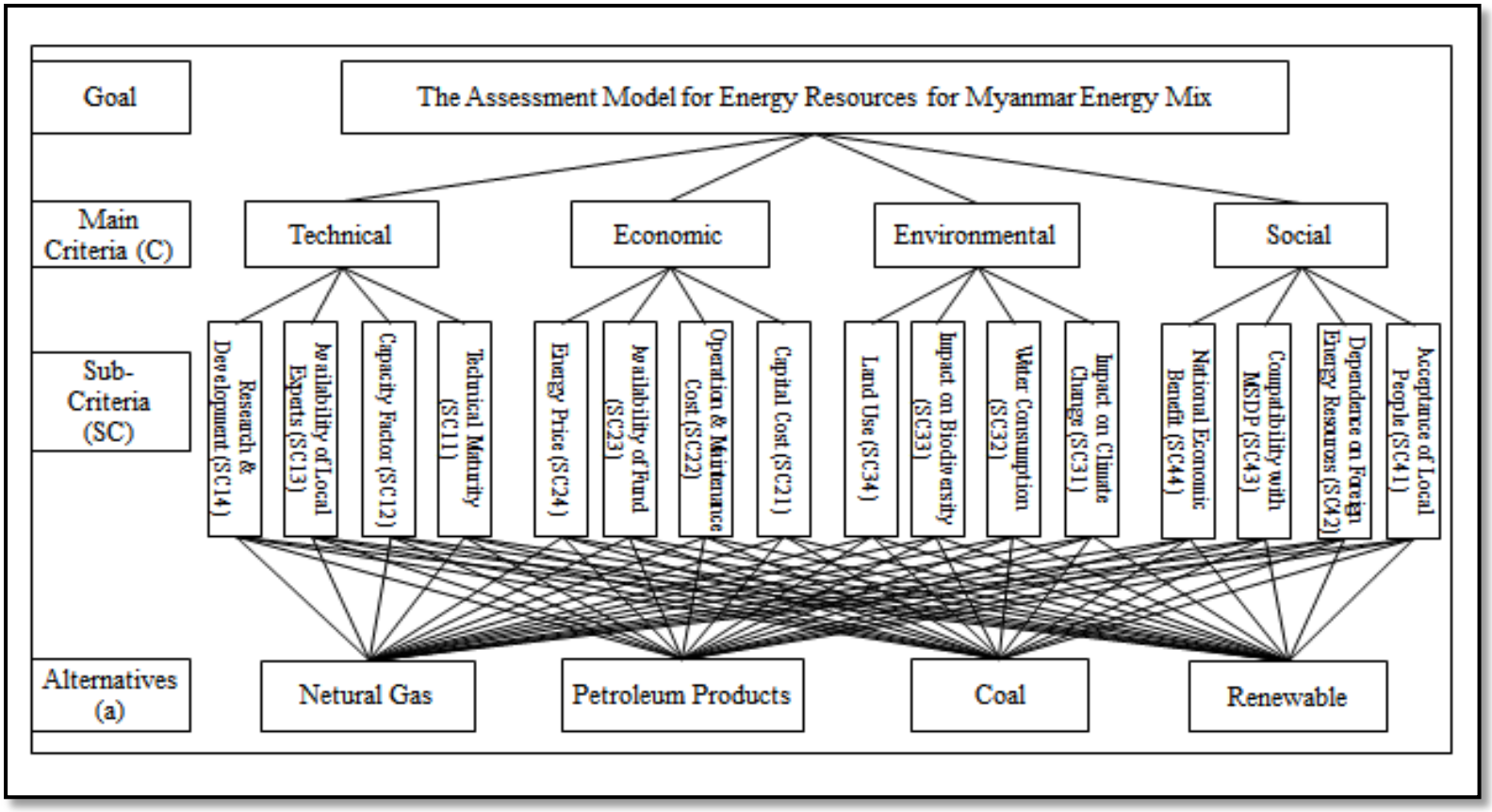

Figure 5.4. Analytical Hierarchy Structure for this study

Table 5.5. Explanations for seletcted sub-criteria

Criteria	Sub-criteria	Description	References
Technical	Technical Maturity	This criterion is to determine a given technology's readiness for ultimate application in future Myanmar Energy Mix. It will evaluate the technical maturity of each energy source.	(Heo, Kim, and Boo 2010)
	Capacity Factor	A measure of the actual total final energy supply over a period of time divided by the maximum energy supply.	(Maxim 2014), (Malkawi, Al-Nimr, and Azizi 2017b)
	Availability of Local Experts	Expert manpower available in the country to operate and maintain in the energy industry.	(Amer and Daim 2011), (Mirjat et al. 2018)
	R & D	Expenses occurred on the research and development of a technology alternative.	(Amer and Daim 2011)
Economic	Capital Cost	Capital cost comprise of land cost, the costs of the necessary buildings and infrastructures and equipment to supply energy consumption in the Myanmar energy industry. Labor and infrastructures maintenance costs are not included in capital costs.	(Kahraman and Kaya 2010), (Amer and Daim 2011), (Brand and Missaoui 2014)
	Operation & Maintenance Cost	Operation and Maintenance Cost include wages of the labors, and the funds spent for the energy, the products and services of energy industry.	(Chatzimouratidis and Pilavachi 2009), (Daim et al. 2009), (Wang et al. 2009)

	Availability of Funds	This criterion evaluates the national and international funds and economic support of government.	(Kahraman and Kaya 2010), (Kumar et al. 2017b), (Mirjat et al. 2018)
	Energy Price	The price of energy offered by the energy supplied system includes all the costs over the lifetime of the systems: initial investment, operation and maintenance, fuel cost, and cost of capital.	(Maxim 2014), (Malkawi, Al-Nimr, and Azizi 2017b)
Environmental	Impact on Climate Change	It represents the climate change impacts caused by energy consumption of each sector, especially greenhouse gases (CO2, NOx, SO2) , small particles etc.	(Kablan 1997), (Amer and Daim 2011), (Kahraman and Kaya 2010), (Mirjat et al. 2018)
	Water Consumption	It represents water consumed per unit of energy consumption, especially electricity generation.	(Chanchawee and Usapein 2018),
	Impact on Biodiversity	It refers to the impacts on biodiversity due to energy production and consumption.	(Kablan 1997), (Daniel et al. 2010), (Kahraman and Kaya 2010)
	Land Use	It refers to the land used over the entire life-cycle of the unit (e.g. fuel extraction, processing and delivery, construction, operation and decommissioning)	(Wang et al. 2009), (Chatzimouratidis and Pilavachi 2009), (Amer and Daim 2011)

Socio-Political	Acceptance of Local People and Politicians	Social acceptability expresses the overview of opinions related to the energy systems by the local population regarding the hypothesized realization of the projects under review from the consumer point of view.	(Kahraman and Kaya 2010), (Amer and Daim 2011), (Wang et al. 2009), (Brand and Missaoui 2014)
	Dependence on Foreign Energy Sources	This criterion will evaluate energy security in term of dependency on the foreign energy resources.	(Amer and Daim 2011), (Kahraman and Kaya 2010), (Brand and Missaoui 2014)
	Compatibility with MSDP	This criterion will takes into account the compatibility with Myanmar Sustainable Development Plan, especially Strategy 5.4 Provide affordable and reliable energy to populations and industries via an appropriate energy mix.	(Mirjat et al. 2018), (Kahraman and Kaya 2010), (Sadeghi and Larimian 2018)
	National Economic Benefits	It represents benefits to the national economy by utilizing a certain energy mix.	(Amer and Daim 2011), (Nigim, Munier, and Green 2004), (Brand and Missaoui 2014)

Then, the questionnaires with pairwise comparisons of criteria, sub-criteria, and alternatives were constructed (see Appendix 3). The questionnaires applied for this research included three sections as follow:

1 Section (A) on demographic information of the respondent such as name, email, affiliation, position, duration of current position, etc.
2 Section (B) on pairwise comparisons of main criteria and sub-criteria.
3 Section (C) on pairwise comparisons of alternatives.

Those questionnaires were distributed to 30 experts but 25 of those 30 experts answered their judgments of each pair of criteria, sub-criteria, and alternatives for evaluation of sustainable energy mix in Myanmar. For each expert, 11 matrices of comparison were elaborated distributed as follows: Criteria, technology sub-criteria, economic sub-criteria, environmental sub-criteria, and socio-political sub-criteria, energy resources alternatives with respect to technology, economic, environmental, and socio-political. Each expert was assigned the same weight, so a process of aggregation of all the judgments was performed using the geometric mean. In order to facilitate the calculations, expert choice software was used, which enters the individual judgments of the experts and generates the local and global preferences of all levels of the hierarchical tree. The importance of expert choice software was verified to facilitate the processing of expert judgments, as well as the calculation of CRs for matrices obtained from paired comparisons.

5.4 Empirical Results

This chapter presents the analysis results of the survey forms and a discussion of these results. As mentioned before, a total of 25 experts from three different ministries were requested to fill out the questionnaire survey forms and provide their judgements on a set of comparisons related to the selected criteria, sub-criteria and alternatives. After the experts' judgement was received, aggregate matrices were created for all criteria, sub-criteria and alternatives to calculate the priority eigenvectors, priority weights and to check their consistency. In case inconsistencies were identified, the experts were requested to fill out the survey forms again until the level of inconsistency met Saaty's 0.10 limit. In order to facilitate the calculations, expert choice software was used, which enters the individual judgments of the experts and generates the local and global preferences of all levels of the hierarchical tree.

5.4.1 Consistency Ratio of Main Criteria

Figure 5.5 shows the consistency ratio of main criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

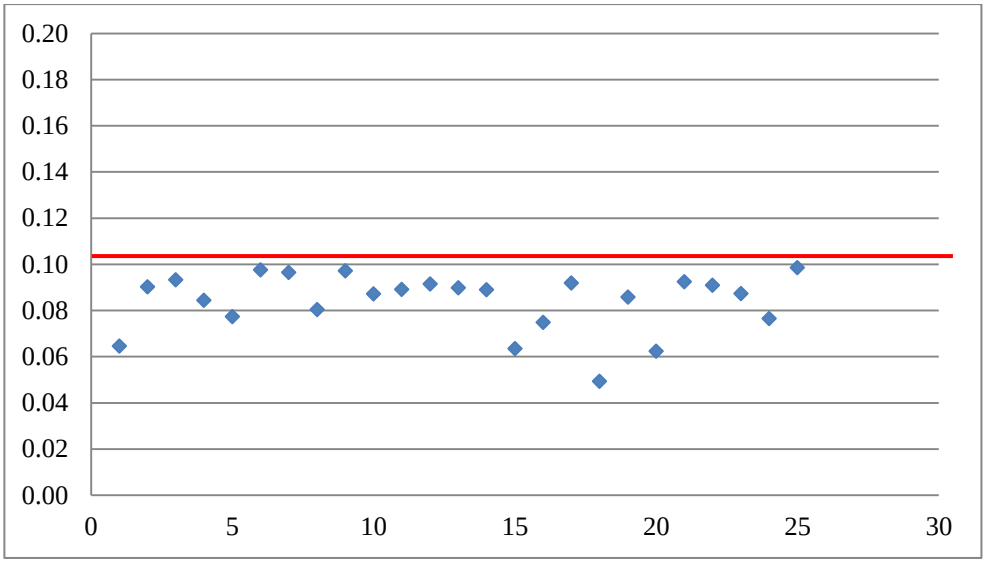

Figure 5.5. Consistency Ratio in Main Criteria

5.4.2 Consistency Ratio of Technology Sub-Criteria

Figure 5.6 states the consistency ratio of Technology sub-criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

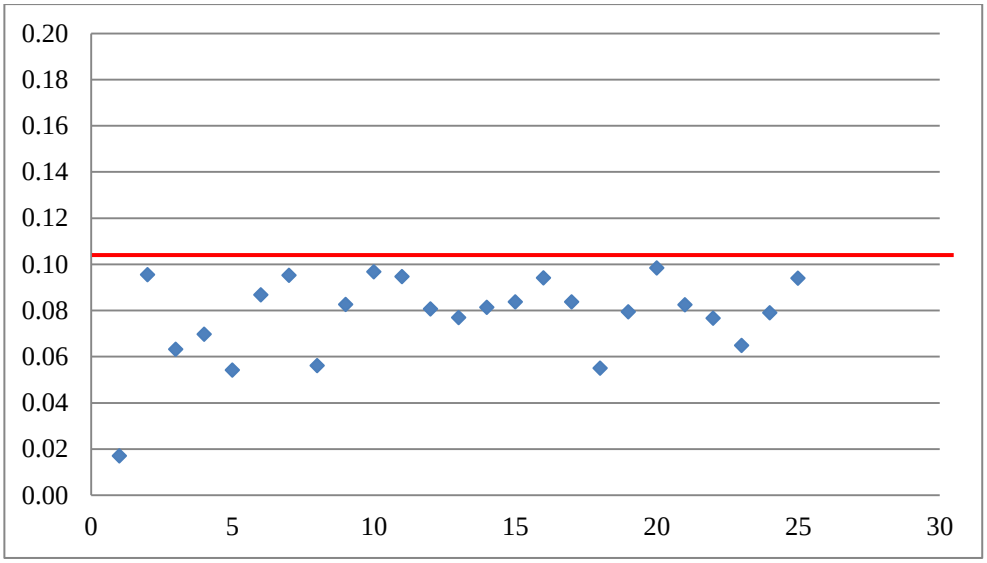

Figure 5.6. Consistency Ratio in Technology Sub-Criteria

5.4.3 Consistency Ratio of Economic Sub-Criteria

Figure 5.7 states the consistency ratio of Economic sub-criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

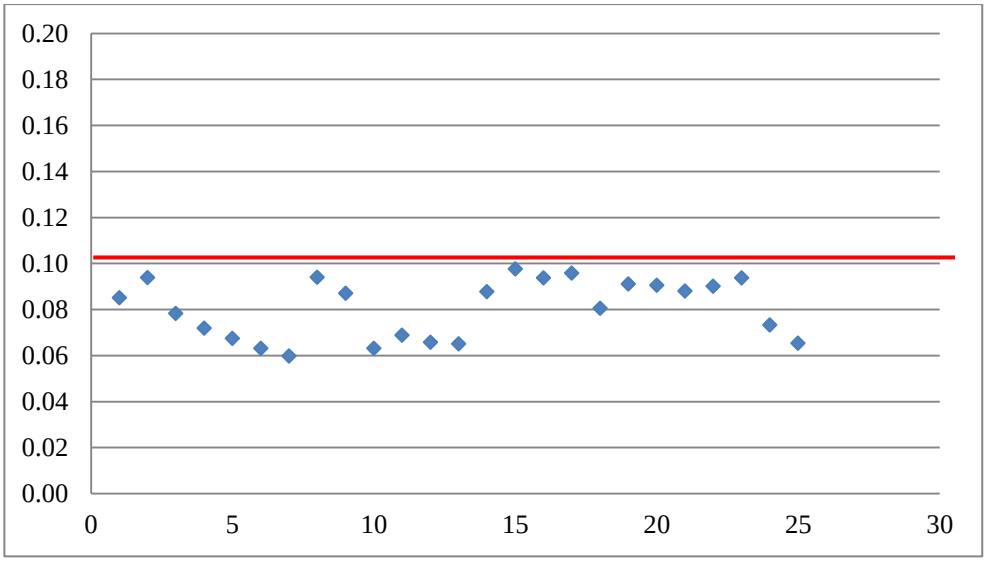

Figure 5.7. Consistency Ratio in Economic Sub-Criteria

5.4.4 Consistency Ratio of Environmental Sub-Criteria

Figure 5.8 states the consistency ratio of Environmental sub-criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

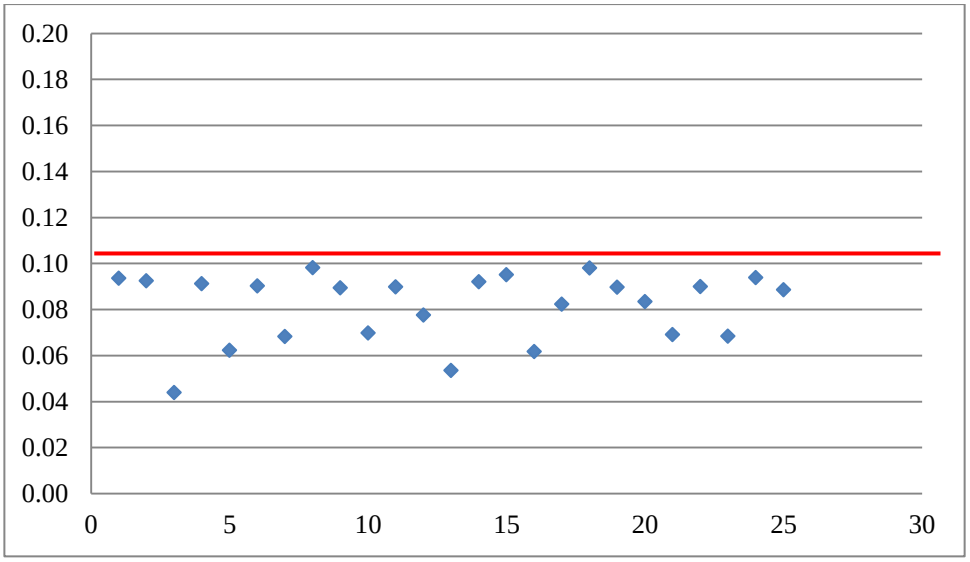

Figure 5.8.Consistency Ratio in Environmental Sub-Criteria

5.4.5 Consistency Ratio of Socio-Political Sub-Criteria

Figure 5.9 states the consistency ratio of Socio-Political sub-criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

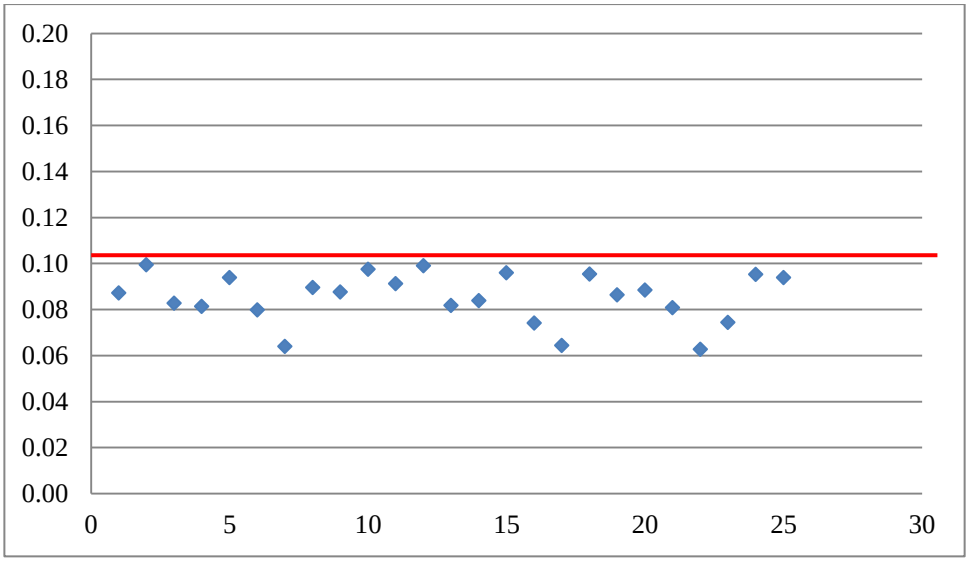

Figure 5.9.Consistency Ratio in Socio-Political Sub-Criteria

5.4.6 Consistency Ratio of Alternatives

Figure 5.10 states the consistency ratio of Socio-Political sub-criteria. The 25 respondents out of 30 respondents from Ministry of Electricity and Energy, Ministry of Natural Resourses and Environmental Conservation, and Ministry of Planning, Finance, and Industry have consistency ratio below the 0.1 or 10% . The 5 respondents who had inconsistent were not considering for this study.

