M.S. Dissertation in Engineering

The Impact of Energy Use on the Growing Economy of Mongolia

August 2016

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

Ganzorig Shagdarsuren

Abstract

The Impact of Energy Use on the Growing Economy of Mongolia

Ganzorig Shagdarsuren
Technology Management, Economics and Policy Program
College of Engineering
Seoul National University

In the contemporary world, energy is a very important factor for economic development, especially when a country is in the process of accelerating its economy into an industrialized one, as in the developing countries like Mongolia. The nexus between energy consumption and economic growth has been widely studied by various researchers from different countries. To date, however, this matter has not been sufficiently researched on for Mongolia, mostly due to data limitations and the country's transitional economic circumstances. This study investigated the causal relationships (i.e., the short- and long-term structural associations) between the gross domestic product (GDP) and different energy variables of Mongolia by applying a modeling strategy based on the Granger causality from the vector error correction model, the augmented Dickey-Fuller and Phillips-Perron unit root tests, and the Johansen cointegration test.

The study results showed that the consumptions of primary energy, oil, and electricity are associated with the GDP, respectively, and that they moved together for Mongolia in the sample period. The model determined a long-term unidirectional causality from electricity consumption to GDP, a long-term bidirectional causality between GDP and oil consumption, and a long-term bidirectional causality between primary energy and GDP. Furthermore, short-term unidirectional causalities were discovered from GDP to electricity, from GDP to oil, and from GDP to primary energy consumption.

When energy consumption leads to economic growth in the long-term perspective, as in the case of electricity, primary energy, and oil, it means that Mongolia has a primary-energy-dependent economy and more primary energy is required to encourage economic development. This also implies that the increase of primary energy consumption as well electricity consumption may positively affect the country's economic growth, that the application of strong energy conservation policies can negatively affect the country's economic growth, and that it is possible to implement energy and electricity efficiency policies.

Furthermore, Mongolia's energy policymakers should diversify the country's energy supply structure, should simultaneously continue implementing the electricity use subsidization policy for the general population and the commercial consumers. Moreover, in the long-term phase, Mongolia should vigorously develop its other clean energies, such us distributed generation based on a smart grid system using renewable technology, which can guarantee energy security for Mongolia as well as environmental protection in the region.

Finally, the overall efficiency in all the sectors as well as the seasonal efficiency for individual residents and energy consumers should be improved, after which the investment in energy development technologies should be increased.

Keywords: Energy consumption, Granger causality, Mongolia, economic growth, Johansen test for cointegration, Vector error correction model

Student No: 2014-22104

Table of contents

List of tables

List of figures

Chapter 1.Introduction

The relationship between energy consumption and economic growth has been a fascinating question since the occurrence of the energy crisis in the 1970s until today. The nexus between energy consumption and economic growth has been widely studied by various researchers from different countries. There is no doubt that energy is one of the major triggers of national economic growth, which plays an important role in the national production and life. Correspondingly, the Mongolian economy, which is based on the natural resources and mining sector, is expected to expand substantially over the next few decades. At the same time, the energy demand is expected to increase dramatically because the development of mega projects involving coal, copper, gold, iron ore, and uranium mining can dramatically increase the energy demand in the following decades so that energy can also play a vital role in the Mongolian economy and in the development of the country's society.

As noted by Jumbe (2004), among others, if a causality runs from energy consumption to GDP, then an economy is energy-dependent, and hence, energy is a stimulus to growth and that a shortage of energy may negatively affect the country's economic growth or may cause poor economic performance on the part of the country, leading to a fall in income and employment. In other words, energy is a limiting factor to economic growth (Stern, 2000). Conversely, if a causality runs from GDP to energy consumption, then the economy is not energy-dependent, and hence, as noted by Masih and Masih (1997), among others, energy conservation policies may be implemented with no adverse effect on growth and employment.

If, on the other hand, there is no causality in either direction (referred to as the "neutrality hypothesis"), then energy consumption is not correlated with the GDP, and as such, energy conservation policies may be pursued without adversely affecting the economy (Jumbe, 2004).

The cointegration methodology is applied for many country cases for finding a causality between energy consumption and economic growth.

The main purpose of this study is to identify the existence of a causal relationship between the consumptions of different forms of energy and the economic growth of Mongolia, and if such a causal relationship is found, to determine the direction or directions of such. It aimed to investigate this matter empirically by applying a modeling strategy based on the Granger causality from the vector error correction model, the augmented Dickey-Fuller and Phillips-Perron unit root tests, and the Johansen cointegration test. The data that were used in this study were obtained from the U.S. Energy Information Administration website and from the World Development Indicators from the World Bank statistics, and they cover the years 1985 to 2012.

The empirical findings that were obtained in this study regarding the causal relationships between the consumptions of different forms of energy and economic growth can be categorized into five distinct cases, as shown below.

For long-term causality:

- No causality (Lngdp-Lnelc) or "neutrality hypothesis" – no causality from economic growth to electricity consumption and from economic growth to primary energy consumption
- Unidirectional causality running from electricity consumption to economic growth (Lnelc→Lngdp), or "growth hypothesis"
- Bidirectional causality between oil consumption and economic growth and also between primary energy consumption and economic growth (Lnoc↔Lngdp, Penc↔gdpn), or "feedback hypothesis" showing a simultaneous interaction among oil, primary energy consumption, and economic growth

For short-term causality:

- No causality (Lnelc-Lngdp, Lnoc-Lngdp, Penc-gdpn) or "neutrality hypothesis" – no causality from electricity consumption to economic growth, from oil consumption to economic growth, and from primary energy consumption to economic growth
- Unidirectional causality from economic growth to electricity consumption, from economic growth to oil consumption, and from economic growth to primary

energy consumption (Lngdp→Lnelc, Lngdp→Lnoc, gdpn→Penc), or "conservation hypothesis''

Table 1 shows the modes of the causal relationships that were tested in this study between the consumption of different forms of energy and economic growth.

	Links	Short-run	Long-Run
1	**GDP → Electricity**	+	—
2	**Electricity → GDP**	—	+
3	**GDP → Oil**	+	+
4	**Oil → GDP**	—	+
5	**GDP → Primary energy**	+	+
6	**Primary energy → GDP**	—	+

+, - denotes existence of causality

Table 1. Mood of Causal Relationships

The discovery of the directions of the causalities between the consumption of different forms of energy and economic growth has important policy implications. For instance, the energy conservation policies cannot decrease the economic growth in the case of a unidirectional causality from economic growth to the consumption of different forms of energy, as with the link between electricity and GDP in the empirical analysis in this study for the long-term condition.

In the case of a unidirectional causality from economic growth to the consumption of different forms of energy, energy conservation policies may have a positive or no effect on economic growth.

Moreover, if there is a bidirectional causality between energy consumption and GDP, the policymakers have to think of balancing the energy conservation policies and meeting the increasing energy needs of the rapidly developing country.

1.1 Research motivation

Many studies have tried to test the relationship between energy consumption and economic growth. The link between these two has been widely studied in the economic literature, but there has been no discussion of the causal relationship between energy consumption and economic growth for Mongolia, mostly due to data limitations and probably Mongolia's transitional economic circumstances.

Actually, in terms of energy deposits, Mongolia has abundant energy resources, including conventional and non-conventional resources, within its boundaries, and supposedly, energy can be one of the major triggers of economic development in Mongolia.

Moreover, understanding the relationship between energy consumption and economic growth in Mongolia can provide insights for policy implementations to achieve sustained economic growth under various energy scenarios in the context of the rising international debate on global warming and the reduction of greenhouse gas emissions. On the other hand, it is very applicable to the successful crafting of appropriate energy policies in the short or long term that will be essential to Mongolia's rapid economic development.

1.2 Research questions

The aspiration of this study was to address the following research questions:

- 1. Is there any causal relationship between the consumption of different forms of energy and the GDP of Mongolia during the period 1985-2012?
  - A. In the case of electricity consumption
  - B. In the case of oil consumption
  - C. In the case of primary energy consumption
- 2. What are the directions of the long- and short-term causalities between the consumption of different forms of energy and the GDP?
- 3. What are the policy implications if a causality nexus exists between the consumption of different forms of energy and the GDP?

1.3 The research objective and structure

The main purpose of this study was to determine if causal relationships exist between the consumption of different forms of energy and economic growth in Mongolia, and if so, to determine the directions of such causal relationships. Thus, the study aimed to empirically investigate the causal relationships between different variables.

In this study, an attempt was made to identify proofs of this nexus (no causality, unidirectional causality, or bidirectional causality between the consumption of different forms of energy and the GDP of Mongolia) based on the relevant data from 1985 to 2012. The directions of the causalities between the consumption of different forms of energy and economic growth have important policy implications.

On the other hand, if unidirectional causality is found to run from energy consumption to economic growth, any constraint put on energy consumption could lead to an economic downfall, and if "no causality" is found in either direction, the so-called "neutrality hypothesis" would imply that energy conservation policies would not affect the economic growth (Chontanawat et al., 2008).

Moreover, by identifying the directions of the causal relationships between the main energy factors and economic growth, energy policies with well-suited tendencies would be encouraged. Moreover, it would be very feasible to base energy policy recommendations on the study results obtained, and to support the rapidly growing economy without any negative or adverse effect.

Research structure

Chapter 1 introduces the study. Chapter 2 presents the study background, including an introduction to Mongolia's energy sector and economy. Chapter 3 is the literature review. Chapter 4 presents the study's theoretical framework, hypotheses, and methodology. Chapter 5 examines the empirical results as well as the directions of causality and the short- and long-term structural relationships between the consumption of different forms of energy and the GDP in Mongolia during the period 1985-2012.

The following models are analyzed: model 1, electricity consumption-GDP; model 2, oil consumption-GDP; and model 3, primary energy consumption-GDP. Finally, Chapter 6 cites and discusses the policy implications, which will be used to provide advice for the effective management of Mongolia's energy sector, and the study's conclusions.

Chapter 2. Overview of energy sector

2.1 Background

Mongolia is a Central Asian country with about 2.98 million population and 1,565,600 km^2 territory, neighboring with the Russian Federation (on north, 3,485 km border line) and the People's Republic of China (on south, 4,677 km border line).

Mongolia is one of the scarcely populated countries in the world. Capital city is Ulaanbaatar with approximately 1.3 million populations. Other major cities include Darkhan, an industrial centre near the Russian border in the northern part of Mongolia, and Erdenet, known with its large copper plant, also in the northern part. About 40% of the population lives in the countryside, primarily nomadic livestock herders. Figure 1 shows map of Mongolia.

Since the collapse of the Soviet Union and COMECON in 1990 (withdraw of Soviet assistance was equivalent to the loss of 30 percent of GDP), Mongolia has faced with restructuring and transforming its previously centrally planned economy into one that is market-based and private sector driven. This formidable task has been met with impressive results.

After the economic transition period, until the 2000, Mongolian economy is recovering and growing fast with 4 to 10 % annual growth rate of GDP. In the last two years it reached at 17.3% in 2011, 17.3% in 2012. In those years electricity demand had some tendency and the demand is increasing from 2000.

Figure 2 shows annual GDP and Electricity demand growth rate of Mongolia in the last two decades and figure 3 shows the Electricity demand Projection of Mongolia also table 2 shows us the general country profile of Mongolia. Due to the economic intensive expansion and mining sector development in the last decade, in the near future, the country is facing lack of power resource, which is almost equals with today's installed capacity of 1176 MW.

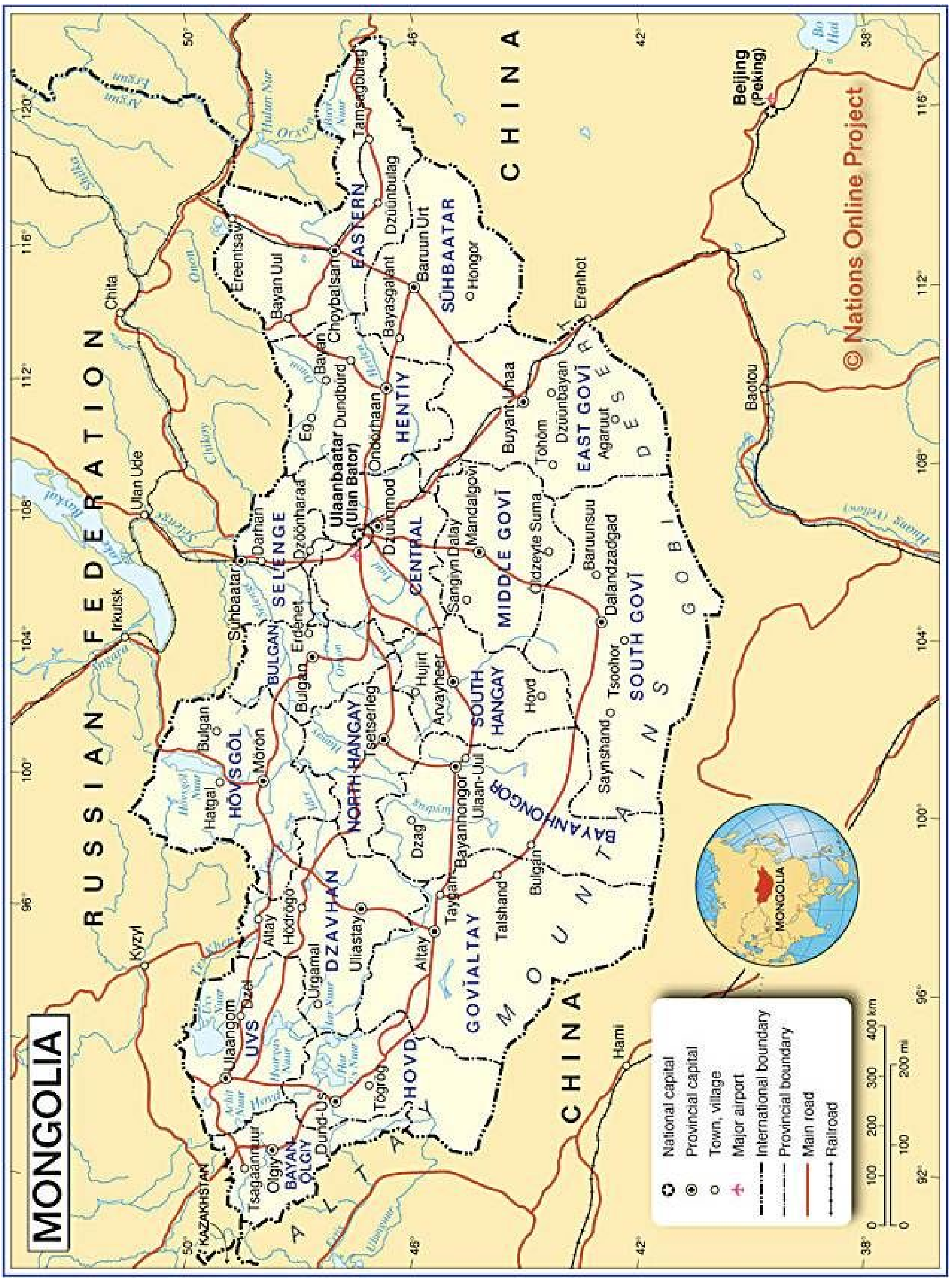


Figure 1: Map of Mongolia

General Country Profile

Area	- 1,564 mill. square kilometers
Capital	Ulaanbaatar, coldest capital
Population	2,992,908
Climate	- characterized as extreme continental with large temperature fluctuations . 4 seasons. Winter temperatures -40°C (-13°F). Windy 4-9m/c
literacy rate:	98.4%
GDP per capita (PPP)	11.900 US $
Urban population	72%
Labor force	1,128 million

Source: The World Factbook

Table 2. General country Profile

(https://www.cia.gov/library/publications/the-world-factbook/geos/mg.html)

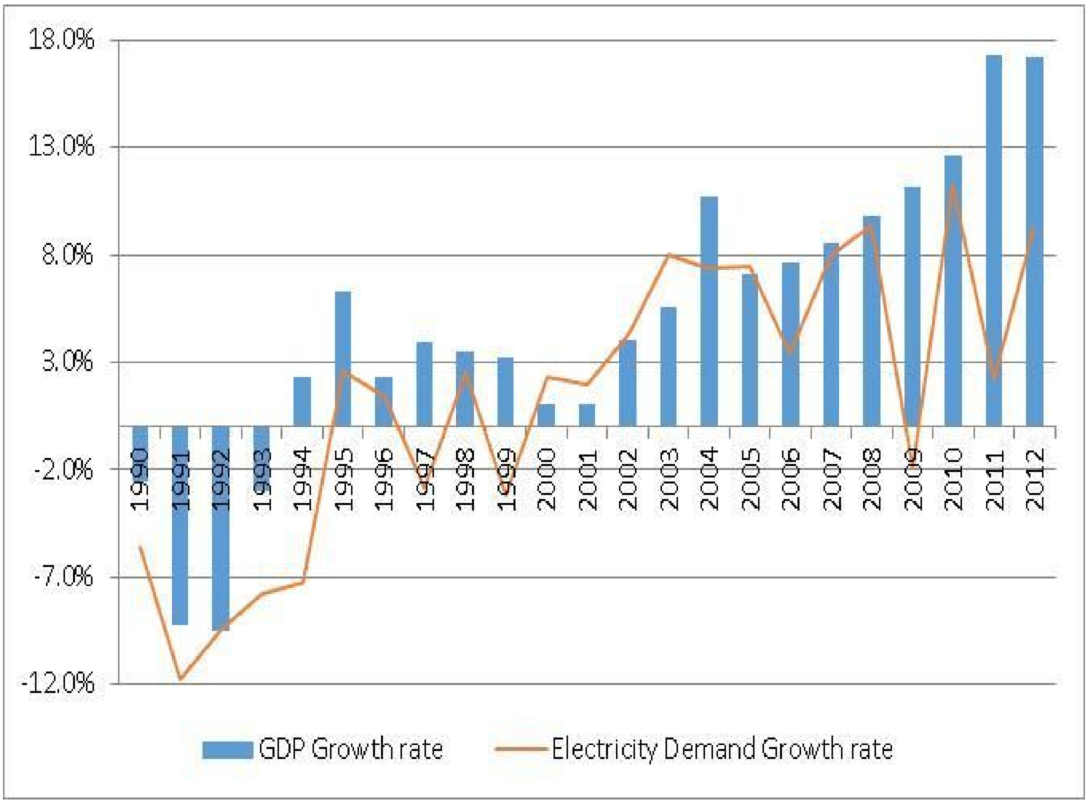


Figure 2: Annual GDP and Electricity Demand Growth Rate of Mongolia
Source: National Statistical Yearbooks of Mongolia, 1999-2012