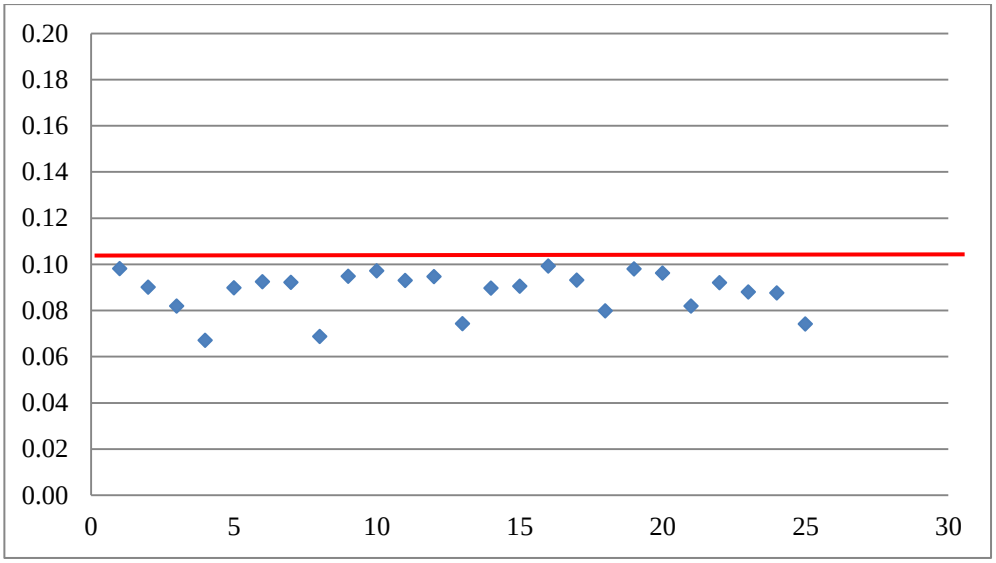

Figure 5.10.Consistency Ratio in Alternatives

5.5 Results of Ministry of Electricity and Energy

5.5.1 Results of Priorities of Criteria

In this section, the study presents the priorities of criteria from the respondents of Ministry of Electrictiy and Energy for the evaluation of sustainable energy mix in Myanmar. The aggregated results from respondents shows that the technology criteria (37.5%) had the greated influence on decision making. The technology criteria was followed by the economic criteria (34.5%), the socio-political criteria (15.6%), and the environmental criteria (12.3%) respectively. The results of four main criteria are shown in Table 5.6 and Figure 5.11.

Table 5.6. Priorities and Ranking for four main criteria

Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Technology	0.375	37.5%	1
Economic	0.345	34.5%	2
Socio-Political	0.156	15.6%	3
Environmental	0.123	12.3%	4
Total	**1**	**100%**	

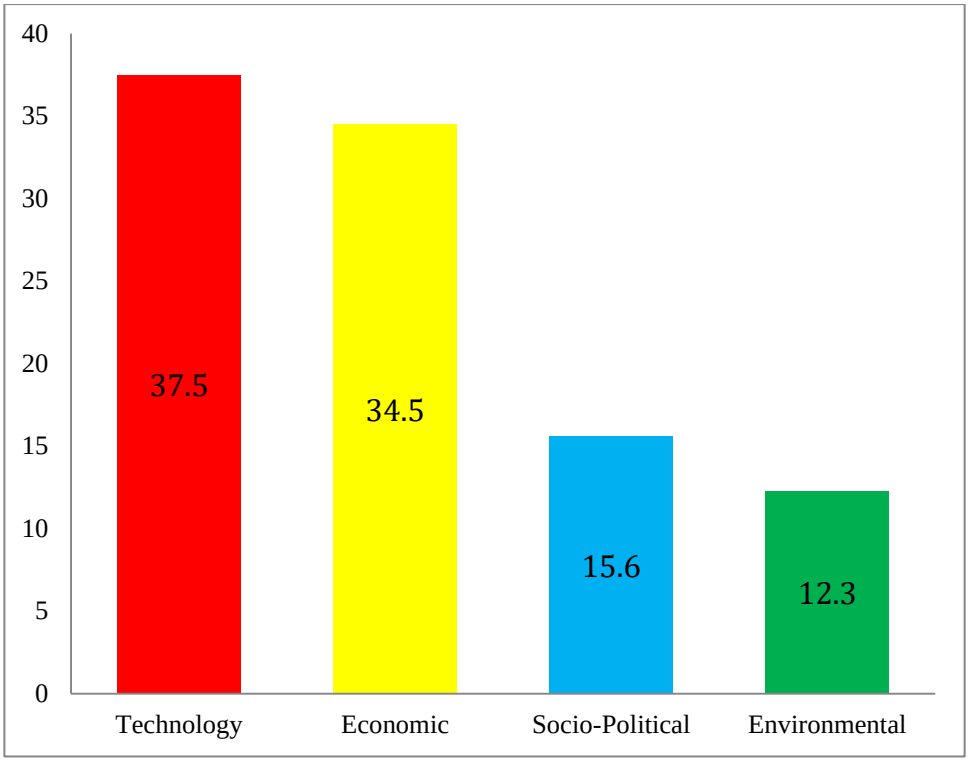

Figure 5.11. Priorities for four main criteria

5.5.2 Results of Global Priorities for Sub-criteria

In this section shows the global priorities results of sub-criteria in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondents from Ministry of Electricity and Energy, the most important priority was the availability of local expert (15%). It was followed by the availability of fund (12%), the capital cost (11%), the technical maturity (9.1%), the capacity factor (8.2%), the national benefit (7.9%), the research and development (7.6%), the energy price (7.4%), the operation and maintainance cost (3.6%), the acceptance of local people and politicians

(3.6%), the compactability with Myanmar sustainable development plan (3%), the impact of biodiversity (2.9%), the impact on climate change (2.3%), the water consumption (2.2%), the dependence on foreign energy resources (2.2%), the land use (2%), respectively. The results of global priorities for sub-criteria are presented in Table 5.7 and Figure 5.12.

Table 5.7. The results of global priorities for sub-criteria

Sub-Criteria	**Priority Weight**	**Priority Weight (%)**	**Rank**
Availability of Local Expert	0.15	15%	1
Availability of Fund	0.12	12%	2
Capital Cost	0.11	11%	3
Technical Maturity	0.091	9.1%	4
Capacity Factor	0.082	8.2%	5
National Benefit	0.079	7.9%	6
R & D	0.076	7.6%	7
Energy Price	0.074	7.4%	8
Operation & Maintainance Cost	0.036	3.6%	9
Acceptance of Local People	0.036	3.6%	10
Compactability with MSDP	0.03	3%	11
Impact of Biodiversity	0.029	2.9%	12
Impact of Climate Change	0.023	2.3%	13
Water Consumption	0.022	2.2%	14
Dependence on Foreign Energy Resources	0.022	2.2%	15
Land Use	0.02	2%	16
Total	**1**	**100%**	

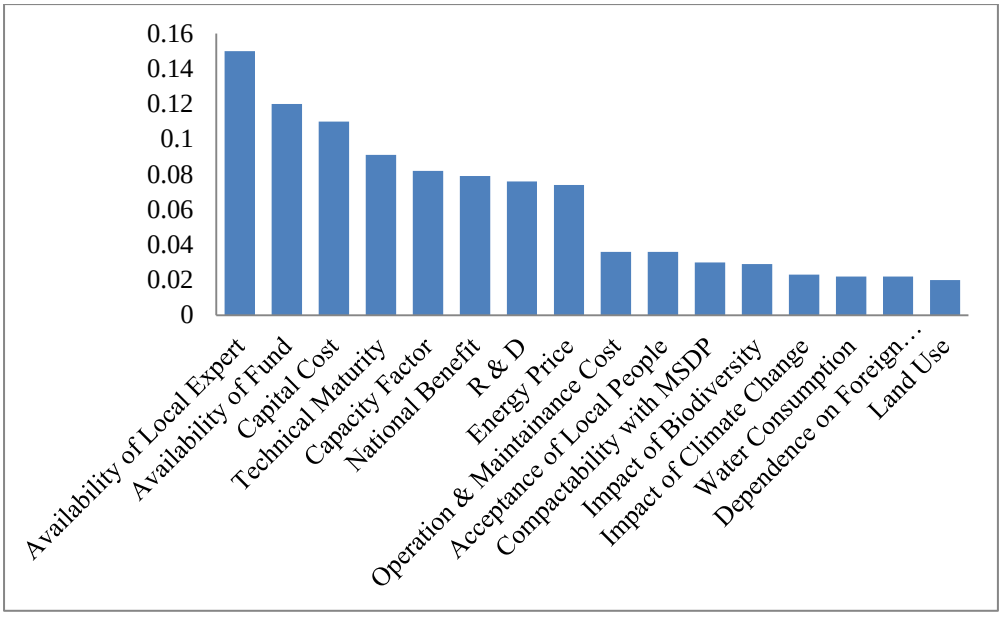

Figure 5.12. The results of global priorities for sub-criteria

5.5.3 Results of Global Priorities for Alternatives

In this section shows the global priorities results of alternatives in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondenses from Ministry of Electricity and Energy, the most important priority alternative was the natural gas (37.6%), followed by the oil (35.5%), the renewable (15.8%), and the coal (11.1%), respectively. The results of global priorities for alternatives are presented in Table 5.8 and Figure 5.13.

Table 5.8. The results of global priorities for alternatives

Alternatives	**Priority Weight**	**Priority Weight (%)**	**Rank**
Natural Gas	0.376	37.6%	1
Oil	0.355	35.5%	2
Renewable	0.158	15.8%	3
Coal	0.111	11.1%	4
Total	**1**	**100%**	

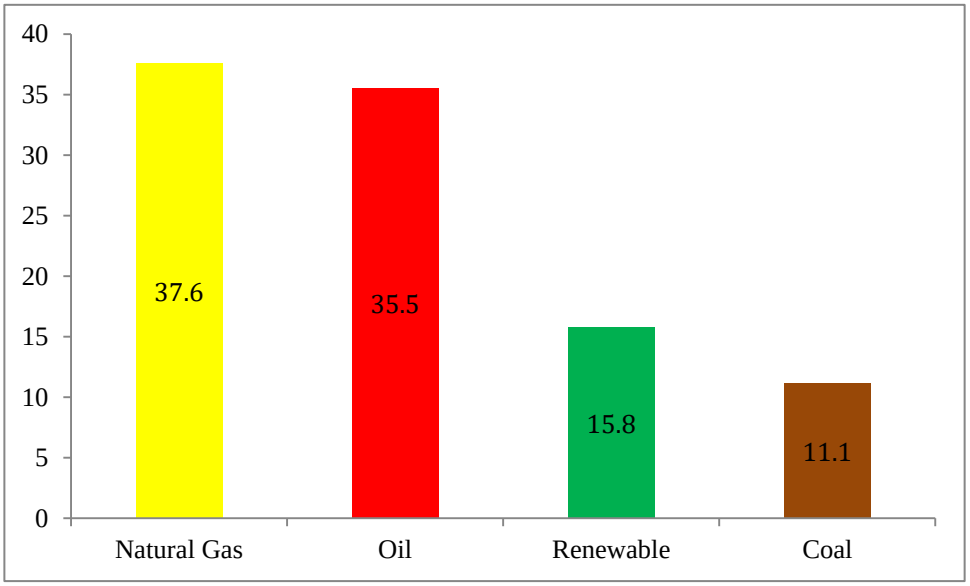

Figure 5.13. The results of global priorities for alternatives

5.6 Results of Ministry of Natural Resources and Environmental Conservation

5.6.1 Results of Priorities of Criteria

In this section, the study presents the priorities of criteria from the respondents of Ministry of Natural Resources and Environmental Conservation for the evaluation of sustainable energy mix in Myanmar. The aggregated results from respondents shows that the environmental criteria (35.2%) had the greated influence on decision making. It was followed by the technology criteria (33.7%), the economic criteria (20.2%), and the socio-political criteria (10.9%), respectively. The results of four main criteria are shown in Table 5.9 and Figure 5.14.

Table 5.9. Priorities and Ranking for four main criteria

Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Environmental	0.352	35.2%	1
Technology	0.337	33.7%	2
Economic	0.202	20.2%	3
Socio-Political	0.109	10.9%	4
Total	**1**	**100%**	

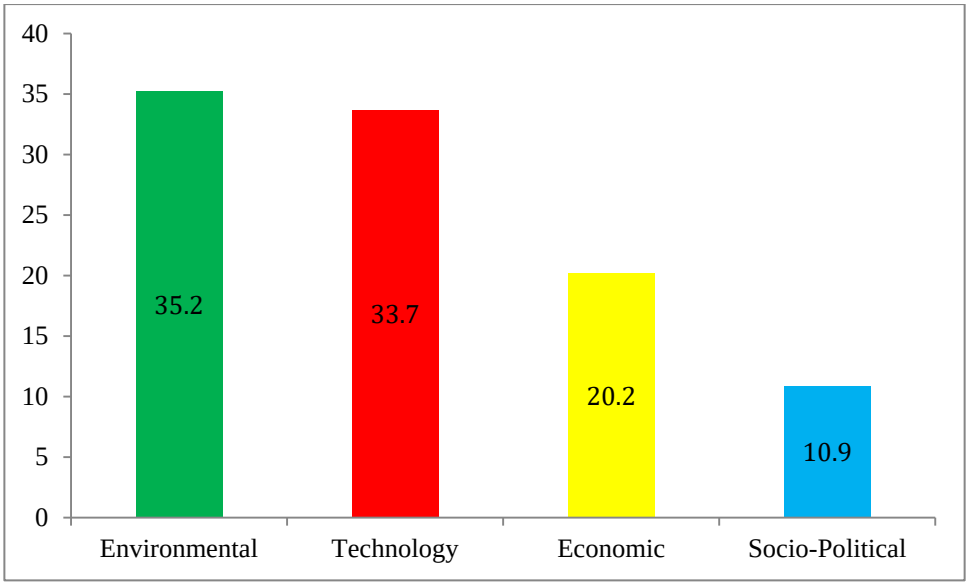

Figure 5.14. Priorities and Ranking for four main criteria

5.6.2 Results of Global Priorities for Sub-criteria

In this section shows the global priorities results of sub-criteria in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondents from Ministry of Natural Resources and Environmental Conservation, the most important priority was the impact on climate change (13%). It was followed by the capital cost (11%), the impact of biodiversity (9.4%), the research and development (9%), the capacity factor (8.2%), the technical maturity (8%), the energy price (7.4%), the national benefit (6.6%), the availability of fund (5.3%), the compactability with Myanmar sustainable development plan (5%), the land use (4%), the operation and maintainance cost (3.8%), the acceptance of local people and politicians (3.4%), the water consumption (2.8%), the dependence on foreign energy resources (1.5%), the availability of local expert (1.18%),

respectively. The results of global priorities for sub-criteria are presented in Table 5.10 and Figure 5.15.