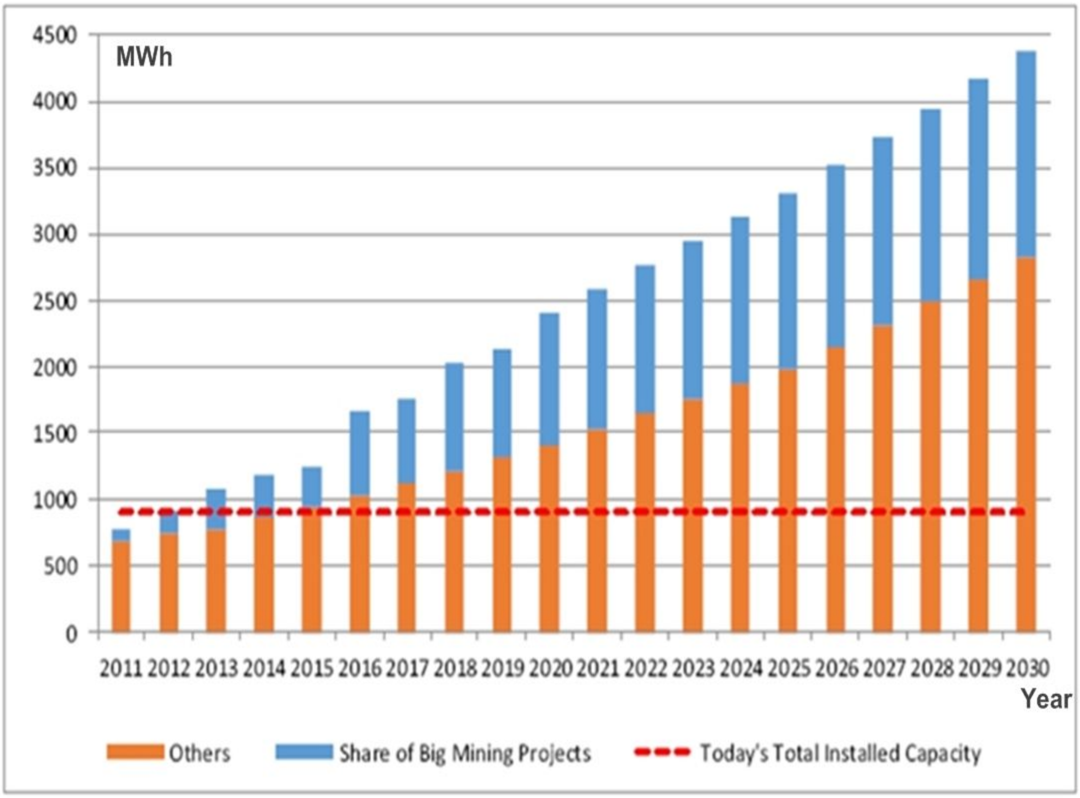


Figure 3: Electricity Demand Projection of Mongolia
Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)'

2.2 Energy endowments

2.2.1 Coal

Mongolia has estimated total coal resources of approximately 173 billion tons found within 15 coal basins. About one third of the resources are in the Gobi region in the south, one third in the eastern region and the balance in the rest of the country, of which the Central Region accounts for about half[1]. Bituminous coal is found in South Gobi and Western basins. Most of the resources in the central, north and western regions are sub-bituminous or lignite. Coal deposits in Mongolia are typically suitable for open cast mining because of their geological condition.

Within this resource base there are 85 deposits and over 370 identified occurrences and findings. Reserves established through preliminary and detailed exploration are about 22 billion tons and the number is increasing annually as a result of intensifying exploration activities. The share of high calorific value thermal and coking coal is estimated at 7 to 8 billion tons. The proven reserves are at 12 billion tons including 2 billion tons of coking coal and 10 billion tons of thermal coal. Figure 4 shows us the coal basins in Mongolia. The resource and reserve estimates carried out by the private sector companies in compliance with the Australian JORC or Canadian National Instrument 43-101 are not all publicly available, which results in varying and sometimes conflicting estimates of Mongolia's resources appearing in public media.

The quoted resources above (2012) are also not consistent and not adequately reflected in the reports of various international energy sector agencies and other organizations maintaining energy statistics. The following figure and table show us the locations of the aforementioned resources as per the Ministry of Mineral Resources and Energy. Even though coal resources are abundant, the infrastructure needed for large scale coal production in Mongolia still needs to be further developed.

[1]Ministry of Mineral Resources and Energy, Energy Balances of Mongolia, Ulaanbaatar 2010, 2011, 2012

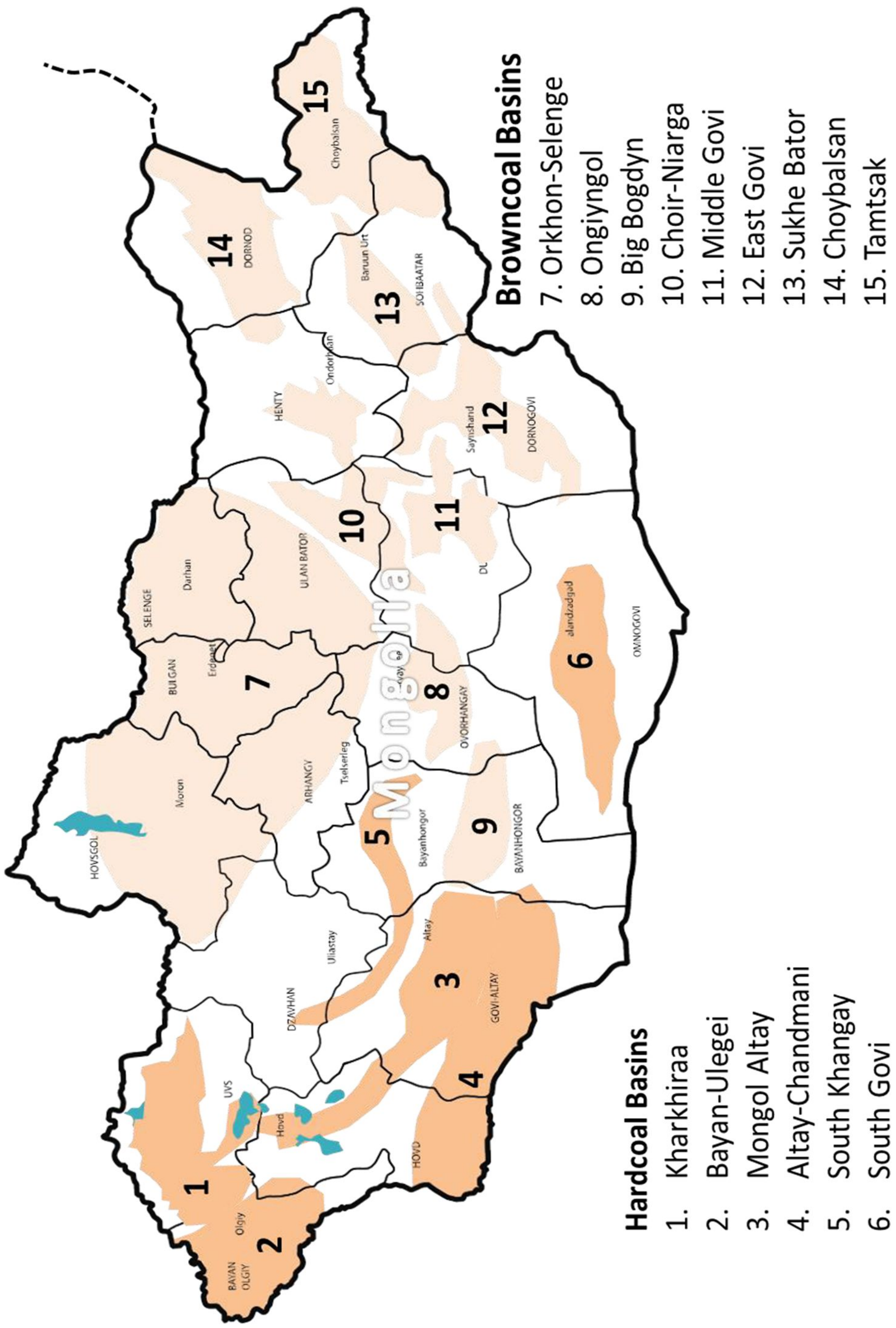


Figure 4: Coal basins in Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)'Ulaanbaatar 2013

Among the pre-requisites of coal-fired power and heat generation are that (i) there are deposits of sufficient size and scale of operation to support continuous and long-term fuel supply, (ii) the parameters of coal such as calorific value, moisture and ash, among others, are suitable for the planned energy conversion technology, and (iii) the transport distance is not too great so that the transport logistics work well for the plant, for example, coal transport via railway[2].

Coal deposits in and around the CES area produce mostly lignite with calorific value of around 3,000 kcal/kg. The coal supply in the CES area is dominated by three mines, which are Baganuur, Shivee Ovoo and Sharyn Gol. These three mines are all connected to the railway which enables them to supply coal to the capital and other major cities along the Mongolian railway system. Sharyn Gol is managed by a listed company, but in Baganuur and Shivee Ovoo are state-owned companies. There are other mines as well within CES area serving primarily the fuel needs of small boilers, HOBs and the retail market, and new mining development is on-going.

Moisture in coal results in efficiency losses in energy conversion. The efficiency of a coal fired power generation drops by about 4 percentage points and 9 percentage points when coal moisture content increases from 10% to 40% and 60% respectively. High moisture content also results in higher capital cost of the plant as the physical size of the boiler and flue gas channels need to be increased in dimension to accommodate the water vapors as a result of high-moisture coal combustion. High ash content also has an impact to the efficiency. Key deposits with high ash content coal (over 20%) in Mongolia include Maanit, NuurstKhotgor, SaikhanOvoo, Tal Bulag, Tevshiin Gobi, Khar Tarbagatai, Tsakhiurt, Shariin Gol and AlagTolgoi. Figure 5 shows the key coal mines in Mongolia.

The increasing production of metallurgical coal will give coal washing technologies new impetus in Mongolia. The first coal washing plant was implemented in two stages by Mongolian Mining Corporation (MMC) in 2011 and 2012 at Ukhaa

[2] the Ministry of Mineral Resources and Energy, Energy Balances of Mongolia, Ulaanbaatar 2012

Khudag mine, which is part of TavanTolgoi deposit. The capacity of the washing facility is 10 million tons, and it will be expanded to 15 million tons by 2015. More washing facilities are likely to come on line in the near term.

Generally, fluidized bed combustion boilers are less sensitive to coal calorific value variation, ash and sulphur content than pulverized coal combustion. At present all boilers in Mongolia use pulverized coal combustion method, but CFB technology has been proposed for CHP5 project. Recent development has brought and will continue to bring several new mines into operation in the near future. Focus of recent mine development has been primarily in the south of Mongolia, and for metallurgical coal and exports. Tavan Tolgoi in South Gobi alone, the largest one, has 7.4 billion tons in resources and 1 billion tons of proven and probable coal reserves.

The mine will produce 20 million tons of coal by 2017; 73% of the coal is metallurgical, while 27% is thermal coal that is suitable for power generation. This equals to approximately 5 million tons of sub-bituminous coal in 2017, an amount sufficient for a 1,200 MW base load plant. Many bituminous coal mines are waiting for or under active development in the Southern Mongolia. Even on the basis of the known reserves at the TavanTolgoi fields, Mongolia has the potential to become a major exporter of coking coal.