Table 5.10. The results of global priorities for sub-criteria

Sub-Criteria	**Priority Weight**	**Priority Weight (%)**	**Rank**
Impact of Climate Change	0.13	13.0%	1
Capital Cost	0.11	11.0%	2
Impact of Biodiversity	0.094	9.4%	3
R & D	0.09	9.0%	4
Capacity Factor	0.082	8.2%	5
Technical Maturity	0.08	8.0%	6
Energy Price	0.074	7.4%	7
National Benefit	0.066	6.6%	8
Availability of Fund	0.053	5.3%	9
Compatibility with MSDP	0.05	5.0%	10
Land Use	0.04	4.0%	11
Operation & Maintenance Cost	0.038	3.8%	12
Acceptance of Local People	0.034	3.4%	13
Water Consumption	0.028	2.8%	14
Dependence on Foreign Energy Resources	0.015	1.5%	15
Land Use	0.0118	1.2%	16
Total	**1**	**100%**	

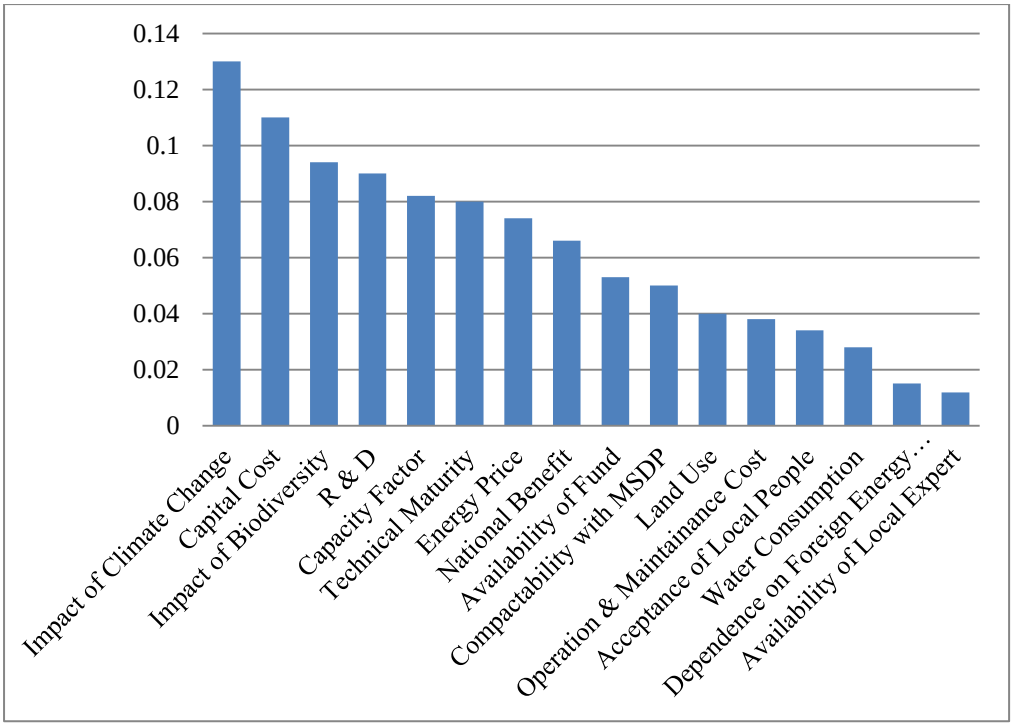

Figure 5.15. The results of global priorities for sub-criteria

5.6.3 Results of Global Priorities for Alternatives

In this section shows the global priorities results of alternatives in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondenses from Ministry of Electricity and Energy, the most important priority alternative was the natural gas (37.6%), followed by the oil (35.5%), the renewable (15.8%), and the coal (11.1%), respectively. The results of global priorities for alternatives are presented in Table 5.11 and Figure 5.16.

Table 5.11. The results of global priorities for alternatives

Alternatives	**Priority Weight**	**Priority Weight (%)**	**Rank**
Renewable	38	38%	1
Natural Gas	33.4	33.4%	2
Oil	20.3	20.3%	3
Coal	8.3	8.3%	4
Total	**1**	**100%**	

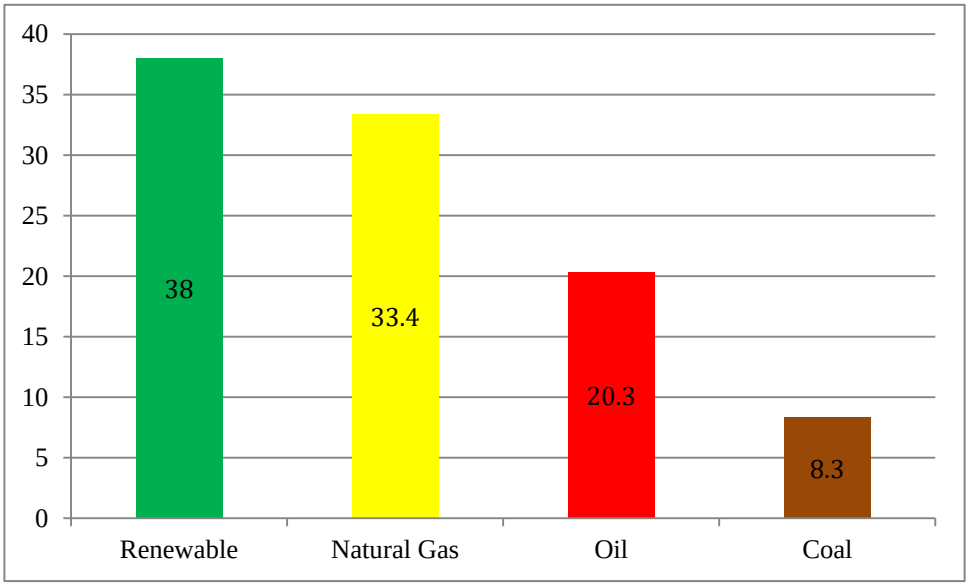

Figure 5.16. The results of global priorities for alternatives

5.7 Results of Ministry of Planning, Finance and Industry

5.7.1 Results of Priorities of Criteria

In this section, the study presents the priorities of criteria from the respondents of Ministry of Planning, Finance and Industry for the evaluation of sustainable energy mix in Myanmar. The aggregated results from respondents shows that the technology criteria (40%) had the greated influence on decision making. The technology criteria was followed by the economic criteria (34.5%), the socio-political criteria (14.3%), and the environmental criteria (11.2%) respectively. The results of four main criteria are shown in Table 5.12 and Figure 5.17.

Table 5.12. Priorities and Ranking for four main criteria

Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Technology	0.40	40%	1
Economic	0.345	34.5%	2
Socio-Political	0.143	14.3%	3
Environmental	0.112	11.2%	4
Total	**1**	**100%**	

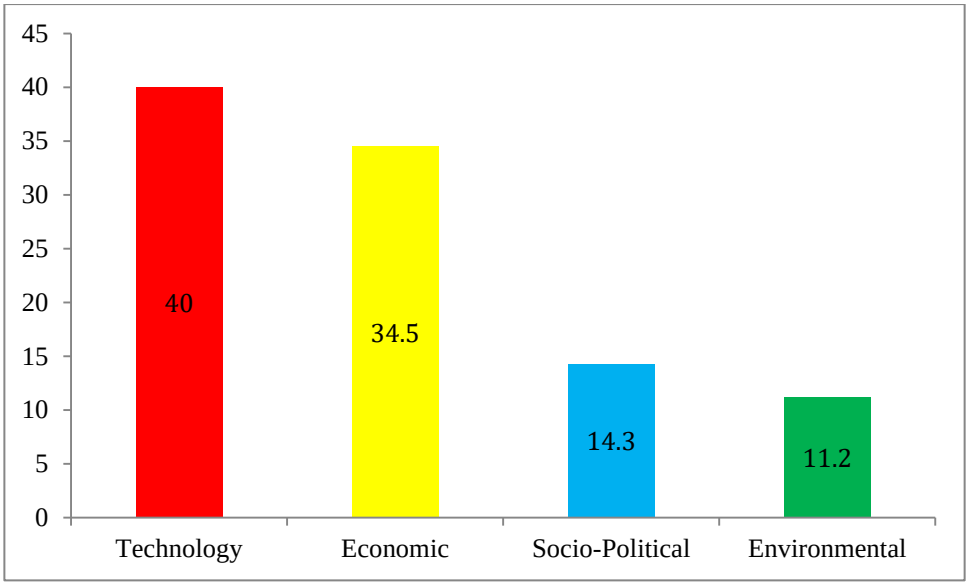

Figure 5.17. Priorities and Ranking for four main criteria

5.7.2 Results of Global Priorities for Sub-criteria

In this section shows the global priorities results of sub-criteria in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondents from Ministry of Planning, Finance and Industry, the most important priority was the availability of local expert (14%). It was followed by the technical maturity (12.6%), the availability of fund (11%), the capital cost (10%), the national benefit (9%), the research and development (8.8%), the capacity factor (8%), the energy price (6.4%), the operation and maintainance cost (5.8%), the impact on climate change (2.9%), the impact of biodiversity (2.8%), the compactability with Myanmar sustainable development plan (2.2%), the water consumption (2.1%), the acceptance of local people and politicians (2%), the dependence on foreign

energy resources (1.2%), the land use (1.2%), respectively. The results of global priorities for sub-criteria are presented in Table 5.13 and Figure 5.18.

Table 5.13. The results of global priorities for sub-criteria

Sub-Criteria	**Priority Weight**	**Priority Weight (%)**	**Rank**
Availability of Local Expert	0.14	14.0%	1
Technical Maturity	0.126	12.6%	2
Availability of Fund	0.11	11.0%	3
Capital Cost	0.1	10.0%	4
National Benefit	0.09	9.0%	5
R & D	0.088	8.8%	6
Capacity Factor	0.08	8.0%	7
Energy Price	0.064	6.4%	8
Operation & Maintenance Cost	0.058	5.8%	9
Impact of Climate Change	0.029	2.9%	10
Impact of Biodiversity	0.028	2.8%	11
Compatibility with MSDP	0.022	2.2%	12
Water Consumption	0.021	2.1%	13
Acceptance of Local People	0.02	2.0%	14
Dependence on Foreign Energy Resources	0.012	1.2%	15
Land Use	0.012	1.2%	16
Total	**1**	**100%**	

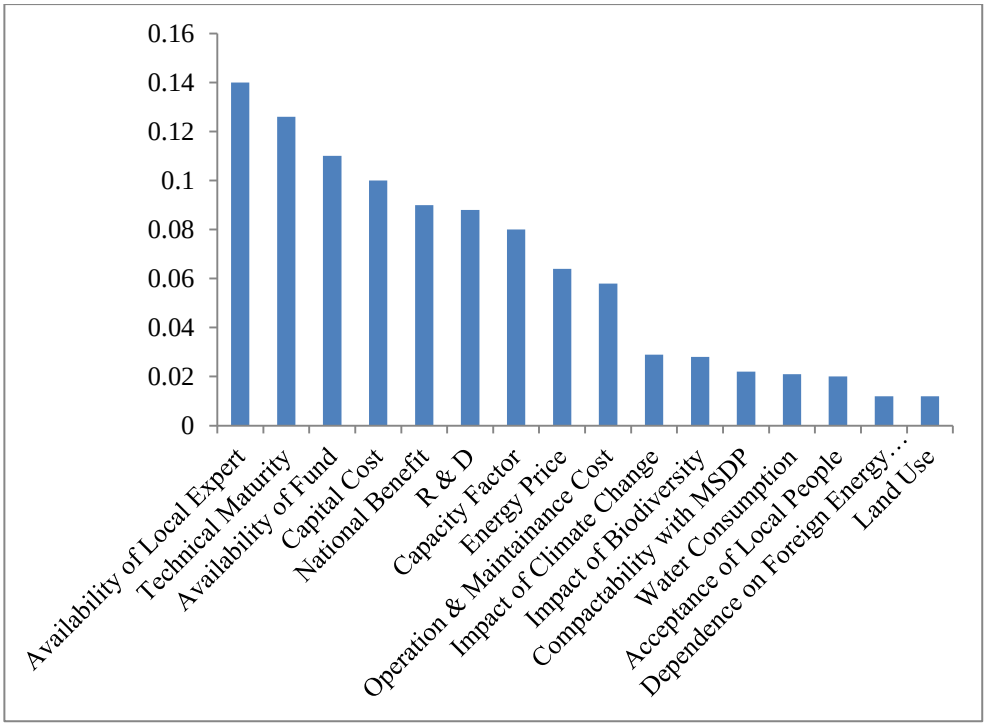

Figure 5.18. The results of global priorities for sub-criteria

5.7.3 Results of Global Priorities for Alternatives

In this section shows the global priorities results of alternatives in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondenses from Ministry of Planning, Finance and Industry, the most important priority alternative was the natural gas (36.6%), followed by the oil (30.5%), the renewable (20.8%), and the coal (12.1%), respectively. The results of global priorities for alternatives are presented in Table 5.14 and Figure 5.19.

Table 5.14. The results of global priorities for alternatives

Alternatives	**Priority Weight**	**Priority Weight (%)**	**Rank**
Natural Gas	0.366	36.6%	1
Oil	0.305	30.5%	2
Renewable	0.208	20.8%	3
Coal	0.121	12.1%	4
Total	**1**	**100%**	

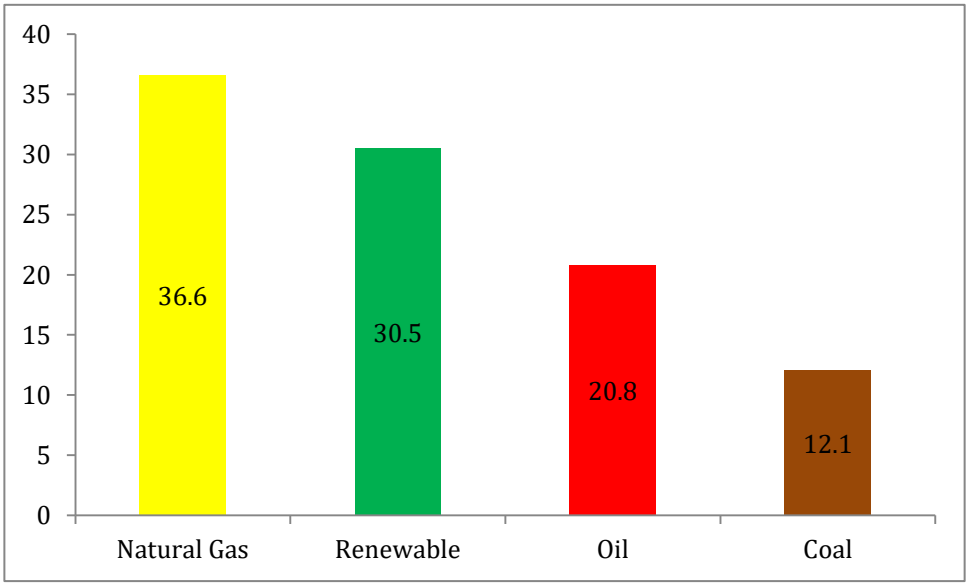

Figure 5.19. The results of global priorities for alternatives

5.8 The Result of All Respondents

5.8.1 Results of Priorities of Criteria

In this section, the study presents the overall priorities of criteria for the evaluation of sustainable energy mix in Myanmar. The aggregated results from respondents shows that the technology criteria (34.5%) had the greated influence on decision making. The technology criteria was followed by the economic criteria (27.5%), the socio-political criteria (19.6%), and the environmental criteria (18.3%) respectively. The results of four main criteria are shown in Table 5.15 and Figure 5.20.

Table 5.15. Priorities and Ranking for four main criteria

Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Technology	0.345	34.5%	1
Economic	0.275	27.5%	2
Socio-Political	0.196	19.6%	3
Environmental	0.183	18.3%	4
Total	**1**	**100%**	

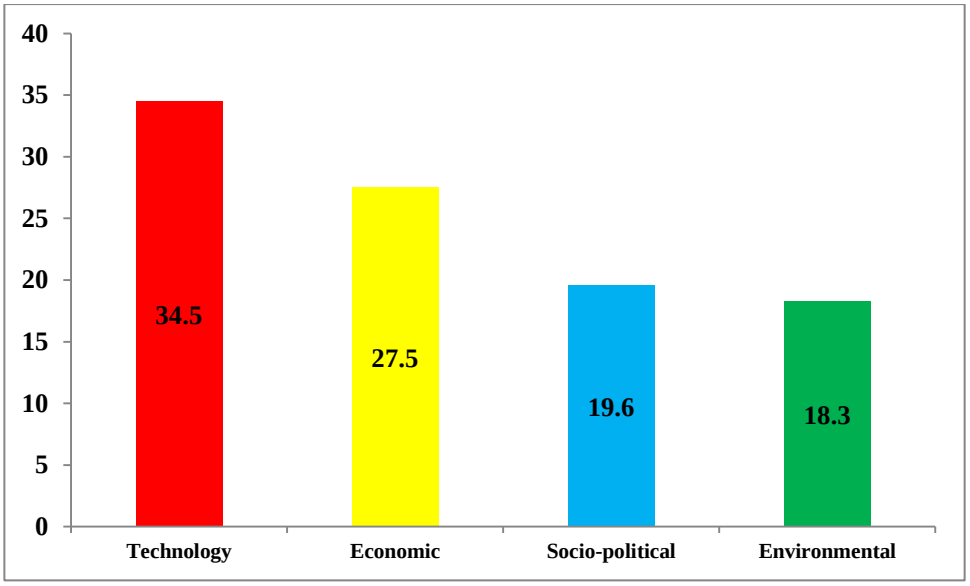

Figure 5.20. Priorities for four main criteria

5.8.2 The Results of Local Priorities for Technology Sub-criteria

In the technology sub-criteria, the first priority is the availability of local expert (34.8%), followed by the research and development (26.2%), the capacity factor (24.1%), and the technical maturity (14.9%) respectively. The results of the technology sub-criteria are shown in Table 5.16 and Figure 5.21.