Present infrastructural constraints, not the least of which are the lack of adequate power supplies, lack of access to a railway system, and water supply constraints, pose the main challenges for the mining sector to overcome in releasing the potential.

Mining development will cause the need for mine mouth power generation to serve the mining operations and this may provide opportunities for supplying excess power to the grid or for exports .Large mine mouth power plant on this basis have been proposed, among others, to Baganuur coal mine and Chandgana mine (owned by Canadian Prophecy Coal). Currently the southern mines' electricity demand is fulfilled by a combination of on-site diesel engines and coal fired plants. There is a 220 kV overhead line nearly completed (2012) from Mandalgovi to TavanTolgoi region, which would connect the nearby mines to the CES network.

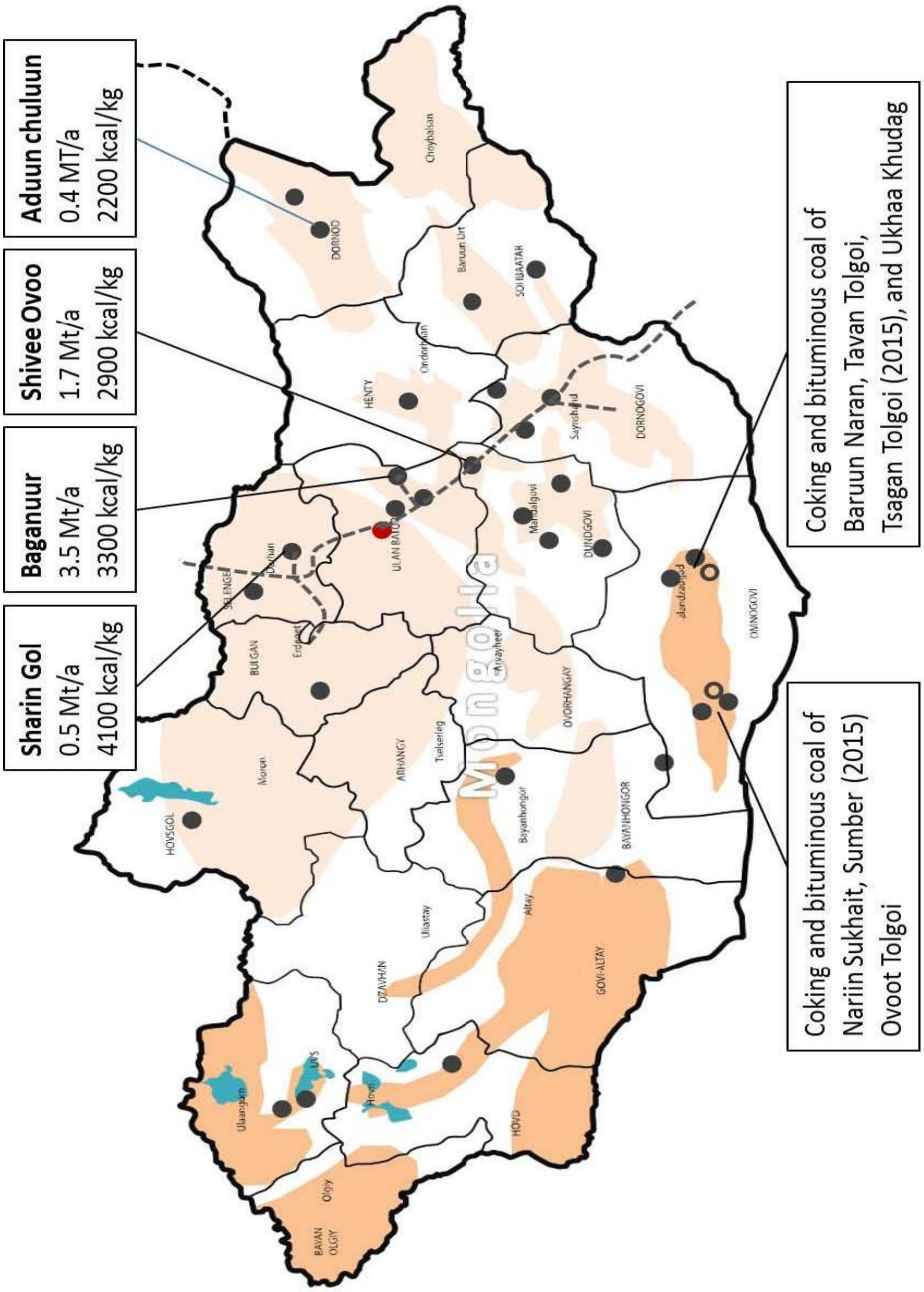


Figure 5: Key coal mines

Source: ADB ‘Updating Energy Sector Development Plan (TA No. 7619-MON)’Ulaanbaatar 2013

Coal production and export are of high importance to Mongolia. Coal today provides primary energy for 65% of Mongolia's total energy use, and for over 90% of power and heat generation. Coal represents 40-50 % of Mongolia's export revenues (47% in 2011), and according to the Mongolian Economic Research Institute, over 10% of budget revenues and 80 % of foreign direct investment. Figure 6 shows us the Coal production and Export.

In 2012 Mongolia's coal production reached 29 million tons. Due to weaker demand of China for metallurgical coal than during the previous year, Mongolian coal production decreased. With increasing export of coking coal, the share of domestic consumption has decreased[3]. The breakdown of domestic use by sector is illustrated in Figure 7.

Coal prices for energy production are regulated in Mongolia for the CHP plants and urban heating. These regulated contract prices are negotiated annually. Because coal is the primary cost factor behind the electricity and heat prices, sharp price increases have been avoided and the Government has kept prices close to the break-even cost levels. The mines sell coal also in the open spot market. This coal is typically transported by 1 ton or 5 ton trucks to markets in the urban centres. The spot prices for retail consumers are a multi-fold of the regulated price.

The following graph presents the coal overground prices of four key mines that supply fuel to the CHP plants in CES and EES areas. It should be noted that coal from different mines have varying calorific values, which explains a major part of the contract price differences. The graph also shows a line calculated as a weighted average using both the calorific values and production volumes as weights. The graph illustrates clearly that in 2010 there was a notable price increase. The average cost of MNT 20,000 per ton equals to about $ 15 per ton. The calorific value of the 'weighted average coal' is 3,232 kcal/kg.

[3]the Ministry of Mineral Resources and Energy, Energy Balances of Mongolia, Ulaanbaatar 2012

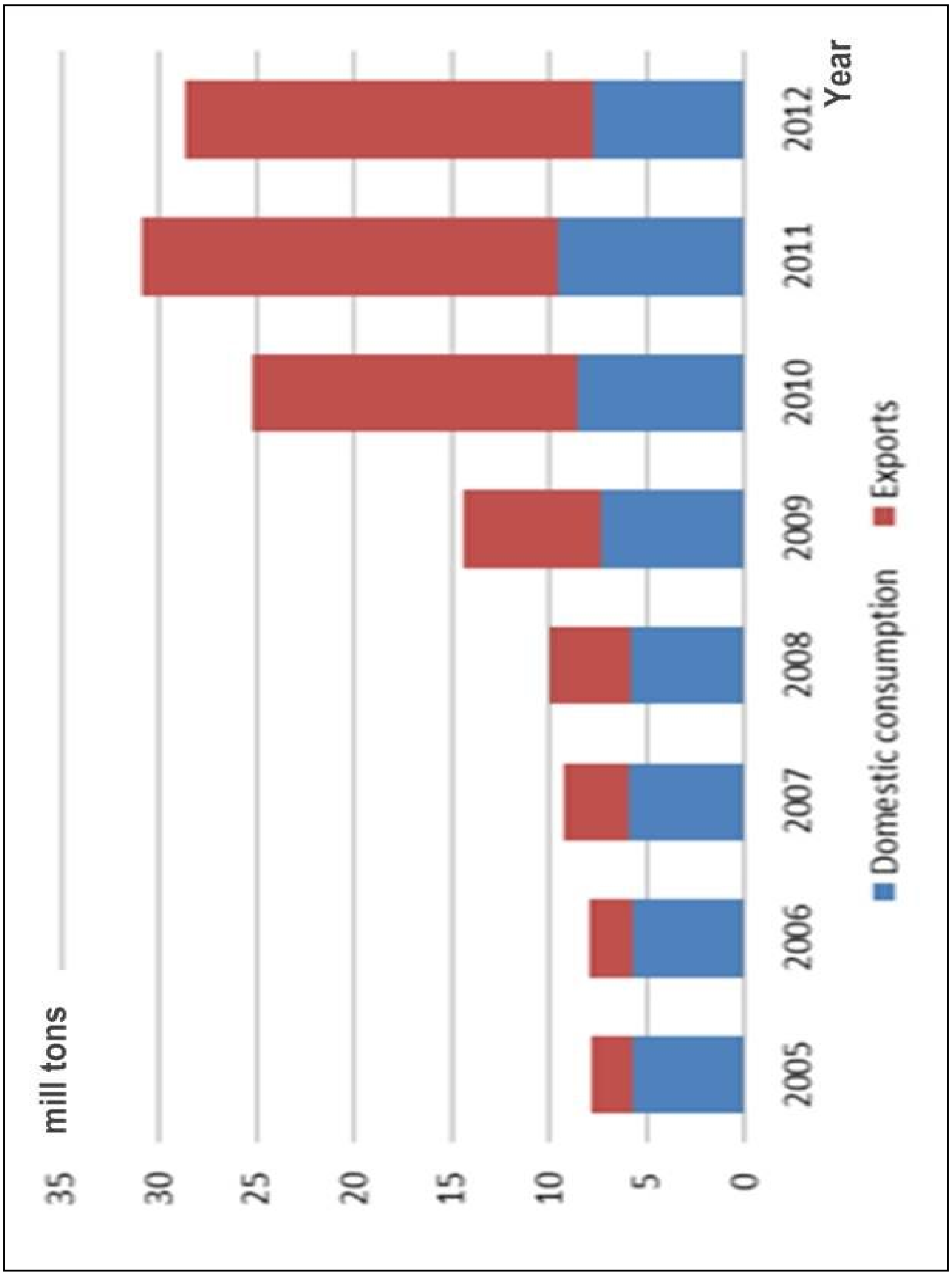
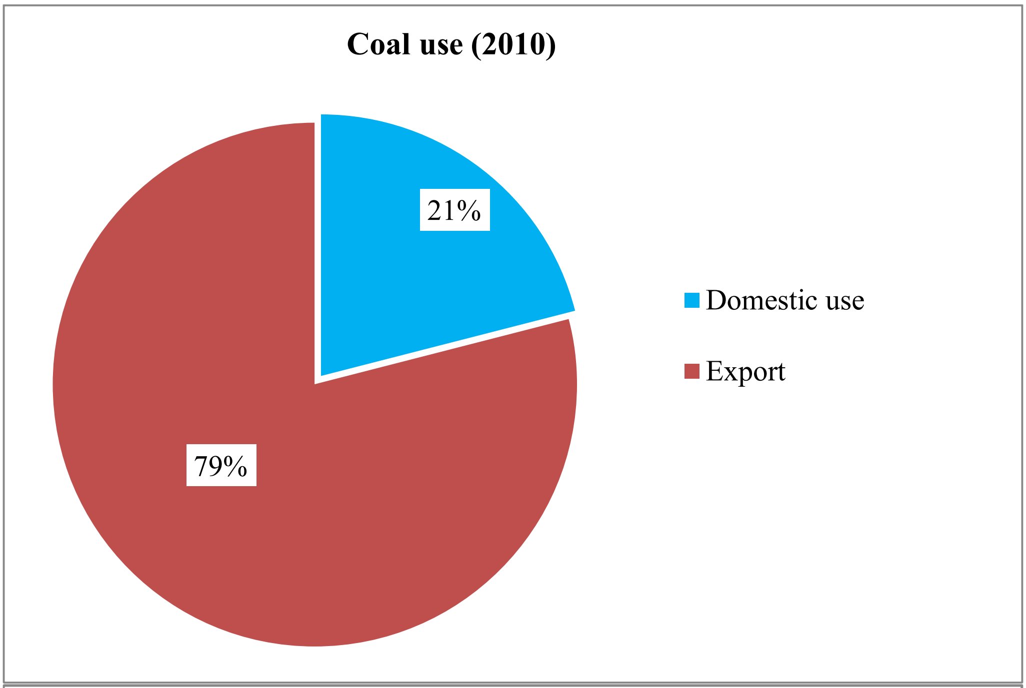


Figure 6: Coal production and Export

Source: ADB ‘Updating Energy Sector Development Plan (TA No. 7619-MON)’Ulaanbaatar 2013



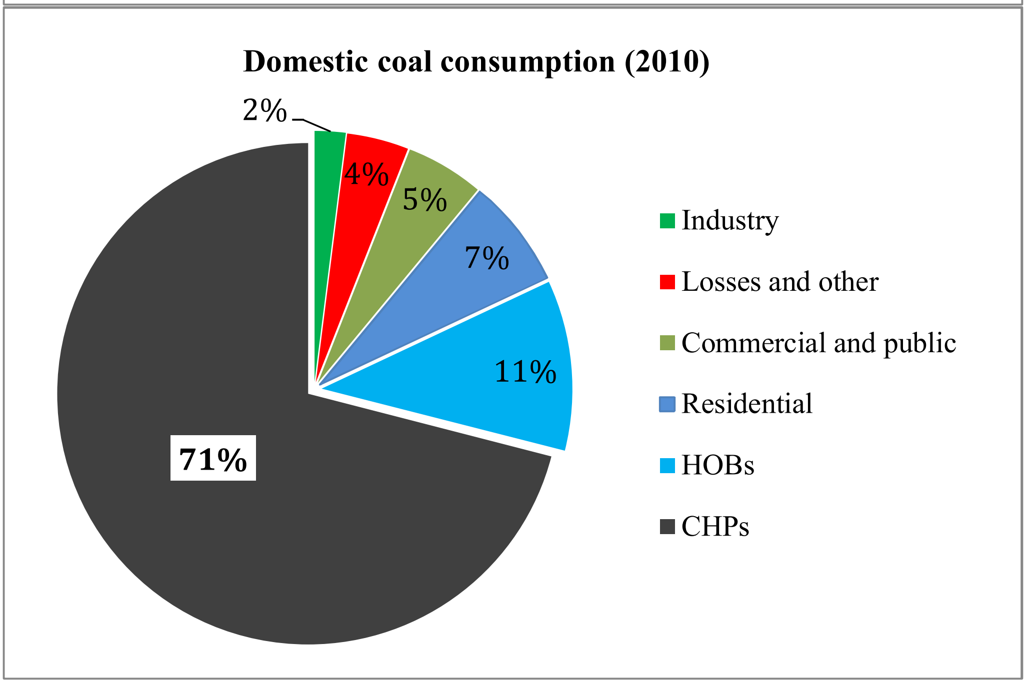


Figure 7: Structure of Coal consumption of Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)'Ulaanbaatar 2013

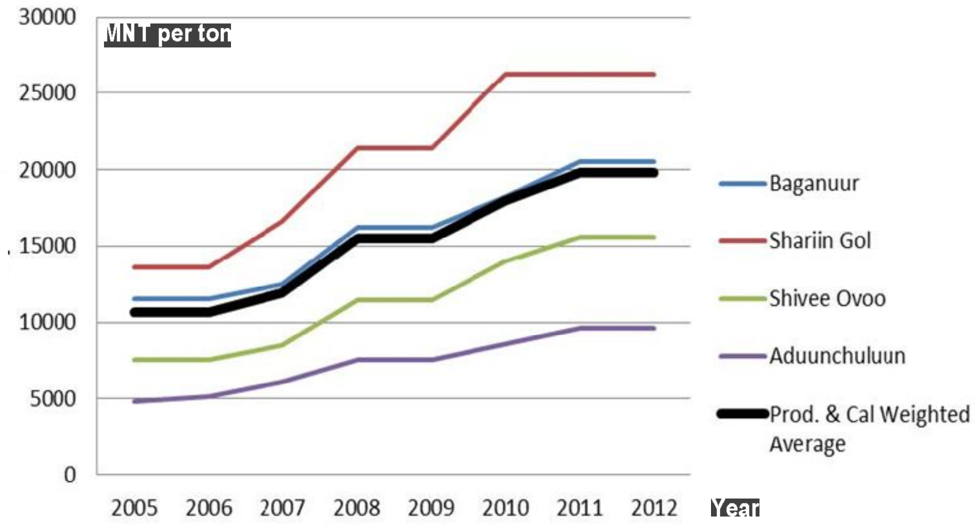


Figure 8: Development of over ground Prices of Key Mines

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)'Ulaanbaatar 2013

Coal price will be one of the most important variables of the analysis comparing various construction programmers for system expansion in Mongolia. The coal price to be used in the economic analysis should be such that it promotes the best use of the country's resources. It should be free of taxes and subsidies. In valuing the economic benefit of an input, such as coal, the most important issue to be considered is its opportunity value. Determining the opportunity value depends on whether or not the commodity is a traded or non-traded one. Figure 8 shows the development of over ground Prices of Key Mines.

In the event Mongolian coal would be tradable internationally, its economic value could be established on basis of its FOB border price. However, even though Mongolian thermal coal can theoretically be traded internationally, the de facto situation is that by today coal from the northern mines, which feed coal to the CHP plants, has not been exported.

The overground contract prices of 'big three' mines in the CES area are currently (2012) from 23 to 27 USD per ton when expressed in US dollars and adjusted to calorific value of 5500 kcal/kg NAR (net as received).

In line with an established assumption, it can be considered for the purpose of this study that with all abovementioned costs included, and considering the initial quality of lignite, there is currently no export market for the coal that is used by the CHP plants in Mongolia. Furthermore, a comparison of Mongolian prices against the mine mouth prices of mines in Chinese Inner-Mongolia, results in similar conclusion.

Therefore, the economic value of coal is not established here on basis of a netback analysis. However, this assumption is made in understanding that the coal market conditions may vary over years and that, for example, coal of Sharin gol, which is of relatively higher calorific value, may have an opportunity in the export markets in the future provided it is washed to the required quality.

Other Coal Based Fuels

Other coal based fuels include liquid fuels from coal or oil shale, and gaseous fuel from coal mines (CBM) or by converting coal to gas.

Preliminary studies of Coal Bed Methane (CBM) have been carried out in Mongolia. Overall the resources seem indicatively substantial but more detailed studies on selected deposits have not confirmed economic feasibility. Most coal production in Mongolia is from surface mines, whereby the potential of extracting CBM relates primarily to the pre-mining drainage prior to surface mining activity. NarinSukhait mine has been estimated to have CBM resources of 17-34 bcm. Even if the resources are significant, no economic reserves have been identified. TavanTolgoi is estimated to hold a potential of 12 bcm of CBM. NuurstHotgor mine in western Mongolia has 2.5 bcm of preliminary estimated potential.

The technical potential is significant. As a reference for the above mentioned volumes, approximately 2.5 bcm of CBM would be sufficient to fuel a base load combined cycle gas turbine plant of 100 MW for 20 years (52% efficiency, 7000 h/a).

Coal-to-Gas technologies can be utilized for (i) the provision of city gas through a piped network to consumers, and (ii) for cleaner electricity production by Integrated Gasification Combined Cycle (IGCC) plant. As there is no natural gas infrastructure in

Mongolia, the easiest way of using coal based gas by injecting it directly to an existing gas network in the country.
Even though there is no detailed analysis of the matter in Mongolia, economic justification of piped coal gas is probably low in Mongolia as cities and towns already have widespread district heating pipeline systems for space heating and hot domestic water. Therefore, gas distribution would provide only marginal value in the residential sector as a fuel for cooking.