Table 5.16. Local Priorities and Rankings for Technology sub-criteria

Technology Sub-criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Availability of Local Expert	0.348	34.8%	1
R & D	0.262	26.2%	2
Capacity Factor	0.241	24.1%	3
Technical Maturity	0.149	14.9%	4
Total	**1**	**100%**	

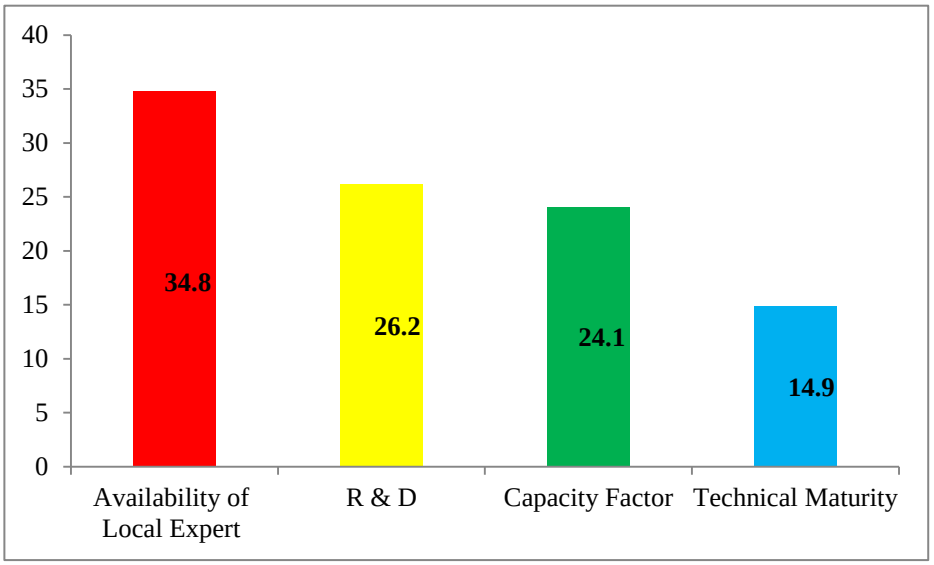

Figure 5.21. Local Priorities for Technology sub-criteria

In the economic sub-criteria, the first priority is the availability of fund (34.2%), followed by the energy price (26.8%), the operation and maintainance cost (20.4%), and the capital cost (18.6%), respectively. The results of the technology sub-criteria are shown in Table 5.17 and Figure 5.22.

Table 5.17. Local Priorities and Rankings for economic sub-criteria

Economic Sub-criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Availability of Fund	0.342	34.2%	1
Energy Price	0.268	26.8%	2
Operation and Manitainance Cost	0.204	20.4%	3
Capital Cost	0.186	18.6%	4
Total	**1**	**100%**	

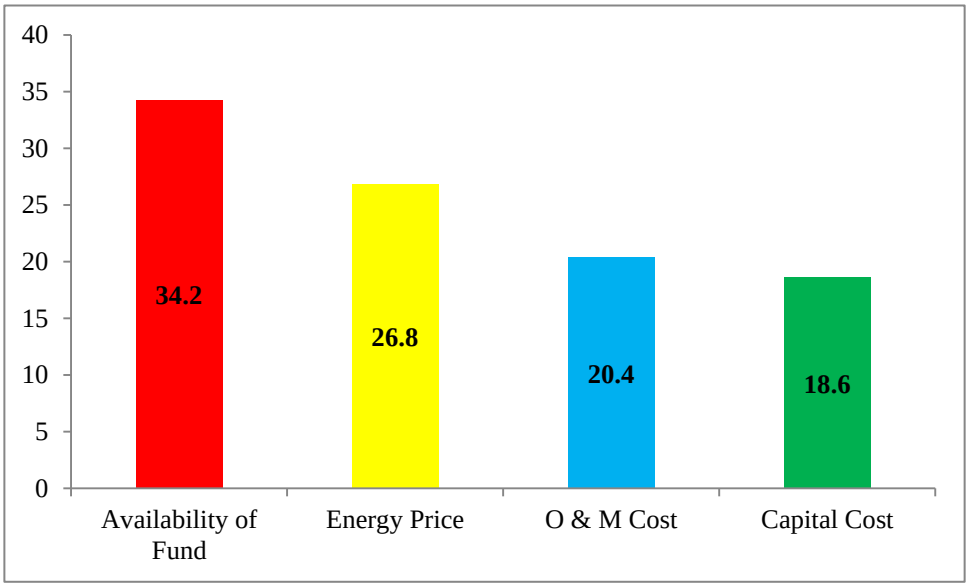

Figure 5.22. Local Priorities for Economic Sub-criteria

In the environmental sub-criteria, the first priority is the water consumption (33.5%), followed by the impact on biodiversity (27.3%), the land use (21.1%), and the impact on climate change (18.2%) respectively. The results of the technology sub-criteria are shown in Table 5.18 and Figure 5.23.

Table 5.18. Priorities and Rankings for Environmental sub-criteria

Environmental Sub-criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Water Consumption	0.335	33.5%	1
Impact on Biodiversity	0.273	27.3%	2
Land Use	0.211	21.1%	3
Impact on Climate Change	0.182	18.2%	4
Total	**1**	**100%**	

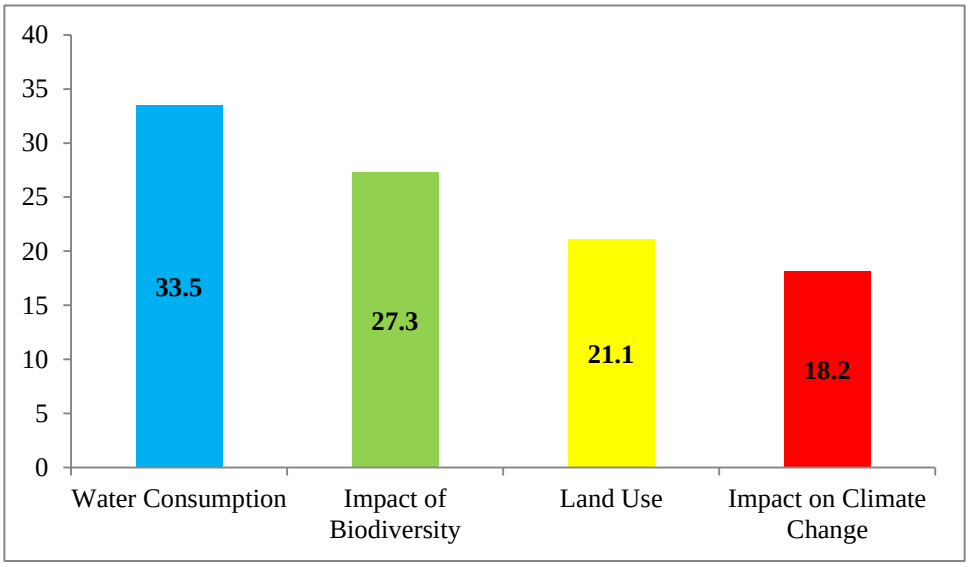

Figure 5.23. Priorities for Environmental sub-criteria

In the socio-political sub-criteria, the first priority is the national benefit (40.6%), followed by the compactability with Myanmar Sustainable Development Plan (23.8%), the acceptance of local people and politicians (18.7%), and the dependence on foreign energy resources (16.9%) respectively. The results of the technology sub-criteria are shown in Table 5.19 and Figure 5.24.

Table 5.19. Priorities and Rankings for Socio-Political sub-criteria

Socio-political Sub-criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
National Benefit	0.406	40.6%	1
Compactability with MSDP	0.238	23.8%	2
Acceptance of Local People	0.187	18.7%	3
Dependence on Foreign Energy Resources	0.169	16.9%	4
Total	**1**	**100%**	

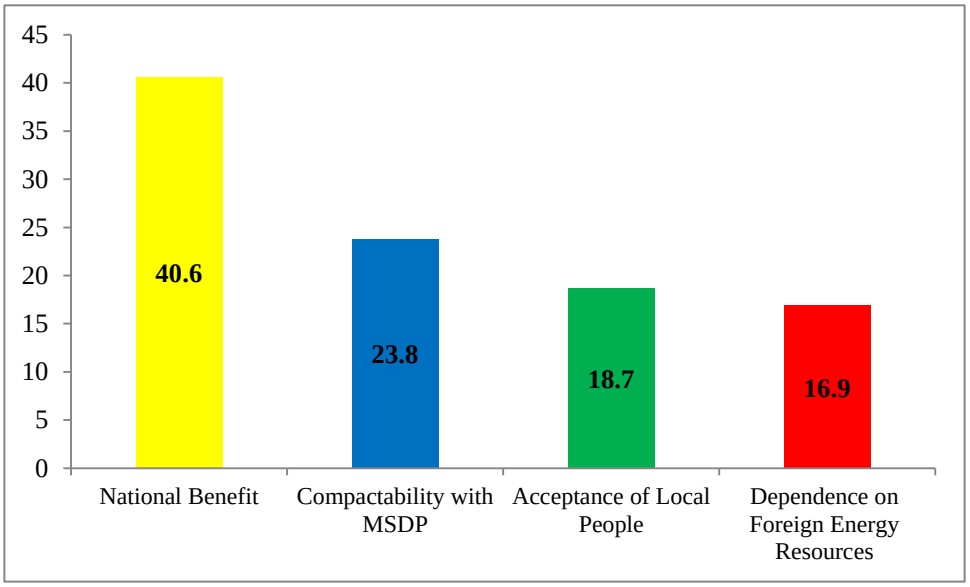

Figure 5.24. Priorities for Socio-Political sub-criteria

5.8.3 Results of Local Priorities for Alternatives

The study continues to calculate the results of local priorities for alternatives in the evaluation of sustainable energy mix in Myanmar.

In the technology criteria, the first priority of alternatives was natural gas (46.3%). The second priority was renewable (31.6%), the third was oil (15.7%), and the last was coal (6.3%) respectively. The results of the local priorities and rankings of alternatives with respect to the technology criteria are presented in Table 5.20 and Figure 5.25.

Table 5.20. Local Priorities and Rankings for Alternative to Technology Criteria

Alternatives to Technology Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Natural Gas	0.463	46.3%	1
Renewable	0.316	31.6%	2
Oil	0.157	15.7%	3
Coal	0.063	6.3%	4
Total	**1**	**100%**	

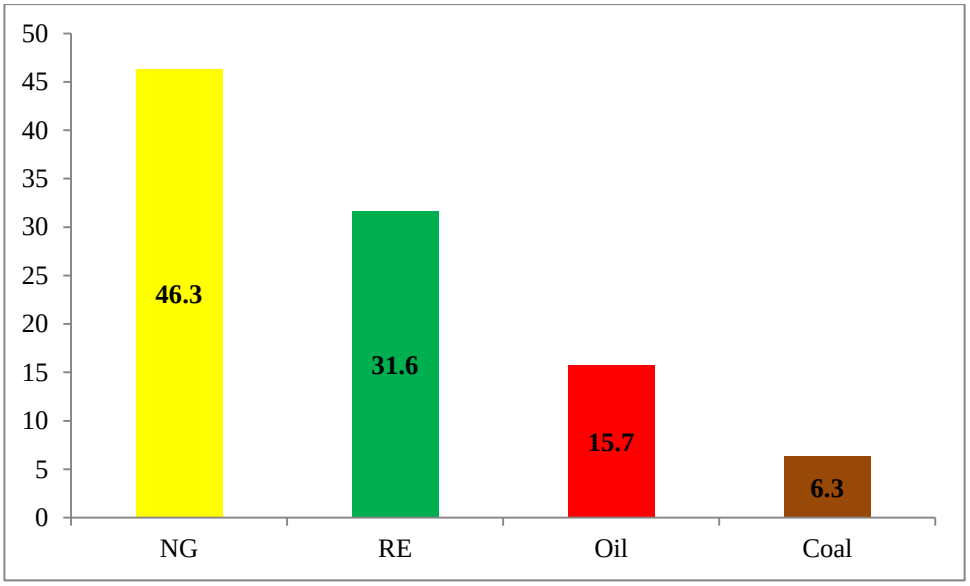

Figure 5.25. Local Priorities for Alternatives to Technology Criteria

In the economic criteria, the answers of respondenses state that the first priority was natural gas (40.6%), followed by renewable (26.3%), oil (24.5%), and coal (8.5%) respectively. The results of the priorities and rankings of alternatives to economic criteria are shown in Table 5.21 and Figure 5.26.

Table 5.21. Local Priorities and Rankings for Alternatives to Economic Criteria

Alternatives to Economic Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Natural Gas	0.406	40.6%	1
Renewable	0.263	26.3%	2
Oil	0.245	24.5%	3
Coal	0.085	8.5%	4
Total	**1**	**100%**	

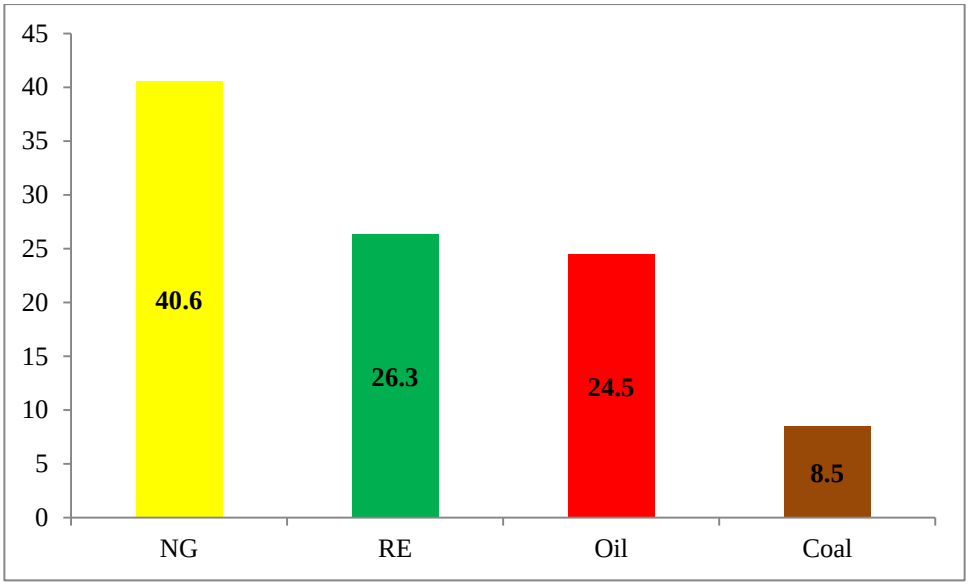

Figure 5.26. Local Priorities for Alternatives to Economic Criteria

In the environmental criteria, renewable (46.8%) was as the best option, followed by natural gas (32.2%), oil (14.5%), and coal (6.5%), respectively. The results of local priorities and rankings of alternatives with respect to the environmental criteria are presented in Table 5.22 and Figure 5.27.

Table 5.22. Local Priorities and Ranking for Alternatives to Environmental Criteria

Alternatives to Environmental Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Renewable	0.468	46.8%	1
Natural Gas	0.322	32.2%	2
Oil	0.145	14.5%	3
Coal	0.065	6.5%	4
Total	**1**	**100%**	

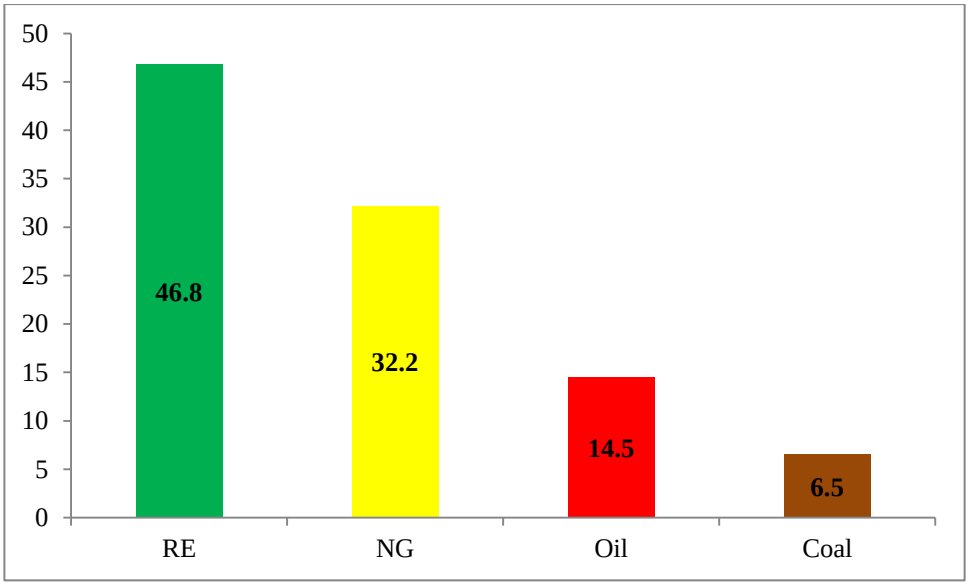

Figure 5.27. Local Priorities for Alternatives to Environmental Criteria

For the alternatives with respect to socio-political criteria, the expert answered that the most important energy resource was natural gas (43%), followed by renewable (36.5%), oil (14.4%), and coal (6%). The results of the local priorities and rankings for alternatives to socio-political criteria are shown in Table 5.23 and Figure 5.28.