The cooking fuel, fuel shift prospect together with the remaining open possibilities for gas utilization would probably not be sufficient to cover the capital cost of the associated new gas network infrastructure, which for the heat consumers would run parallel with the existing heat network. The feasibility of piped gas from coal is more likely in towns that will be developed in connection with new mining activities, and in the new Greenfield industrial areas which are planned for downstream processing of minerals and metals. In these cases gas could provide the primary source of energy for both heating and cooking.

Another way of using coal based gas is IGCC technology, which is considered for the planned Sainshand Industrial Complex. Again, as an emerging technology the capital cost of IGCC is substantially higher than that of power plants using standard pulverized coal combustion methods at mine mouth locations.

Therefore, unless IGCC technology is substantially credited for its better environmental performance, its high capital cost would make it clearly not feasible in the Mongolian context. There are clearly opportunities of diversifying coal use in Mongolia either by applying coal-to-liquid or coal-to-gas technologies. However, the end user requirements and product value lies in liquid fuels and chemicals rather than in electricity[4].

2.2.2 Oil and Gas

Oil and gas are widely utilized across the globe for power generation. Despite worldwide effort to give up using oil as a primary fuel for electricity, it continues to

[4]the Ministry of Mineral Resources and Energy, Energy Balances of Mongolia, Ulaanbaatar 2012

have a major role as a secondary fuel to support combustion of solid fuels in large boilers. At the moment in Mongolia, imported oil from Russian (Mazut) is used as the support fuel in CHP plants. Mazut is also used as the main fuel for some HOBs and diesel plants in small towns.

Mongolia is a rising oil country with substantial potential to improve its self-sufficiency in liquid fuel supply. At present, crude oil production in eastern Mongolia by Petro China Dajing amounts to about 1 million tons annually. All production is exported for refining in China, and therefore all petroleum products consumed in the country are currently imported.Mongolia has been divided into 25 oil exploration blocks (in total 528 thousand square kilometers). Current investor interest concerns operations in 13 oil basins of which six fields are currently being intensively explored: Tamsag basin, Zuun Bayan, TsagaanEls basins and Western Mongolia.Mongolia's total oil resources are estimated to amount to 1,600 million tons. Tamsag basin alone has estimated reserves of 600 million tons.The Government has decided to select appropriate technology to process domestic crude oil and to construct a refinery to meet domestic demand for petroleum and petroleum products. With this respect, MMRE is currently studying three project proposals. Figure 9 illustrates Petroleum Exploration Blocks of Mongolia in below.

There are 25 oil shale deposits identified in Mongolia, of which 23 are in Tuv and Dundgobi aimags. Some estimates have assumes that Uvduq Bulag, Khugshingol and Zuunbular deposits hold large-scale resources. Oil shale resources provide an alternative to fuel oil production. Equally there are plans to establish a coal-to-liquid (CTL) plant in Mongolia. Uvdug Khudag deposit is among the best in Mongolia for this purpose. The mine is also favorably located alongside the railway that is planned to TavanTolgoi and OyuTolgoi deposits.

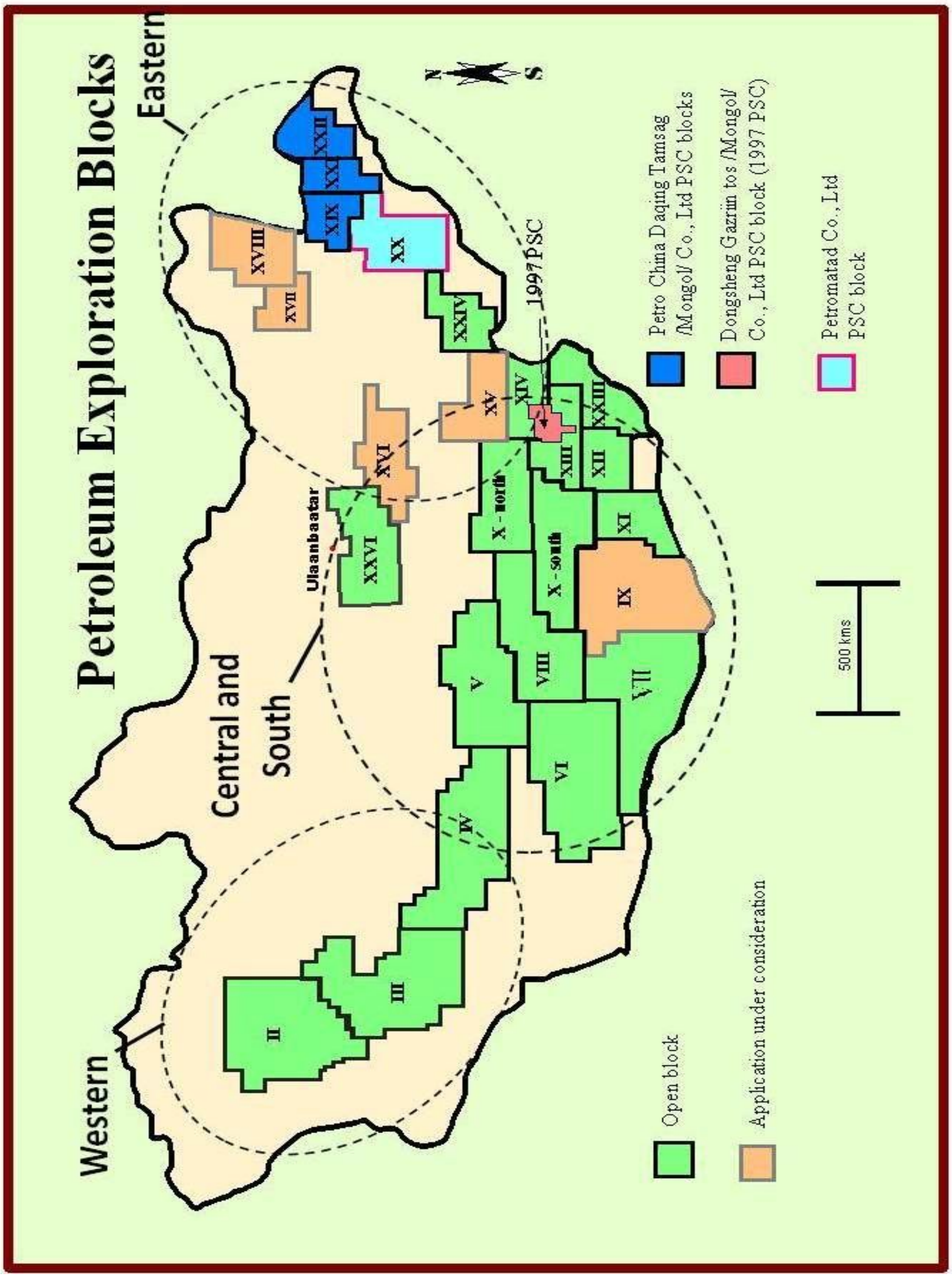


Figure 9: Petroleum Exploration Blocks of Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)' Ulaanbaatar 2013

Even though these emerging technologies have importance to the industrial strategy of Mongolia, and they provide an opportunity to develop higher value products to serve particularly the country's transport sector with liquid fuel, they have only little bearing to the electricity and heating sectors' primary fuel base.

No domestic natural gas resources have been found in Mongolia. There have been plans to construct a natural gas pipeline from Russia to China via Mongolia from the huge Kovykta gas field in Siberia. However, those plans are subject political and economic considerations involving all three governments, and are currently on hold.

Oil prices in Mongolia generally follow world market prices. CIF prices are subject to import tariff (10%), VAT, fuel tax and excise tax.

2.2.3 Hydropower

Another potential source of primary energy that will, most likely, factor into Mongolia's medium term energy mix is hydropower. There is significant potential in Mongolia for hydro power generation that is, as of yet, almost entirely untapped. There are around 3,800 small rivers in Mongolia with a total length of 65,000 km with gross theoretical potential of about 6.2 GW. At present, more than 1 GW of these has been identified.

Hydropower resources can be found in the Altai ranges, Tagna and Khan Khukhii ranges, in the mountainous areas of Khuvsgul, Khangai, Khentii and the KhalkhGol River. There are 13 hydropower stations in Mongolia in operation; most of them are small or medium sized plants. Only four plants are connected to local grids while the rest serve isolated grids of nearby soums (local centers). There are three plants larger than 1 MW, namely Durghun (12 MW), Taishir (11 MW) and Bogdiingol (2 MW).

Various studies have identified within CES regionprospects to develop five projects in the Selenge river system. These are Shuren 300 MW, Orkhon 100 MW, Egiin 220 MW, Buring 161 MW, and Artset 118 MW hydropower projects. In addition, a 100 MW pumped-storage HPP close to Ulaanbaatar has often been named among the candidates for mid-term implementation. Figure 10 shows the hydro power resources and plants that currently operate in Mongolia. Within WRES there are three projects of 69 MW, 58 MW and 12 MW, and within ERES region one project of 8MW.

Totally in all Mongolia the identified hydropower projects could provide new capacity to about 1,000 MW. The resources of Selenge river, which the biggest river of Mongolia, and its tributaries have drawn most attention and research for hydropower development in Mongolia. Prospects associated with Selenge are not only the largest ones; they are also geographically positioned to the north of the country, within the area of CES, where the electricity demand is the highest.

Out of many projects Shuren, which is located in the main stream of Selenge river, and Egiin, which is a tributary of Selenge, stand out most often.

Another large tributary, Orkhon, joins the river close to Sukhbataatar city, nearly 10 km away from the Russian border, and has also been of interest for hydropower development. Water catchment area of the Selenge is 425,200 km2, of which 282,000km2or 66 percent is located at Mongolian territory. The length of river is 1,095 km, and its average incline is 0.0019.The nominal heads of most important identified dam sites in the Selenge river system vary from 50 to 75 meters.

Orkhon rises in the Khangai Mountains of Arkhangaiaimag and flows northwards before joining the Selenge River, which then flows north into Russia and Lake Baikal. The Orkhon is longer than the Selenge, making it the longest river in Mongolia. Major tributaries of the Orkhon River are the Tuul River, which passes Ulaanbaatar, and TamirRiver.The overall length of Orkhon is 1,124 km and the catchment area is132, 800 km2. Considering the remoteness of the area and harsh climate, raw data of the Selengeriver has been collected very conscientiously over the years.