Table 5.23. The results of local priorities and rankings for Alternatives to Socio-Political Criteria

Alternatives to Socio-Political Criteria	**Priority Weight**	**Priority Weight(%)**	**Rank**
Natural Gas	0.430	43%	1
Renewable	0.365	36.5%	2
Oil	0.144	14.4%	3
Coal	0.060	6%	4
Total	**1**	**100%**	

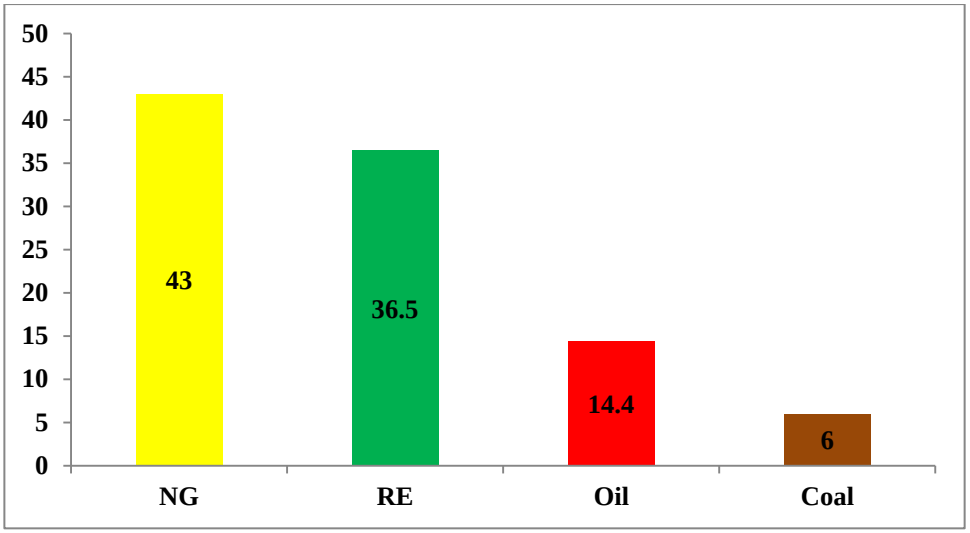

Figure 5.28. The results of local priorities for Alternatives to Socio-Political Criteria

5.8.4 Results of Global Priorities for Sub-criteria

In this section shows the global priorities results of sub-criteria in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondents, the most important priority was the availability of local expert (12%). It was followed by the availability of fund (9.5%), the research and development (9.1%), the capacity factor (8.2%), the national benefit (7.9%), the energy price (7.4%), the water consumption (6.2%), the operation and maintainance cost (5.6%), the technical maturity (5.2%), the capital cost (5%), the impact of biodiversity (4.9%), the compactability with Myanmar sustainable development plan (4.8%), the land use (3.9%), the acceptance of local people and politicians (3.6%), the impact on climate change (3.3%), and dependence on foreign energy resources (3.3%), respectively. The results of global priorities for sub-criteria are presented in Figure 5.29 and Table 5.24.

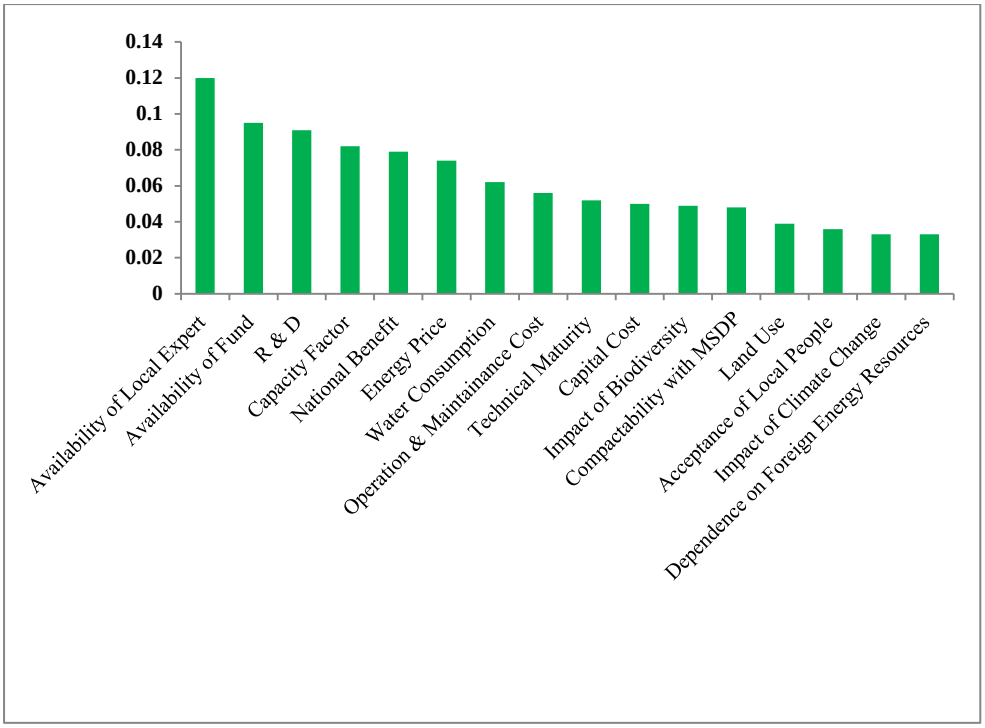

Figure 5.29.The results of global priorities for sub-criteria

Table 5.24. The results of global priorities for sub-criteria

Sub-Criteria	**Priority Weight**	**Priority Weight (%)**	**Rank**
Availability of Local Expert	0.120	12%	1
Availability of Fund	0.095	9.5%	2
R & D	0.091	9.1%	3
Capacity Factor	0.082	8.2%	4
National Benefit	0.079	7.9%	5
Energy Price	0.074	7.4%	6
Water Consumption	0.062	6.2%	7
Operation & Maintainance Cost	0.056	5.6%	8
Technical Maturity	0.052	5.2%	9
Capital Cost	0.050	5%	10
Impact of Biodiversity	0.049	4.9%	11
Compactability with MSDP	0.048	4.8%	12
Land Use	0.039	3.9%	13
Acceptance of Local People	0.036	3.6%	14
Impact of Climate Change	0.033	3.3%	15
Dependence on Foreign Energy Resources	0.033	3.3%	16
Total	**1**	**100%**	

5.8.5 Results of Global Priorities for Alternatives

In this section shows the global priorities results of alternatives in the evaluation of the sustainable energy mix in Myanmar. According to the answers of respondenses, the most important priority alternative was the natural gas (41.5%), followed by the renewable (34%), the oil (17.6%), and the coal (6.8%), respectively. The results of global priorities for alternatives are presented in Table 5.25 and Figure 5.30.

Table 5.25.The results of global priorities for alternatives

Alternatives	**Priority Weight**	**Priority Weight (%)**	**Rank**
Natural Gas	0.415	41.5%	1
Renewable	0.340	34%	2
Oil	0.176	17.6%	3
Coal	0.068	6.8%	4
Total	**1**	**100%**	

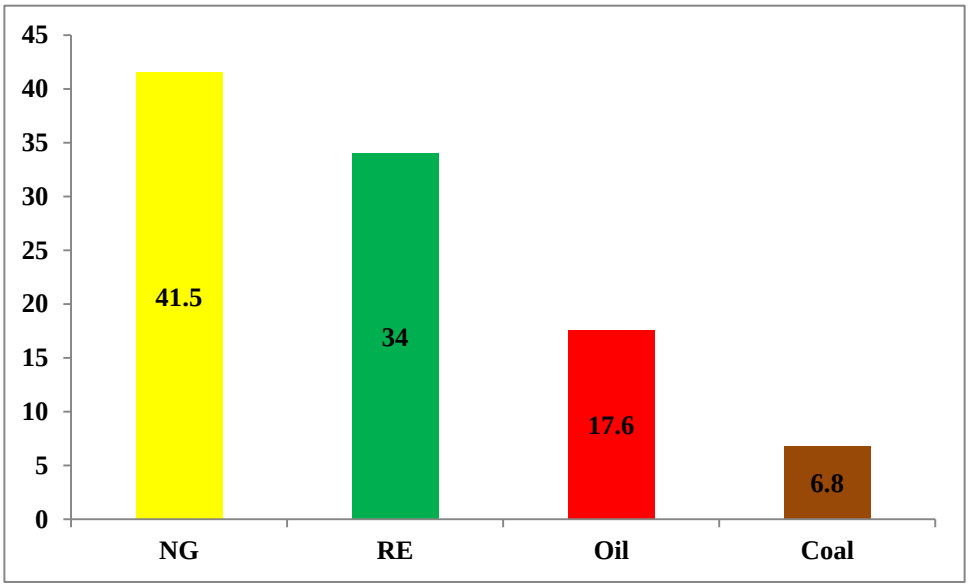

Figure 5.30.The results of global priorities for alternatives

5.9 Sensitivity Analysis

In this section, the study continues sensitivity analysis to evaluate the robustness of the calculated result of the evaluation of sustainable energy mix in Myanmar. It is used to calculate any major or minor variation in the obtained result. Moreover, the sensitivity analysis can confirm the changes in the final priortization of minor changes in priority weights of criteria. Thus, the weight of main criteria has been changed to determine the impact of criteria weights on ranking of energy resources alternatives. For this objective, the following 9 scenarios were divided:

Scenario 1: Baseline Scenario

Scenario 2: 20% Increased Technology Scenario

Scenario 3: 20% Decreased Technology Scenario

Scenario 4: 20% Increased Economic Scenario

Scenario 5: 20% Decreased Economic Scenario

Scenario 6: 20% Increased Environmental Scenario

Scenario 7: 20% Decreased Environmental Scenario

Scenario 8: 20% Increased Socio-Political Scenario

Scenario 9: 20% Decreased Socio-Political Scenario

In each scenario, one main criteria weight is set as 20% increased and decreased. The priority weights used are stated in Table 5.26.

Table 5.26. Criteria weight used for sensitivity analysis

	Technology	**Economic**	**Environmental**	**Socio-Political**
Scenario 1 Baseline	34.5	27.4	18.4	19.7
Scenario 2 20% I (TEC)	**41.3**	24.6	16.5	17.6
Scenario 3 20% D (TEC)	**27.7**	30.3	20.3	21.7
Scenario 4 20% I (ECO)	31.8	**33.1**	17.0	18.1
Scenario 5 20% D (ECO)	37.1	**22.0**	19.8	21.1
Scenario 6 20% I (ENV)	33.0	26.2	**22.0**	18.8
Scenario 7 20% D (ENV)	35.9	28.6	**15.0**	20.5
Scenario 8 20% I (S-P)	32.6	26.0	17.4	**24.0**
Scenario 9 20% D (S-P)	36.1	28.7	19.3	**15.9**

5.9.1 Scenario 1: Baseline Scenario

This scenario states the answers of respondenses to evaluation for sustainable energy mix in Myanmar. Therefore, the priority weights of the main criteria selected by respondenses were applied to calculate for this scenario. According to the answers of respondenses, the technology criteria (34.5%), the economic criteria (27.4%), the environmental criteria (18.4%), and the socio-political criteria (19.7%) were defined. The overall priority weight of alternatives show that the best option in the baseline scenario was the natural gas (41.5%), followed by the renewable (33.9%), the oil (17.7%), and the coal (6.9%). The baseline scenario results are shown in Figure 5.31.

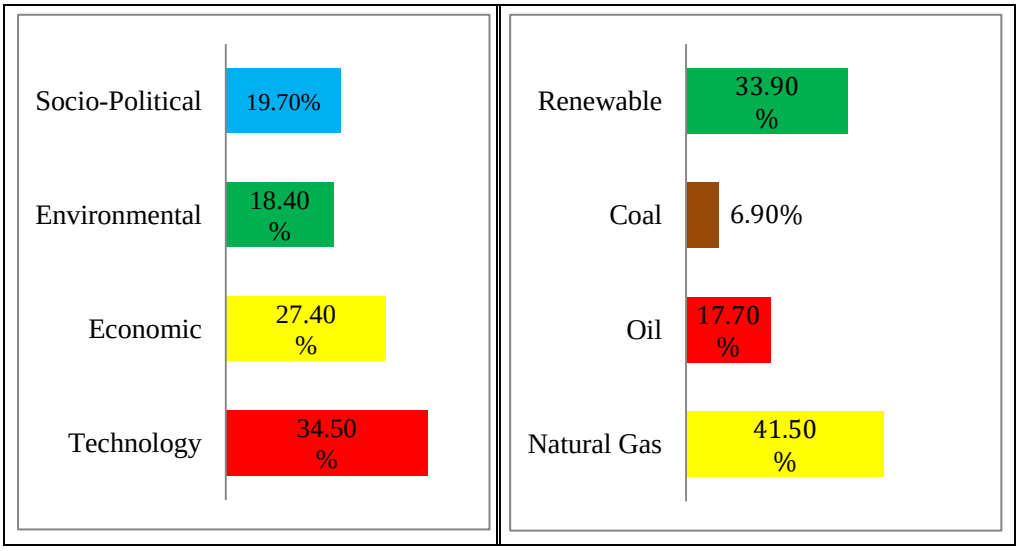

Figure 5.31. The results of baseline scenario

5.9.2 Scenario 2: 20% Increased Technology Scenario

To analysis sensitivity analysis for scenario 2, the technology criteria was considered as increased 20% to the baseline result. After chainging 20% increased the technology criteria, the priority weights of main criteria will be changed as technology criteria (41.3%), the economic criteria (24.6%), the environmental criteria (16.5%), and the socio-political criteria (17.6%). The overall priority weight of alternatives have been changed that the best option in the scenario 2 was the natural gas (42%), followed by the renewable (33.7%), the oil (17.5%), and the coal (6.8%). The scenario 2 results are shown in Figure 5.32. Therefore, the rankings in scenario 3 were the same as those in the baseline scenario.

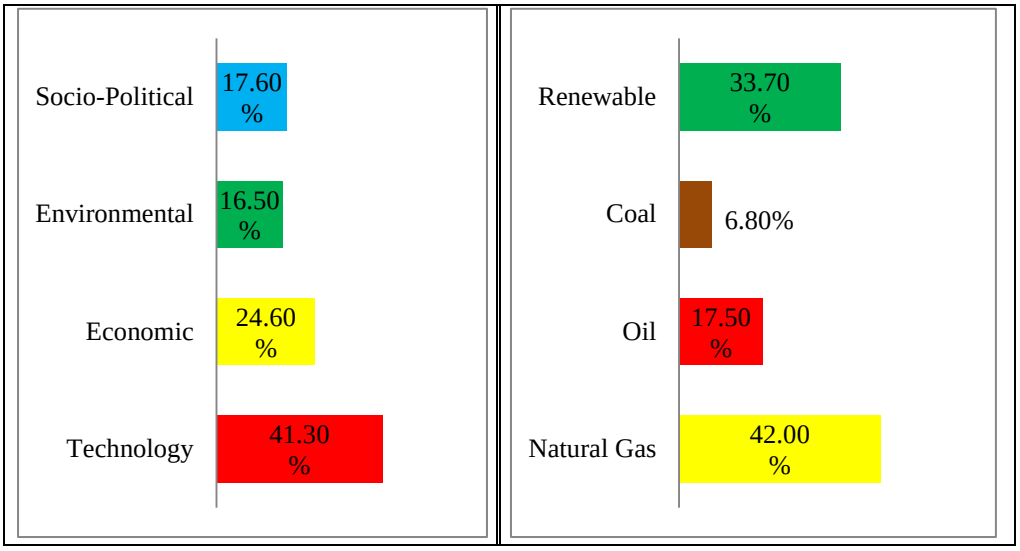

Figure 5.32.20% increase in Technology dimension

5.9.3 Scenario 3: 20% Decreased Technology Scenario

To calculate this scenario 3, the technology criteria was considered 20% decrease. Then, the priority weights of main criteria will be changed as technology criteria (27.7%), the economic criteria (30.3%), the environmental criteria (20.3%), and the socio-political criteria (21.7%). The results in Figure 5.33 shows that the best answer of this scenario 3 was the natural gas (41%), followed by the renewable (34.1%), the oil (17.9%), and the coal (7%). Therefore, the rankings in scenario 3 were the same as those in the baseline scenario.

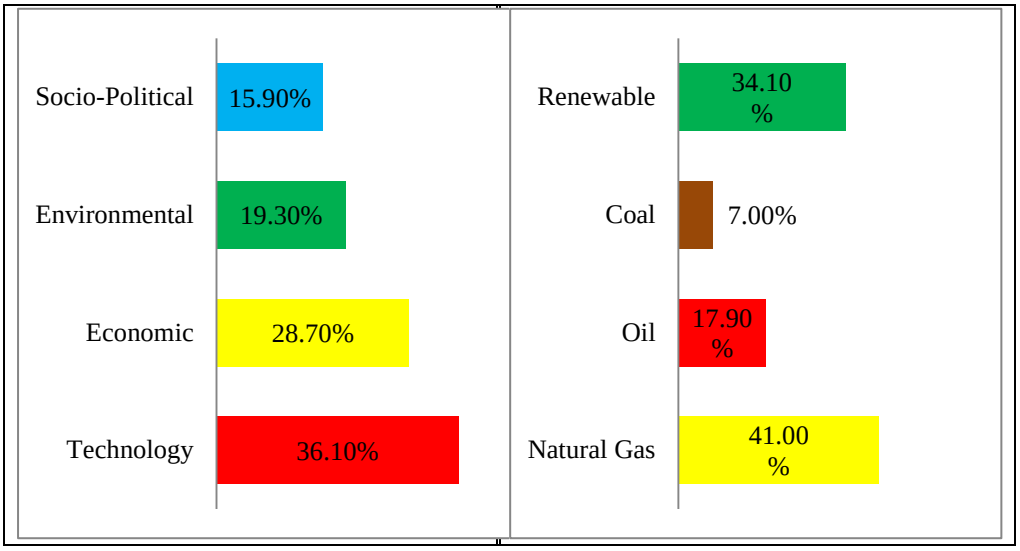

Figure 5.33. 20% decrease in Technology dimension

5.9.4 Scenario 4: 20% Increased Economic Scenario

After the economic criteria of baseline result increased 20%, the priority weights of main criteria have been changed the technology criteria (31.8%), the economic criteria (33.1%), the environmental criteria (17%), and the socio-political criteria (18.1%). Meanwhile, the first priority natural gas (41.5%), followed by the renewable (33.3%), the oil (18.2%), and coal (7%) were the best option in this scenario 4. The scenario 4 results are shown in Figure 5.34.

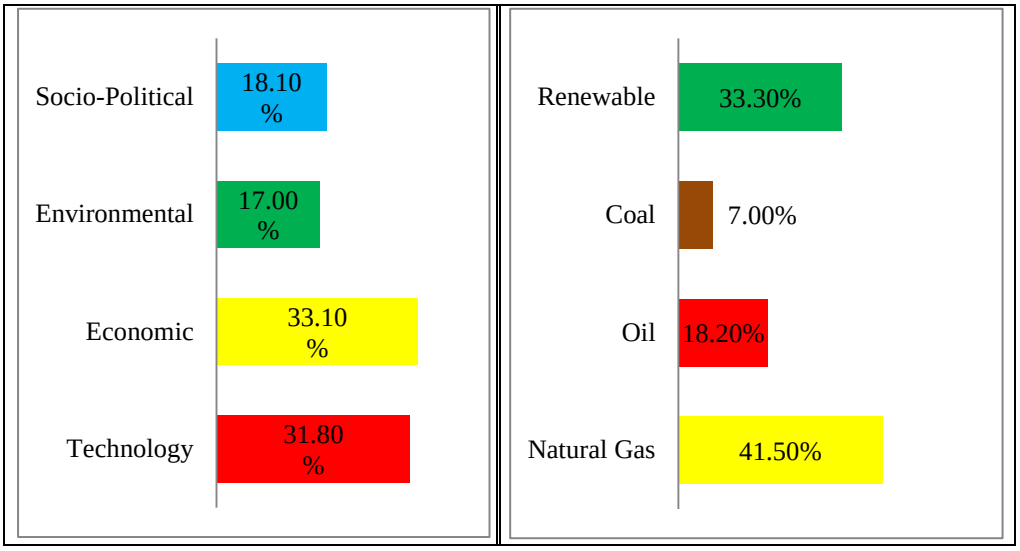

Figure 5.34. 20% increase in economic dimension

5.9.5 Scenario 5: 20% Decreased Economic Scenario

After the economic criteria of baseline result decreased 20%, the priority weights of main criteria have been changed the technology criteria (37.1%), the economic criteria (22%), the environmental criteria (19.8%), and the socio-political criteria (21.1%). Meanwhile, the natural gas (41.6%), followed by the renewable (34.5%), the oil (17.1%), and coal (6.8%) were the best option in this scenario 5. The scenario 5 results are shown in Figure 5.35.

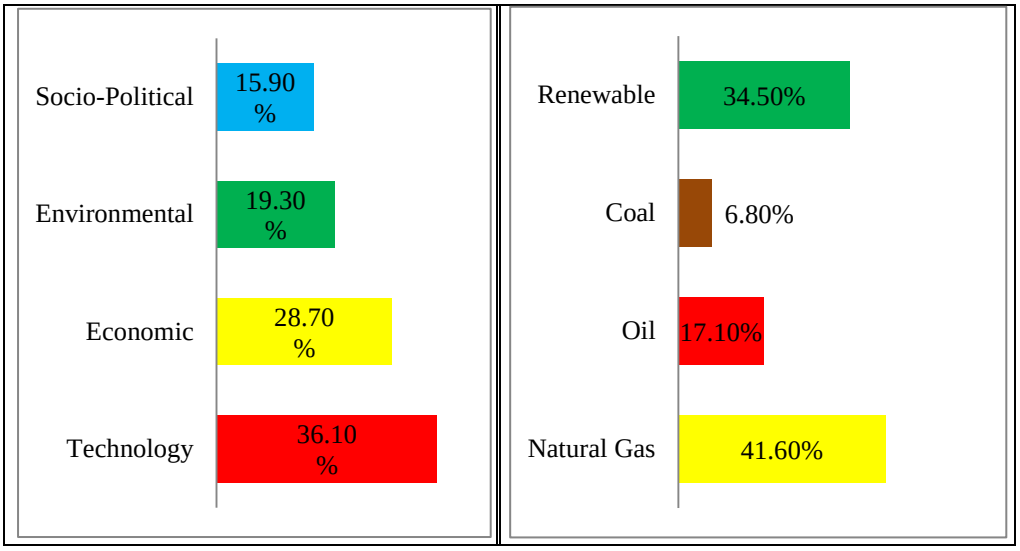

Figure 5.35. 20% decrease in economic dimension

5.9.6 Scenario 6: 20% Increased Environmental Scenario

After the environmental criteria of baseline result increased 20%, the priority weights of main criteria have been changed the technology criteria (33%), the economic criteria (26.2%), the environmental criteria (22%), and the socio-political criteria (18.8%). Meanwhile, the natural gas (41.1%), followed by the renewable (34.5%), the oil (17.5%), and coal (6.9%) were the best option in this scenario 6. The scenario 6 results are shown in Figure 5.36.

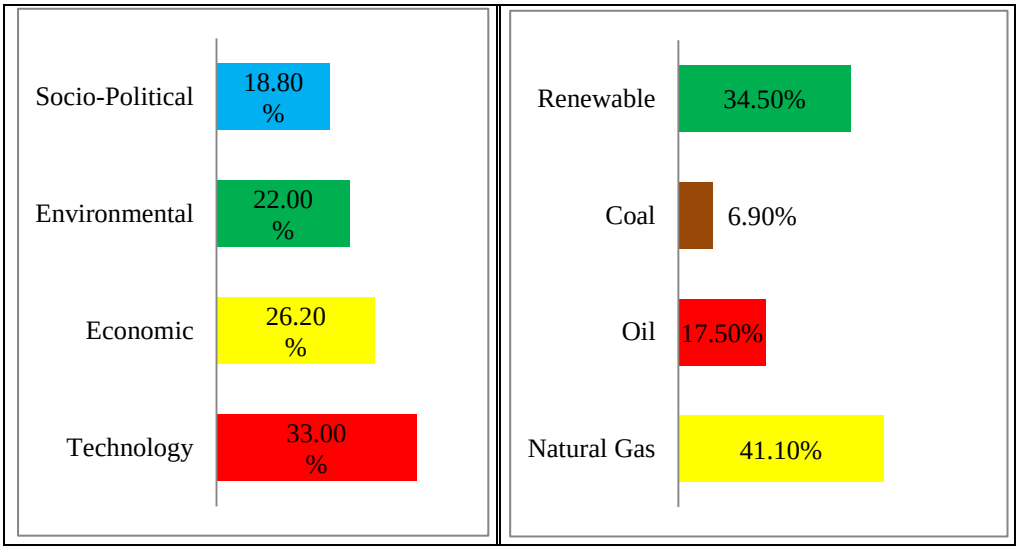

Figure 5.36. 20% increase in environmental dimension

5.9.7 Scenario 7: 20% Decreased Environmental Scenario

After the environmental criteria of baseline result decreased 20%, the priority weights of main criteria have been changed the technology criteria (35.9%), the economic criteria (28.6%), the environmental criteria (15%), and the socio-political criteria (20.5%). Meanwhile, the natural gas (41.9%), followed by the renewable (33.4%), the oil (17.8%), and coal (6.9%) were the best option in this scenario 7. The scenario 7 results are shown in Figure 5.37.

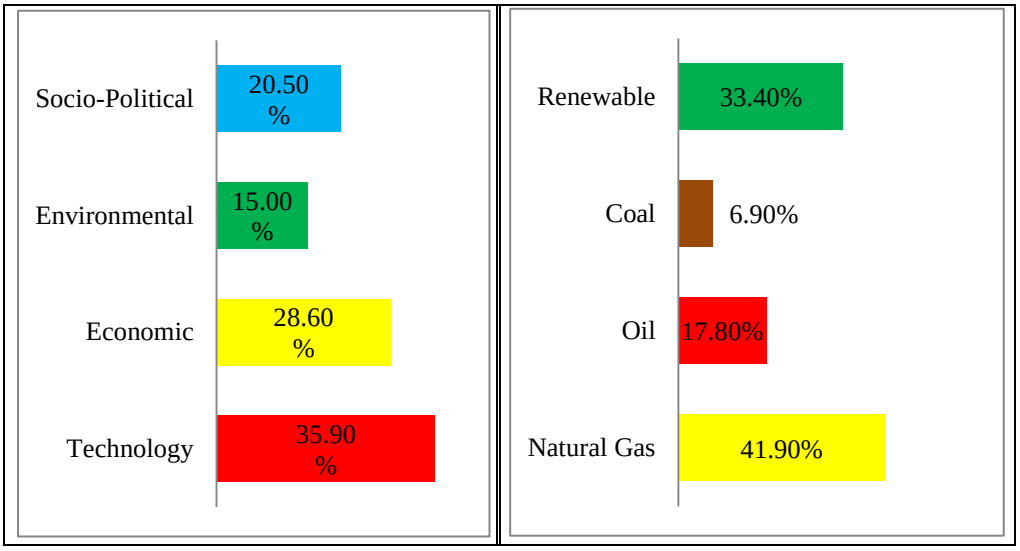

Figure 5.37. 20% decrease in environmental dimension

5.9.8 Scenario 8: 20% Increased Socio-Political Scenario

After the socio-political criteria of baseline result increased 20%, the priority weights of main criteria have been changed the technology criteria (32.6%), the economic criteria (26%), the environmental criteria (17.4%), and the socio-political criteria (24%). Meanwhile, the natural gas (41.6%), followed by the renewable (34%), the oil (17.5%), and coal (6.9%) were the best option in this scenario 8. The scenario 8 results are shown in Figure 5.38.

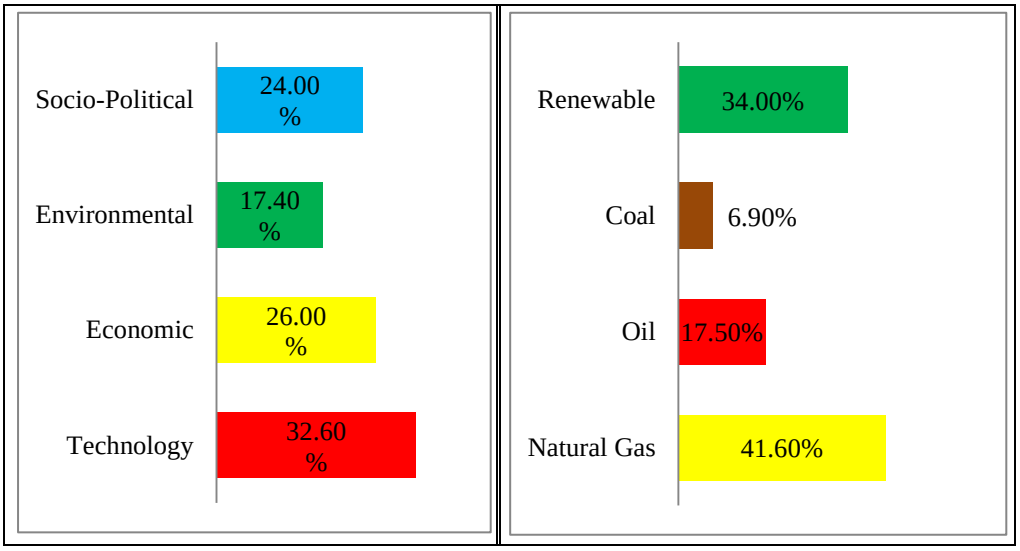

Figure 5.38. 20% increase in socio-political dimension

5.9.9 Scenario 9: 20% Decreased Socio-Political Scenario

After the socio-political criteria of baseline result decreased 20%, the priority weights of main criteria have been changed the technology criteria (36.1%), the economic criteria (28.7%), the environmental criteria (19.3%), and the socio-political criteria (15.9%). Meanwhile, the natural gas (41.5%), followed by the renewable (33.8%), the oil (17.8%), and coal (6.9%) were the best option in this scenario 9. The scenario 9 results are shown in Figure 5.39.

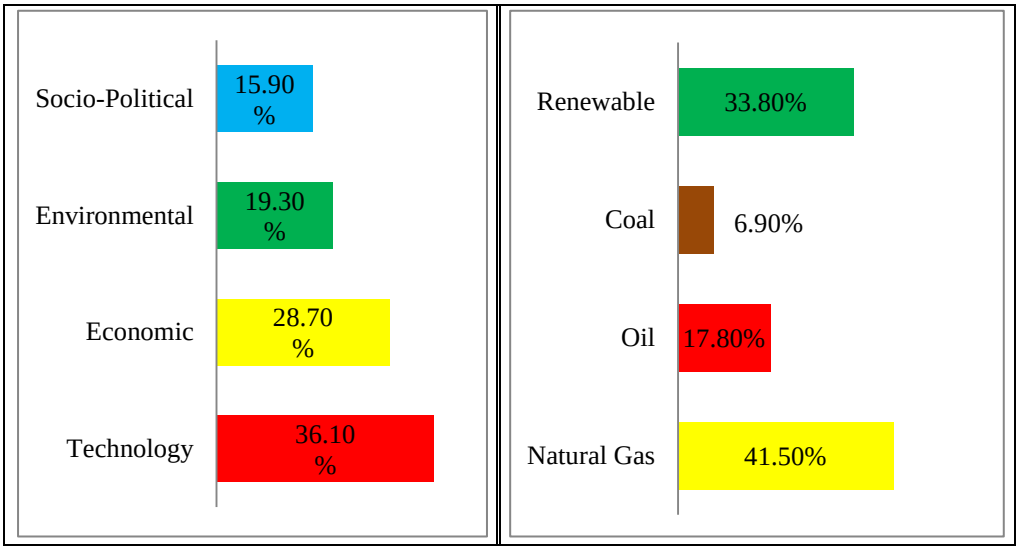

Figure 5.39. 20% decrease in socio-political dimension

According to the results of sensitivity analysis, natural gas is considered as the most significant energy resource for the evaluation of sustainable energy mix in Myanmar. It was followed by renewable, oil, and coal, respectively. The results of alternatives are shown in Table 5.27.

Table 5.27. Ranking of energy resources with priority weight.

		Natural Gas	Renewable	Oil	Coal
Scenario 1 Baseline	Priority weight	41.5%	33.9%	17.7%	6.9%
	Rank	**1**	**2**	**3**	**4**
Scenario 2 20% I (TEC)	Priority weight	42%	33.7%	17.5%	6.8%
	Rank	**1**	**2**	**3**	**4**
Scenario 3 20% D (TEC)	Priority weight	41%	34.1%	17.9%	7%
	Rank	**1**	**2**	**3**	**4**
Scenario 4 20% I (ECO)	Priority weight	41.5%	33.3%	18.2%	7%
	Rank	**1**	**2**	**3**	**4**
Scenario 5 20% D (ECO)	Priority weight	41.6%	34.5%	17.1%	6.8%
	Rank	**1**	**2**	**3**	**4**
Scenario 6 20% I (ENV)	Priority weight	41.1%	34.5%	17.5%	6.9%
	Rank	**1**	**2**	**3**	**4**
Scenario 7 20% D (ENV)	Priority weight	41.9%	33.4%	17.8%	6.9%
	Rank	**1**	**2**	**3**	**4**
Scenario 8 20% I (S-P)	Priority weight	41.6%	34%	17.5%	6.9%
	Rank	**1**	**2**	**3**	**4**
Scenario 9 20% D (S-P)	Priority weight	41.5%	33.8%	17.8%	6.9%
	Rank	**1**	**2**	**3**	**4**

After analysing sensitivity analysis, it can be clarified that the obtained results of AHP are reliable and robust, and there is no notable change in the result. Therefore, this research is very useful for policy and decision-makers in implementing reshaping energy mix of Myanmar energy policy.

5.10 Conclusion

It was possible to establish a multicriteria hierarchy for the selection of energy resources in the sustainable energy mix in Myanmar. It was demonstrated the flexibility and simplicity of the AHP as a useful tool to prioritize criteria, subcriteria and alternatives, in order to offer assistance to the decision maker.

The importance of expert choice software was verified to facilitate the processing of expert judgments, as well as the calculation of CRs for matrices obtained from paired comparisons. Four criteria were established: Technology, economic, environmental, and socio-political; as well as a total of sixteen subcriteria. After the process of aggregation of the individual judgments for all matrices combined, a CR≤10% accepted in the methodology proposed by Saaty for the AHP was obtained. Taking into account that the experts gave their opinions with the verbal scale proposed by Saaty, the geometric mean was obtained by transforming each verbal judgment to its numerical equivalent, using the fundamental scale of Saaty.

In the result of Ministry of Electricity and Energy, the aggregated results from respondents shows that the technology criteria (37.5%) had the greated influence on decision making. The technology criteria was followed by the economic criteria (34.5%), the socio-political criteria (15.6%), and the environmental criteria (12.3%) respectively. According to the answers of respondents from Ministry of Electricity and Energy, the most important priority was the availability of local expert (15%). It was followed by the availability of fund (12%), the capital cost (11%), the technical maturity (9.1%), the capacity factor (8.2%). According to the answers of respondenses from Ministry of Electricity and Energy, the most important priority

alternative was the natural gas (37.6%), followed by the oil (35.5%), the renewable (15.8%), and the coal (11.1%), respectively.