Selenge and Orkhon rivers were studied already in the early 20thcentury by Russian engineers from the point of view of suitability for shipping. Complete long term records since 1941 are available from two sites (Muren and Bulgan), both south of Egiin basin. Since then several gauge stations have been established. Figure 11 shows the Locations of the Three Key HPP Projects in the Selenge River.

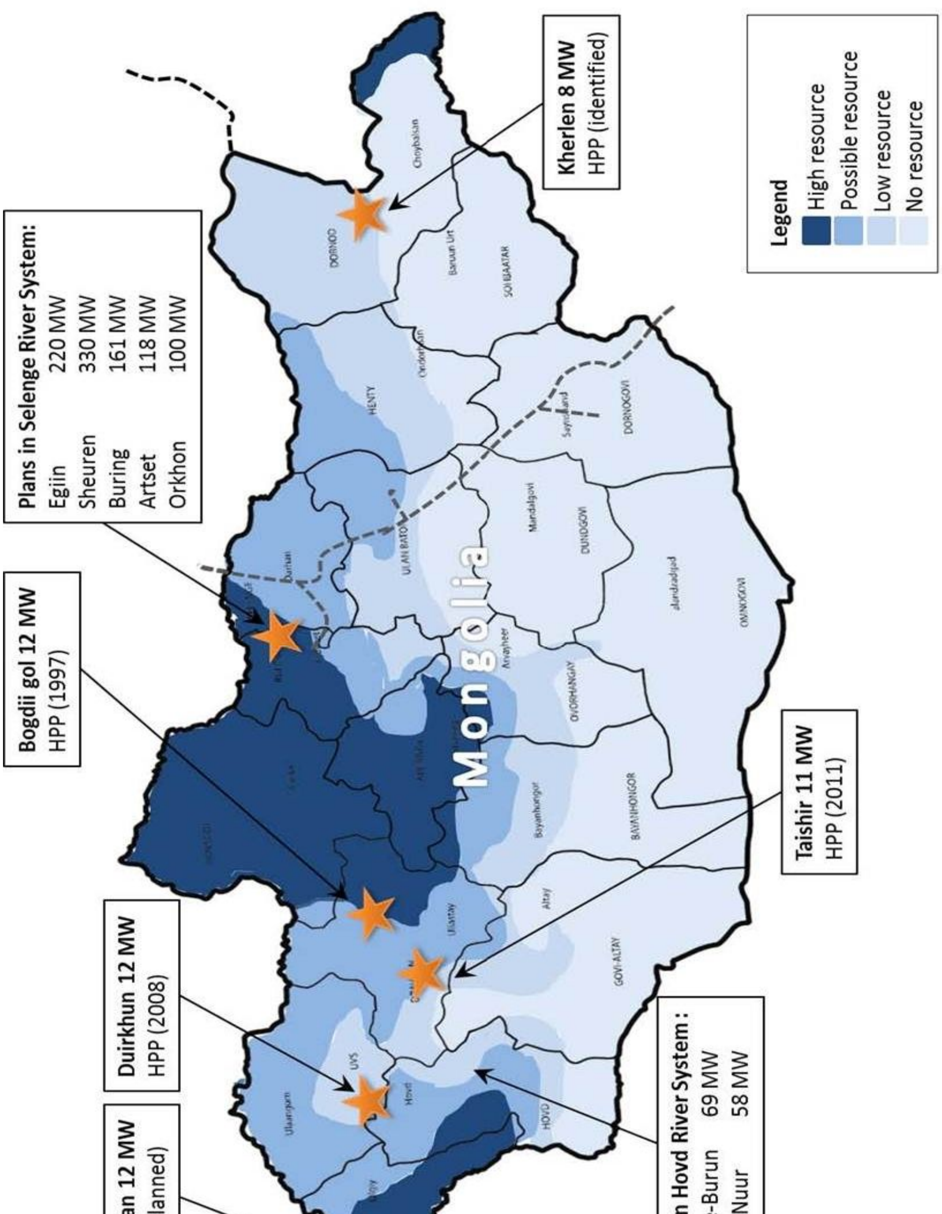


Figure 10: Hydropower Resources in Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)' Ulaanabaatar 2013

The long term average river discharge is 247 m3/s in Shuren, 241 m3/s in Zuunburen, and 290 m3/s in Orkhon-Selenge. Egiin has a meandischarge of 96 m3/s and Orkhon 65 m3/s.Selengeriver has over-flooded in 1879, 1908, 1932,1952,1971,1974, 1986 and 1993. During extreme floods the river flow has reached 4,000 m3/s. The maximum flows occur together with the snow smelting and rainfall from May to August. The water flow during these four months represents 71.5 % of the regular (50 %) water flow. About 90 % of the annual precipitation occurs as rainfall from May to September. The flow is smallest in February (0.9 % of annual discharge at regular water flow).

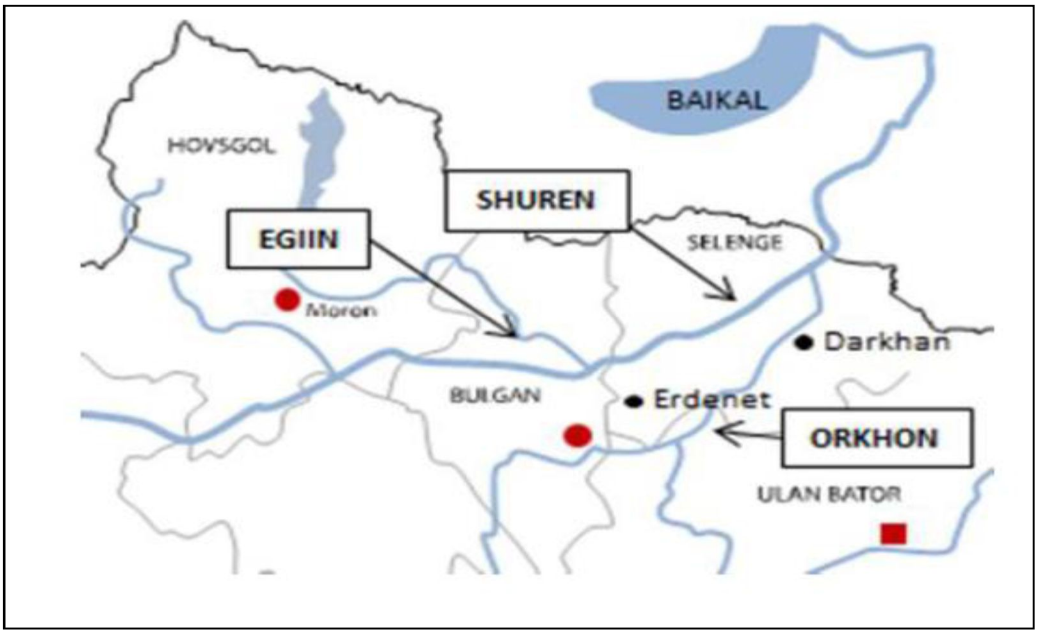


Figure 11: Locations of the Three Key HPP Projects in the Selenge River

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)', Ulaanbaatar 2013

Ice formation is another important feature of local hydrology. Freezing starts typically in October and the northern rivers are fully frozen in November. Ice starts breaking in April and is free from ice by the end of the same month.

2.2.4 Wind

Mongolia has considerable potential for wind energy. Mongolia's wind resources, which can be classified as excellent for utility scale applications (power density of 400-600 W/m2), occupy around 10% of the total land area. There are no resource-based constraints for wind power development. The resources could potentially supply over 1,100 GW of installed capacity. All of the Aimags have at least 6,000 MW of wind potential, three Aimags have at least 20,000 MW and nine Aimags more than 50,000 MW of wind power potential. Existing wind power installations are scattered and report rather poor performance. The largest wind turbines are of 150 kW capacities.

Theoretically, the Government's renewable energy target of 20% by year 2020 could be reached by wind power alone. This would require approximately 600 MW in installed wind power capacity producing 1,800 GWh of energy. The intermittent nature of wind power can be smoothened by geographic spread of projects. The wind power capacity of 600 MW would require about 100 MW of fast regulating capacity, such as hydropower or continued import from Russia, to be available. Figure 12 is a wind resource map for Mongolia and three licensed utility scale projects, which are currently under development.

2.2.5 Solar

Mongolia has resource potential for both solar power and solar heating. Solar irradiation ranges from 4.5 kW/m2per day in the northern part of the country, where recorded annual sunshine are less than 2,600, to 5.5-6.0 kW/m2per day in the Gobi area. Regions with high irradiation account for around 70% of the country, while those with intermediate levels of solar radiation cover 18% of Mongolian territory.

The National Renewable Energy Program has promoted use of solar home systems for herder houses (100,000 Sun RaysProject) as well as for the use of solar PV for isolated soums to provide electricity for telecommunication, TV repeat stations, border control units and hospitals. At present there are no large-scale grid connected solar PV projects implemented. A large solar PV project is proposed to be studied in the Gobi area similar to China's 200 MW Golmud Solar Park or Indian 600 MW Gujarat project. Solar heating is under-developed in Mongolia. One reason is that hot domestic water is provided by the district heating company. Therefore, there is no consumer level incentive to install individual roof-top solar heaters.

Consequently, solar heating potential should be tapped by the district heat distribution companies and possibly housing companies at locations of the nearest heat exchange stations to a block of buildings, i.e. in the secondary networks, where domestic hot water is heated. Cold weather also poses challenges to low pressure water circulated systems and therefore frost-resisting liquids need to be used in the panels. Preliminary studies have been carried out and a proposal for a pilot system has been put forward by the Ministry of Energy. Figure 13 is a the map of Solar Resources in Mongolia.