In the result of Ministry of Natural Resources and Environmental Conservation, the aggregated results from respondents shows that the environmental criteria (35.2%) had the greated influence on decision making. It was followed by the technology criteria (33.7%), the economic criteria (20.2%), and the socio-political criteria (10.9%), respectively. According to the answers of respondents from Ministry of Natural Resources and Environmental Conservation, the most important priority was the impact on climate change (13%). It was followed by the capital cost (11%), the impact of biodiversity (9.4%), the research and development (9%). According to the answers of respondenses from Ministry of Electricity and Energy, the most important priority alternative was the natural gas (37.6%), followed by the oil (35.5%), the renewable (15.8%), and the coal (11.1%), respectively.

In the result of Ministry of Planning, Finance and Industry, the aggregated results from respondents shows that the technology criteria (40%) had the greated influence on decision making. The technology criteria was followed by the economic criteria (34.5%), the socio-political criteria (14.3%), and the environmental criteria (11.2%) respectively. According to the answers of respondents from Ministry of Planning, Finance and Industry, the most important priority was the availability of local expert (14%). It was followed by the technical maturity (12.6%), the availability of fund (11%). According to the answers of respondenses from Ministry of Planning, Finance and Industry, the most important priority alternative was the natural gas (36.6%), followed by the oil (30.5%), the renewable (20.8%), and the coal (12.1%), respectively.

In all of respondents from three ministries, the technology (34.5%) and economic (27.5%) criteria were the most relevant for multicriteria decision-making. In the case of sub-criteria, the highest global priority was for the technology subcriteria of availability of local expert (12%) and availability of fund (9.5%), the research and development (9.1%). Four energy alternative options were defined: Natural Gas (41.5%), Renewable (34%), Oil (17.6%) and Coal (6.8%). Five matrices combined were implemented as a result of the comparisons of pairs of the four energy alternatives with respect to the technology, economic, environmental, and socio-political criteria. The CR obtained for each of the 5 matrices was lower than the 10% proposed for the AHP.

For all the evaluated alternatives, the highest pertinence was for Natural Gas. Second was for Renewable. These results demonstrated the importance that experts gave to these energy resources for sustainable energy mix in Myanmar.

6 General Conclusion and Policy Implications

6.1 General Conclusion

This study consists of three researches. The first one, Does energy consumption drive Economic Growth in Myanmar? Evidence from fuel types, finds the causality relationship between economic growth GDP, total primary energy consumption TPEC, crude oil consumption OC, natural gas consumption NGC, electricity consumption ELC, and coal consumption CC for the Republic of the Union of Myanmar over the period 1990-2017. Time series data of the variables have been analyzed unit root test, Johansen cointegration test, Vector Error Correction Model (VECM) or Vector Autoregression Model (VAR), and Granger Causality Test to evaluate the direction of causality among variables.

The results of total primary energy consumption and economic growth and oil price nexus show that there has long run causality from total primary energy consumption EC to economic growth GDP, when energy consumption increases 1%, economic growth will increase 0.65%, in Myanmar in the period 1990-2017. Similarly, there is long run causality from oil price OP to economic growth GDP, when oil price increases 1%, economic growth will increase 0.16%. On the other hand, there has long run causality from economic growth GDP to total primary energy consumption EC, when economic growth increases 1%, crude oil consumption will increase 0.34%. Nevertheless, the control variable oil price (OP) does not effects to the dependent variable total primary energy consumption (EC). It means that there is no long run causality from oil price OP to total primary energy consumption EC.

The results of the crude oil consumption and economic growth nexus show that there has long run causality between GDP and OC. When crude oil consumption increases 1%, economic growth will increase 0.87%. On the other hand, there is causality from economic growth GDP to crude oil consumption OC, when economic growth increases 1%, crude oil consumption will increase 0.29%. Moreover, it has unidirectional short run causality relationships from economic growth GDP to crude oil consumption OC in Myanmar in the period 1990-2017.

Since, economic growth GDP and natural gas consumption NGC were cointegrated in Johansen cointegration test, the study continued with Wald causality test which was calculated base on the VECM. The result shows that there are long run causaltiy, when natural gas consumption increases 1%, economic growth will increase 2% and when economic growth increases 1%, natural gas consumption will increase 0.65%. Moreover, there is bidirectional short run causality between economic growth GDP and natural gas consumption NGC in Myanmar in the period 1990-2017.

According to the result, in the relationships between economic growth GDP and crude electricity consumption ELC, there has no both long run and short run causality between GDP and ELC in Myanmar in the period 1990-2017.

Base on the results of economic growth GDP and coal consumption CC, there are long run causaltiy, when coal consumption increases 1%, economic growth will increase 0.77% and when economic growth increases 1%, coal consumption will increase 3%. Moreover, there is bidirectional short run cauaslity relationships between economic growth GDP and natural coal consumption CC in Myanmar in the period 1990-2017.

Overall, the study finding of bidirectional Granger causality between economic growth GDP and crude oil consumption OC, unidirection Granger causality from GDP to natural gas consumption NGC, and bidirectional Granger causality between economic growth GDP and coal consumption CC are important implications for policy analysts and forecasters in Myanmar.

The second research is What Is The Role of Sectoral Energy Consumption in Economic Growth? The Case of Myanmar. This study employs a panel data set for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017 to explore the causal relationship between energy consumption and economic growth taking into account other factors as CO2 emission.

Pedroni heterogeneous panel cointegration test reveals there is a long-run equilibrium relationship between economic growth (GDP), energy consumption, and CO2 emission. This long-run relationship suggests that a 1% increase in energy consumption increases GDP by 5.51%; a 1% increase in CO2 emission increases GDP by 7%. Furthermore, the estimation of a panel vector error correction model indicates the presence of both short-run and long-run Granger-causality from energy consumption to economic growth lending support for the growth hypothesis. The positive impact of energy consumption on economic growth suggests that energy consumption plays an important role in the economic growth both directly and indirectly as a complement to CO2 emission for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017.

Similarly, the GDP has a positive long-run impact on energy consumption at a 1% significance level and CO2 emission as well. The energy consumption EC will increase by 0.12% if GDP increases by 1%. Furthermore, the estimation of a panel vector error correction model indicates the presence of both short-run and long-run Granger-causality from economic growth to energy consumption lending support for the growth hypothesis. The positive impact of economic growth on energy consumption suggests that the economic growth plays an important role in energy consumption both directly and indirectly as a complement to CO2 emission for four sectors in Myanmar (Industry sector, Transportation sector, Agricultural sector, and Commercial and Public Service sector) over the period 1990–2017.

It was possible to establish a multicriteria hierarchy for the selection of energy resources in the sustainable energy mix in Myanmar. It was demonstrated the flexibility and simplicity of the AHP as a useful tool to prioritize criteria, subcriteria and alternatives, in order to offer assistance to the decision maker.

The importance of expert choice software was verified to facilitate the processing of expert judgments, as well as the calculation of CRs for matrices obtained from paired comparisons. Four criteria were established: Technology, Economic, Environmental, and Socio-political; as well as a total of sixteen subcriteria. After the process of aggregation of the individual judgments for all matrices combined, a CR≤10% accepted in the methodology proposed by Saaty for the AHP was obtained. Taking into account that the experts gave their opinions with the verbal scale proposed

by Saaty, the geometric mean was obtained by transforming each verbal judgment to its numerical equivalent, using the fundamental scale of Saaty.

The results from Ministry of Electricity and Energy, the technology and economic criteria were the most relevant for multicriteria decision-making. In the case of sub-criteria, the highest global priority was for the technology subcriteria of availability of local expert. Four energy alternative options were defined: Natural Gas (37.6%), Oil (35.5%), Renewable (15.8%), and Coal (11.1%).

The results from Ministry of Natural Resources and Environmental Conservation, the environmental and technology criteria were the most relevant for multicriteria decision-making. In the case of sub-criteria, the highest global priority was for the environmental subcriteria of impact of climate change. Four energy alternative options were defined: Renewable (38%), Natural Gas (33.4%), Oil (20.3%), and Coal (8.3%).

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The technology and economic criteria were the most relevant for multicriteria decision-making. In the case of sub-criteria, the highest global priority was for the technology subcriteria of availability of local expert. Four energy alternative options were defined: Natural Gas (41.5%), Renewable (34%), Oil (17.6%) and Coal (6.8%). Five matrices combined were implemented as a result of the comparisons of pairs of the four energy

alternatives with respect to the technology, economic, environmental, and socio-political criteria. The CR obtained for each of the 5 matrices was lower than the 10% proposed for the AHP.

The main objectives of this study intends to examine the relationship between economic growth as measured by gross domestic product (GDP) and energy consumption for Myanmar from 1990 to 2017. Moreover, in order to fulfill domestic energy consumption, the study also determines the importance of the criteria and sub-criteria to be taken into account in the decision making process for the future energy mix in Myanmar.

Based on the analysis results of the examination, the analysis reveals high energy consumption leads to economic growth GDP, though there are many other factors contributing to economic growth, and energy consumption is only one of such factors. Especially, natural gas consumption is the highest contribution to economic growth, when natural gas consumption increases 1%, the economic growth will be increased by 2%. It followed by oil consumption, if oil consumption incrases 1%, economic growth will be increased 0.87%. After that, coal consumption is the third important to increase GDP of Myanmar, GDP will be growth 0.77% if coal consumption increases by 1%. However, electricity consumption is not effect to economic growth in Myanmar at the same period. Because, Myanmar is still an electricity starved country, with 50% of the households having access to grid based electricity services. Now, Myanmar Government is planned to achieve 100% electricity by 2030.

Regarding the another objective of this study, the selection of energy resources in the sustainable energy mix in Myanmar, the aggregated results based on experts' opinions show that the most important criterion to be

considered in the energy decision making process is the technology criterion. It followed by economic criteria, socio-political criteria and environmental criteria. In the sbu-criteria, the highest global priority was for the technology subcriteria of availability of local expert. Four energy alternative options were defined: Natural Gas (41.5%), Renewable (34%), Oil (17.6%) and Coal (6.8%).

Based on this finding, in order to make sure that energy mix of Myanmar is seletcted while considering technology, economic, environmental and socio-political aspects, this study can help decision-makers with solutions to identify appropriate energy resources to be applied in the future energy planning of Myanmar. The complex process of decision making for the choice of energy resources has been studied from the perspective of Myanmar and the performance of the sensitivity analysis shows that the AHP method applied in this study is flexible and robust.

6.2 Policy Implications

In order to draw effective energy and environmental policies, policymakers need to understand well the relationship between energy consumption and economic growth. As the country is developing, the domestic energy demand is certainly enormous so far. To build a well-disciplined and developed democracy country, the government has simultaneously undertaken economic, political and educational reforms and has been recognized by international circles because of the dramatic changes in Myanmar. Moreover, foreign companies are interested in a huge investment because economic sanctions imposed by the US and the European countries for two decades have been lifted. Increasing investment in Myanmar can create job opportunities and the economy of the country will be booming, needless to say. It is certain that filling the energy consumption which kept abreast of the country development has played a vital role. The relevant ministries are undertaking long-term and short-term plans to meet the domestic energy demand which are essential for the country development.

Myanmar is rich in energy resources such as oil and natural gas, hydro power and coal as well renewable energy such as solar energy, wind energy, geothermal, biomass. Energy consumption of the country per capita has been a little compared with those of neighboring countries. We should try to produce the abundant energy resources in our country as possible as we need to use energy more and more for the development of the country.

It is necessary to seek technical and financial assistance in cooperation with foreign companies to produce oil and gas and to expand fresh onshore and offshore oilfields. In the same way, oil production will be

set up with modern technology. It is necessary to undertake joint venture with private companies and Producing Sharing Contract Agreements for oil and gas exploration, drilling and production activities, production, distribution and sale of petroleum product, transportation, pipeline connection etc. with technical and financial assistance.

Based on the results of this study, energy consumption positively affect to economic growth, especially, natural gas consumption is most effective, and followed by crude oil consumption, coal consumption, respectively. Therefore, this study finding of feedback between energy consumption and economic growth has important implications for policy makers in Myanmar. The results support to the argument that economic growth stimulates energy consumption. Intuitively, increased economic growth needs enormous energy consumption and a high level of energy consumption carries to a high level of economic growth. Though there are many other factors contributing to economic growth, and energy consumption is one of such factors. This implies that energy consumption infrastructure shortage may restrain the economic growth in Myanmar.

In fossil fuel supply sources, the natural gas fuel emission amount is the lowest rather than crude oil, oil product and coal. In this connection, natural gas is one of alternative fuel as CO2 emission issues. In particular, natural gas is used as not only fuel but also raw material as non-energy industry sector, such as making fertilizer, lubricant etc. Obviously, Myanmar is one of the natural gas rich countries in the South East Asia Region and which produces 12776.514 ktoe (kilo tons of oil equivalent) in 2014. Among them, (1543.885 ktoe, 12%) of natural gas are transformed to electricity generation for domestic utilization and utilizes in domestic industry sector

(374.657 ktoe, 3%), transport sector (172.565, 1%), non-energy sector (132.314, 1%) and the rest of (83%) exported to the neighboring countries.

Moreover, Myanmar natural gas utilization is dramatically increased year by year since 1971 (55.401 ktoe) and 2014 (2109.738 ktoe), which is 38 times relatively larger in 48 years. In fact, electricity generating sources by natural gas is significantly higher in 48 times in 48 years. In which, very big demand in natural gas fuel sources for electricity transformation is one of the alternative fuel issue and energy mix scenario in Myanmar. Moreover, the fuel mix for electricity generating by 2030 natural gas scenario is 20% which is equivalent to the 4.758GW installed capacity (Myanmar energy master plan 2015). Therefore, the natural gas demand will be about 1100 mmscfd which is about 2.5 times of current situation.

The BP Statistical Review of World Energy June 2016, natural gas proved reserve is 18.7 TCF. Moreover, new offshore gas field discovery is found in western part of Myanmar (Block A-6) and Deep Sea (Block AD-7). Therefore, the potential of natural gas discovery will be a good chance to support country economic development. In the meantime, natural gas production, distribution and electricity generating industry are going to increase for country development.

Currently, Economic policy is achieved to develop by industrial sector, such as developing into the three special economic zones. For the long term plan, natural gas demanding for industrial sector will be developed too. The Gross Domestic Product (GDP) is the economic indicator of countries economic growth rate and annual growth rate is 8% by 2014.

Myanmar Natural gas industry is one of major roles in country economic development and which is directly related to the industrialization,

electrification etc. Even though, natural gas utilization for domestic sector is limited by the domestic gas quota and natural decline of onshore production.

Nevertheless, GDP growth and natural gas consumption sectors are positively related to each other. In this connection, natural gas utilization in domestic sector is needed to be support by government energy policy. For implementing the new energy policy, GDP and natural gas utilization electricity generating sector is assumed to be cointeration and many of scholars are analyzed for economic growth and natural gas consumption and production. Therefore, Myanmar natural gas utilization industry network is needed to be analyzed by interconnecting between economic growth and sectoral natural gas consumption relationship.

In the policy implication, causality direction is important. When the bidirectional causality is occurred in natural gas production to economic growth, the declining of natural gas production may occur in economic growth. Moreover, the decline in natural gas production may seriously impact to economic growth. In contract, the policy implementing and the alternative fuel source should be considered as big issue. Therfore, Myanmar Government should consider the following policy implications.

Myanmar Government needs to consider energy consumption positively affects to economic growth. Especially natural gas is as the first priority in the decision making process for the future energy mix to obtain sustainable economic growth. Myanmar energy needs are growing along with its economic growth. Natural gas is more reliable than other resources in terms of availability because expansion of reliability electricity supply is necessary. Natural Gas will still have a large share in the energy mix in the

future. Based on this condition, natural gas energy planning has been a priority of the government of Myanmar.

According to the aggregated results from experts' opinions for the selection of energy resources in the sustainable energy mix in Myanmar, the most important criterion to be considered in the energy decision making process is the technology criterion. It followed by economic criteria, socio-political criteria and environmental criteria. In the sbu-criteria, the highest global priority was for the technology subcriteria of availability of local expert. Four energy alternative options were defined: Natural Gas (41.5%), Renewable (34%), Oil (17.6%) and Coal (6.8%).

Based on this finding, in order to make sure that energy mix of Myanmar is seletcted while considering technology, economic, environmental and socio-political aspects, this study can help decision-makers with solutions to identify appropriate energy resources to be applied in the future energy planning of Myanmar.

According to the feedback hypothesis, energy conservation is not an appropriate energy policy at this development stage. Therefore, to boost the economy, Myanmar government and policymakers must give more attention to increasing energy consumption. It's noteworthy to be mentioned that, Myanmar intends to achieve the goals of sustainable development, which needs to consider the environmental side effects of energy consumption. In this case, energy diversification can be considered as an appropriate energy policy.

From the obtained outcomes, natural gas is the main fuel in the energy mix at the first step. However, alongside with more investment in renewable energy sources and technological progress, the government and

policy makers can switch from natural gas to renewable energy sources. Therefore, taking some measures and actions to develop natural gas industry is needed. In order to developing natural gas industry in Myanmar, the government should be implemented as the following;

1. Provision required infrastructure for developing natural gas industry like pipeline network, storage, distribution stations, etc., through allocating subsidy for constructing and expanding the infrastructure, absorbing foreign direct investment (FDI) through launching new rules or revising the current foreign-related regulations to provide an enabling and secure environment for investors (both domestic and foreign).
2. Increasing local expert's capabilities and abilities in natural gas industry through holding training coursework, education-related workshops and conferences, seminars, and so on.
3. Currently, Myanmar exports 75% of natural gas production to neighboring countries such as China and Thailand. Therefore, Myanmar government should review natural gas export policy.
4. Providing Research and Development investment incentives in natural gas consumer through facilitating technology transfer or rendering a part of R&D costs.
5. Energy consumption of industrial sector, agricultural sector, transportation sector, and commercial and public sector has significant impact to GDP. Therefore, the government should put more attention on growing the energy demand in these sectors.
6. Regarding to the results of AHP, technology criteria is most important. Thus, the government shall invite international companies to introduce the appropriate technology to support

Myanmar. Then, the government shall support technology and knowledge transfer between advanced developed countries and Myanmar.

7. From the result of this research, Natural Gas can be considered as a main fuel in the energy mix at the first step. However, over time, with increased investment in Renewable Energy Sources improving technological progress, the government and policy makers can switch from natural gas to RES.

6.3 Limitations of the study

There are many limitations in this study, mostly from the structure and configuration of the models this study utilized and many from the limitations of data from Myanmar. In the first essay, empirical analyses found the causality relationships between economic growth GDP, total primary energy consumption TPEC, crude oil consumption OC, natural gas consumption NGC, electricity consumption ELC, and coal consumption CC for Myanmar over the period 1990-2017. As we know, the economic growth, i.e., GDP, of a country is contributed not just by energy consumption, but also by the inputs of other parameters such as labor inputs, capital investments, foreign direct investment (FDI), government expenditure, export, import, etc. However, due to the lack of the data, and the configuration of the empirical model, the study could not include the contributions of other parameters. Future studies should consider not only energy consumption but also the input of other parameters to the growth to analysis the economic growth of a country. In this study, oil price was implied as control variable. This study did not consider the other parameters as a control variable such as, natural gas price, coal price, exchanged rate, inflation rate, and CO2 emission.

In the second essay, the study employed the causality relationship between economic growth and energy consumption of Myanmar by sectors such as industrial sector, agricultural sector, transportation sector, and commercial and public sector over the period 1990-2017. Despite these four sectors are main contribution to Myanmar economy, residential sector should be consider to analysis the relationship between economic growth and energy consumption. This study did not include the residential sector because of

limitation of the data. Therefore, the future studies should consider the residential sector to investigate the relationship between economic growth and energy consumption for Myanmar. Moreover, this study only considered CO2 emission as a control variable. This study did not consider the other parameters as a control variable such as oil price, labor, capital, and FDI.

In the third essay, the study ranked energy sources for evaluation of the sustainable energy mix in Myanmar by using Analytical Hierarchy Process (AHP) including four main criteria, sixteen sub-criteria, and four alternatives. This study surveyed government officials of three ministries of central Myanmar government due to the authority on developing national energy planning and regulations and also in order to analyze decision making processes of related government ministries. However, to draw a set of policy alternatives in real situations, additional studies that include surveys from the other groups or organizations such as academic institutions, private companies, environmental experts, Non-Government Organizations (NGOs), other concerned parties, etc. are needed. For the future study, it is needed to consider a different set of criteria and sub-criteria and different set of the respondents to evaluate policies for sustainable energy mix in Myanmar.

Moreover, this study only considered four alternatives of energy source category such as natural gas, oil, renewable energy, and coal due to lack of proper data. Adding additional energy sources as alternatives for evaluation of the sustainable energy mix in Myanmar is needed for further study.

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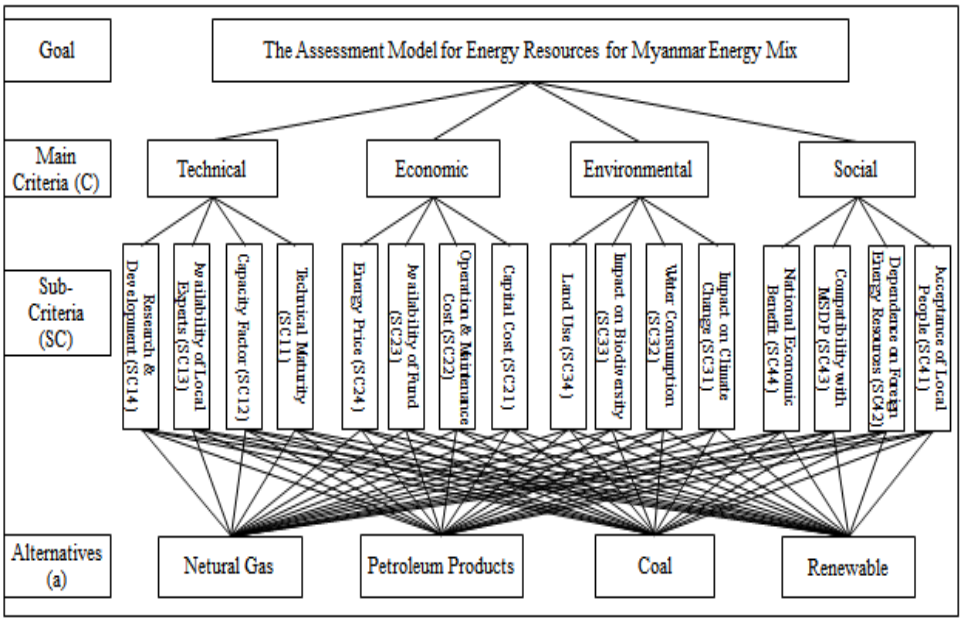
8 Annex

Survey Questionnaire

Evaluation of sustainable future energy mix in Myanmar.

Section A: Participant's Details
Name :
Email:
Organization/ Department:
Designation/ Position:
Total Experience in current occupation: …….. Years

In this questionnaire, the pairwise comparison questions are based on hierarchy tree below, with four criteria, sixteen sub-criteria and four alternative criteria. The important of each criterion, sub-criterion and alternative will be calculated using qualitative and quantitative methods.



How to answer this questionnaire?

You only need to give your judgment based on your own preference and choose the most important factor from two criteria or sub-criteria. Example: You have to compare the relative importance between A and B, to answer the question; you can choose one option among all nine options, which much more represent your view or preference. You must note that the degree of importance for left side criterion, in this case is A, continuous to decline from 1 to 4 while the level of importance for right criterion, in this case is B, continuous to increase from 6 to 9. And if you believe that the two options are equally important, you can choose 5 as your answer.

When “A” is more prefer than “B”:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
A		✓								B

When “B” is more prefer than “A”:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
A							✓			B

When “A” and “B” is equally prefer:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
A					✓					B

Section B : Main Criteria and Sub-Criteria for the Ranking

In this questionnaire, we used the pairwise comparison questions are based on Analytic Hierarchy Process (AHP). Pairwise comparison is to measure relative important between two factors.

Description of each main criterion:

A. Technology Criterion

This criterion used as a calculation on selecting the energy resources based on technical aspect and technology.

B. Economic criterion

This criterion is used as a measurement of cost and benefit can be affected on the energy resources for Myanmar energy mix.

C. Environmental Criterion

This criterion is used to measure the environmental effect that might happen after selecting the energy source for energy mix.

D. Social Criterion

This criterion becoming as consideration in selecting the energy source for future energy mix on socio and political matter. Example the effect of socio-political matter is acceptance of local people after choosing one specific energy source.

Question:

In decision making process of the Assessment Model for Energy Resources of Myanmar Energy Mix, which is criterion that you consider more important?

1) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar, which is criterion that you consider more important?										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Technical										Economic
Technical										Environmental
Technical										Socio-Political
Economic										Environmental
Economic										Socio-Political
Environmental										Socio-Political

Selection in Technology Criteria

Considering the various criteria support for the Assessment Model for Energy Resources of Myanmar Energy Mix, one of those criterions is technology criterion. In this section, you have to provide your personal judgment in comparing two relative important of two factors in technology criterion, by the following question:

Description of each factor:

a) Technical Maturity

This criterion is to determine a given technology's readiness for ultimate application in future Myanmar Energy Mix. It will evaluate the technical maturity of each energy source.

b) Capacity Factor

A measure of the actual total final energy supply over a period of time divided by the maximum energy supply.

c) Availability of Local Experts

Expert manpower available in the country to operate and maintain in the energy industry.

d) Research and Development

Expenses occurred on the research and development of a technology alternative.

Question:

In decision making process of the Assessment Model for Energy Resources of Myanmar Energy Mix, which is criterion that you consider more important?

2) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar, which is criterion that you consider more important?

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Technical Maturity										Capacity Factor
Technical Maturity										Availability of Local Experts
Technical Maturity										Research & Development
Capacity Factor										Availability of Local Experts
Capacity Factor										Research & Development
Availability of Local Experts										Research & Development

Selection in Economic Criteria

Considering the various criteria support for the Assessment Model for Energy Resources of Myanmar Energy Mix, one of those criterions is economic criterion. In this section, you have to provide your personal judgment in comparing two relative important of two factors in technology criterion, by the following question:

Description of each factor:

a) Capital Cost

Capital cost comprise of land cost, the costs of the necessary buildings and infrastructures and equipment to supply energy consumption in the Myanmar energy industry. Labor and infrastructures maintenance costs are not included in capital costs.

b) Operation and Maintenance Cost

Operation and Maintenance Cost include wages of the labors, and the funds spent for the energy, the products and services of energy industry.

c) Availability of Funds

This criterion evaluates the national and international funds and economic support of government.

d) Energy Price

The price of energy offered by the energy supplied system includes all the costs over the lifetime of the systems: initial investment, operation and maintenance, fuel cost, and cost of capital

Question:

In decision making process of the Assessment Model for Energy Resources of Myanmar Energy Mix, which is criterion that you consider more important?

3) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar, which is criterion that you consider more important?										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Capital Cost										Operation & Maintenance Cost
Capital Cost										Availability of Funds
Capital Cost										Energy Price
Operation & Maintenance Cost										Availability of Funds
Operation & Maintenance Cost										Energy Price
Availability of Funds										Energy Price

Selection in Environmental Criteria

Considering the various criteria support for the Assessment Model for Energy Resources of Myanmar Energy Mix, one of those criterions is environmental criterion. In this section, you have to provide your personal judgment in comparing two relative important of two factors in technology criterion, by the following question:

Description of each factor:

a) Impact on Climate Change

It represents the climate change impacts caused by energy consumption of each sector, especially greenhouse gases (CO2, NOx, SO2) , small particles etc.

b) Water Consumption

It represents water consumed per unit of energy consumption, especially electricity generation.

c) Impact on Biodiversity

It refers to the impacts on biodiversity due to energy production and consumption.

d) Land Use

It refers to the land used over the entire lifecycle of the unit (e.g. fuel extraction, processing and delivery, construction, operation and decommissioning)

Question:

In decision making process of the Assessment Model for Energy Resources of Myanmar Energy Mix, which is criterion that you consider more important?

4) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar, which is criterion that you consider more important?										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Impact on climate change										Water Consumption
Impact on climate change										Impact on Biodiversity
Impact on climate change										Land Use
Water Consumption										Impact on Biodiversity
Water Consumption										Land Use
Impact on Biodiversity										Land Use

Selection in Socio-Political Criteria

Considering the various criteria support for the Assessment Model for Energy Resources of Myanmar Energy Mix, one of those criterions is socio-political criterion. In this section, you have to provide your personal judgment in comparing two relative important of two factors in technology criterion, by the following question:

Description of each factor:

a) Acceptance of Local People and Politicians

Social acceptability expresses the overview of opinions related to the energy systems by the local population regarding the hypothesized realization of the projects under review from the consumer point of view.

b) Dependence on Foreign Energy Sources

This criterion will evaluate energy security in term of dependency on the foreign energy resources.

c) Compatibility with Myanmar Sustainable Development Plan (MSDP)

This criterion will takes into account the compatibility with Myanmar's Sustainable Development Plan, especially Strategy 5.4: Provide affordable and reliable energy to populations and industries via an appropriate energy mix.

d) National Economic Benefits

It represents benefits to the national economy by utilizing a certain energy mix.

Question:

In decision making process of the Assessment Model for Energy Resources of Myanmar Energy Mix, which is criterion that you consider more important?

5) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar, which is criterion that you consider more important?										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Acceptance of Local People & Politicians										Dependence on Foreign Energy Resources
Acceptance of Local People & Politicians										Compatibility with MSDP
Acceptance of Local People & Politicians										National Economic Benefit
Dependence on Foreign Energy Resources										Compatibility with MSDP

Dependence on Foreign Energy Resources										National Economic Benefit
Compatibility with MSDP										National Economic Benefit

Section C : Natural Resources for the Ranking

Myanmar is the largest country in mainland of South East Asia, between China and India. Myanmar is endowed with numerous natural resources and current available energy resources for energy are crude oil, natural gas, hydroelectricity, coal and biomass and solar, wind, geothermal as future potential energy resources. Myanmar's energy resources comprise 102 mmbbl of crude oil and 5.6 tcf in onshore area and 43 mmbbl and 11 tcf in offshore, 540 million tons of coal and more than 100 GW of hydropower resources and other resources potential comprise 52000 TWh per year of solar,365 TWh of wind and 93 hot springs of geothermal.

Resource		**Reserve**
Hydropower		**> 100 GW (estimate)**
Crude Oil	**onshore**	**102 mmbbl (proven)**
	offshore	**43 mmbbl (proven)**
Natural Gas	**onshore**	**5.6 TCF (proven)**
	offshore	**11 TCF (proven)**
Coal		**540 million tons (estimate)**
Wind		**365 TWh/year**
Solar		**52,000 TWh/year**

1) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account Technical Maturity.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

2) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Capacity Factor.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

3) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Availability of Local Experts.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

4) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Research & Development.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

5) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Capital Cost.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

6) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Operation and Maintenance Cost.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

7) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Availability of Fund.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

8) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Energy Price.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

9) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Impact on Climate Change.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

10) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Water Consumption.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

11) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Impact on Biodiversity.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

12) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Land Use.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

13) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Acceptance of Local People.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

14) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Dependence on Foreign Energy Resources.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

15) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **Compatibility with Myanmar Sustainable Development Plan (MSDP).**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

16) Please kindly select in Multi-criteria analysis on Energy Mix for national energy consumption in Myanmar between each of the following pairings taking into account **National Economic Benefit.**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Natural Gas										Petroleum Products
Natural Gas										Coal
Natural Gas										Renewable
Petroleum Products										Coal
Petroleum Products										Renewable
Coal										Renewable

국문 초록

미얀마의 에너지 소비, 경제성장 및 에너지 믹스 에 관한 세 가지 에세이

시두조조

협동과정 기술경영경제정책전공

공과대학

서울대학교

2010 년 이후 미얀마는 지속적으로 7%대의 높은 경제성장률을 기록하고 있다. 이에 미얀마는 급증하는 에너지수요를 만족시킬 새로운 에너지공급계획을 수립하고 있다. 본 논문에서는 미얀마의 에너지수요와 공급에 대한 세 가지 계량분석을 실시하여 미얀마 에너지공급계획의 수립과정에 효과적이고 종합적인 자료를 제공하고자 한다.

본 논문은 세 가지 연구로 구성되어 있다. 첫 번째 연구에서는 1990 년에서 2017 년 기간동안의 미얀마의 경제성장률 GDP, 석유 소비 OC, 천연가스 소비 NGC, 전기 소비 ELC, 석탄 소비 CC 의 인과 관계를 분석한다. 시계열분석기법인 VECM 및 VAR 모형 및 그랜저 인과관계분석을 활용하여여 변수 간의 장기귬형관계와 인과관계를 분석하였다. 두 번째 연구에서는 미얀마의 경제부문을 나누어 부문별로 에너지사용이 주는 영향을 살펴보았다. 1990 년과 2017 년 기간 동안의 미얀마의 4 개 분야 (산업, 교통, 농업, 상업 및

공공 서비스)에 대한 패널 데이터를 활용하고 CO2 배출과 같은 다른 요소들을 고려하여 에너지 소비와 경제성장의 인과관계를 분석하였다. 마지막으로 세 번째 연구에서는 에너지계획과 관계된 미얀마 중앙정부 부처 3 개를 선정하여, 이들 부처에 소속된 공무원을 대상으로 설문조사 및 AHP 분석을 실시하여 에너지계획 수립에 대한 미얀마정부 공무원들의 의사결정 구조를 분석하고자 하였다. 이들 연구결과는 향후 미얀마 정부의 지속가능한 에너지정책을 수립하고자 하는 의지를 실현하는 과정에서 중요한 자료로 활용될 수 있다.

세 가지 계량분석연구를 통하여 본 논문에서는 미얀마의 경제성장에 미치는 에너지소비의 중요성을 확인하였으며, 대상이 된 에너지원 중 천연가스가 경제성장에 미치는 중요도는 물론, 정부 공무원들의 천연가스에 대한 선호도를 확인할 수 있었다. 천연가스의 선호도는 41.5%로, 재생에너지(34%), 석유(17.6%), 석탄(6.8%) 등을 앞섰다. 한편 전기소비는 경제성장에 영향을 미치지 않는 것으로 분석되었다. 이는 본 논문의 연구에서 천연가스가 향후 미얀마의 경제성장과 에너지정책수립에 중요한 부분을 차지할 것임을 확인하였다고 할 수 있다.

본 연구는 또한 미얀마의 지속 가능한 에너지정책의 수립에 있어서 의사결정 과정에서 고려해야 할 가장 중요한 기준이 기술과 관련된 요소들임을 확인하였다. 기술관련 요소들은 공무원들의 의사결정 우선

순위에서 경제, 사회, 정치, 환경 기준보다 앞섰다. 세부 요소에서는 특히 지역전문가의 가용성이 가장 중요한 요소로 나타났는데, 이는 기술개발 및 기술인력양성 등 지여전문가의 육성을 위한 정책이 미얀마의 에너지공급정책을 효과적으로 달성하는데 중요한 요소임을 확인하여주고 있다.

주요어 : (에너지소비, 경제성장, AHP, 인과관계, 미얀마)

학 번 : (2018-38085)

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