2.2.6 Geothermal

There is tens of small hot springs in Mongolia and some of them are used for traditional health resorts and small-scale heating. Their value as a means of supply of commercial energy has so far estimated marginal. Further studies are needed to establish whether or not geothermal energy could provide a feasible local energy source for district heating. Some preliminary studies estimate that the cumulative flows of usable heat (>35 C)from hot springs at Aimag levels, where there are some, arebetween1 to 15 MWh.

Geothermal energy, when available, can be combined with heat pump technology to provide district heating. Even though a ground source heat pump can use the top layer of the earth's crust as a source of heat, thus taking advantage of its seasonally moderated temperature, any heat source that is warmer or more easily accessible can improve the efficiency of the system and lower its capital cost. Therefore low grade heat sources such as city waste water plants could be explored as potential heat sources for heat pump technology. Figure 14 is a map of Geothermal Resources in Mongolia.

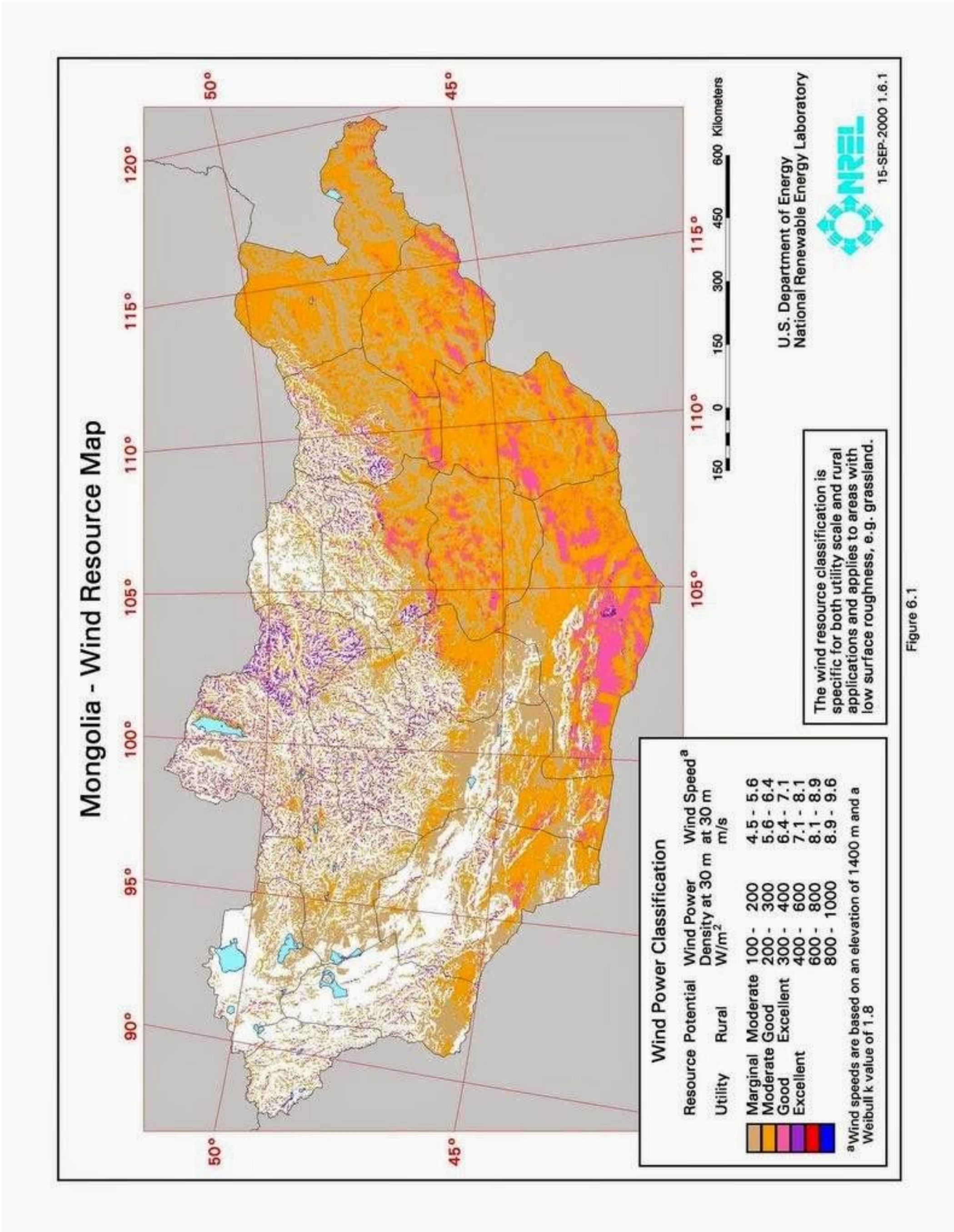


Figure 12: Wind Resources in Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)', Ulaanbaatar 2013

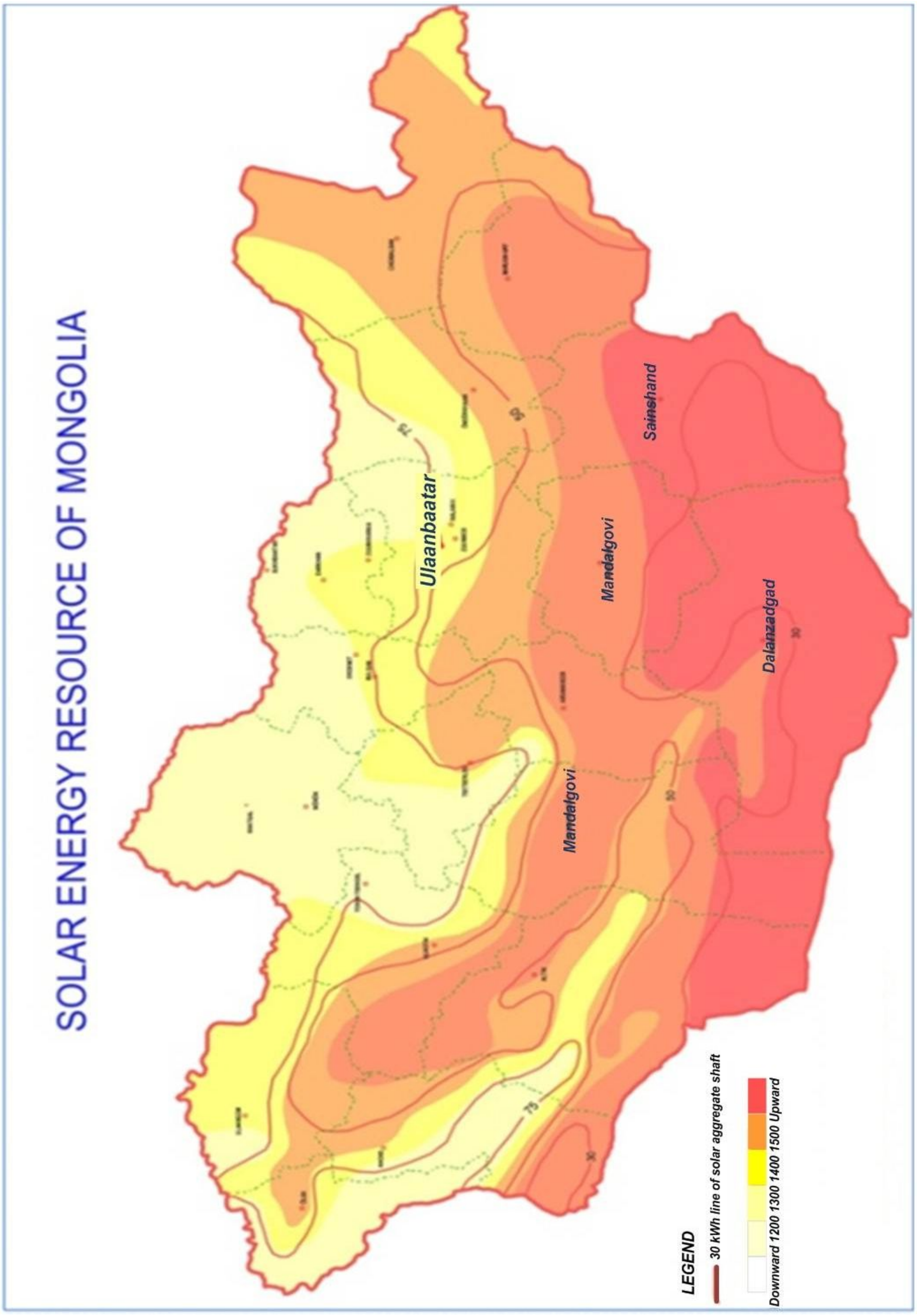


Figure 13: Solar Resources in Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)', Ulaanbaatar 2013

2.2.7 Uranium

Mongolia has substantial known uranium resources and geological potential for more. Mongolia's reasonably assured resources are 37,500 t U to the cost level of US$ 130/kg U and inferred conventional resources 11,800 t U, totally 49,300t U (IAEA, Uranium Resources2009). Uranium was produced from the Dornod deposit in Mongolia by Russian interests until 1995. Russian, Chinese, Canadian, Japanese and French companies have since then sought Mongolian government consents for their quest after Mongolia's uranium potential.

Mongolia joined IAEA in 1993. In July of 2009 parliament declared all Mongolian radioactive mineral deposits strategically important and other regulation in relation to the nuclear energy industry was formalized in a Nuclear Energy Law. A protocol for establishing a JV by Russian ARMZ and MonAtom was signed for revitalizing uranium mining at Dornod. Plans for Dornod are not finalized but there is some expectation of production of 1,000-1,200 tU/yr from about 2015.

Preliminary ideas for a nuclear power plant in Mongolia have been presented based on Russian, Toshiba 4S and Korean Smart reactor technologies. Ulaanbaatar, Dornod and Western Mongolia have been mentioned as potential locations. However, there are no definite plans for developing nuclear energy as for a domestic source of power and nuclear power does not appear in any approved power sector planning documents.

There are 17 ore bodies of different sizes identified. Most of them are in (i) Dornod, (ii) Dornogovi, Dundgovi and Omnogovi, or (iii) in Hovsgol. Figure 15 shows some of the most notable recent uranium mining development sites in Mongolia.

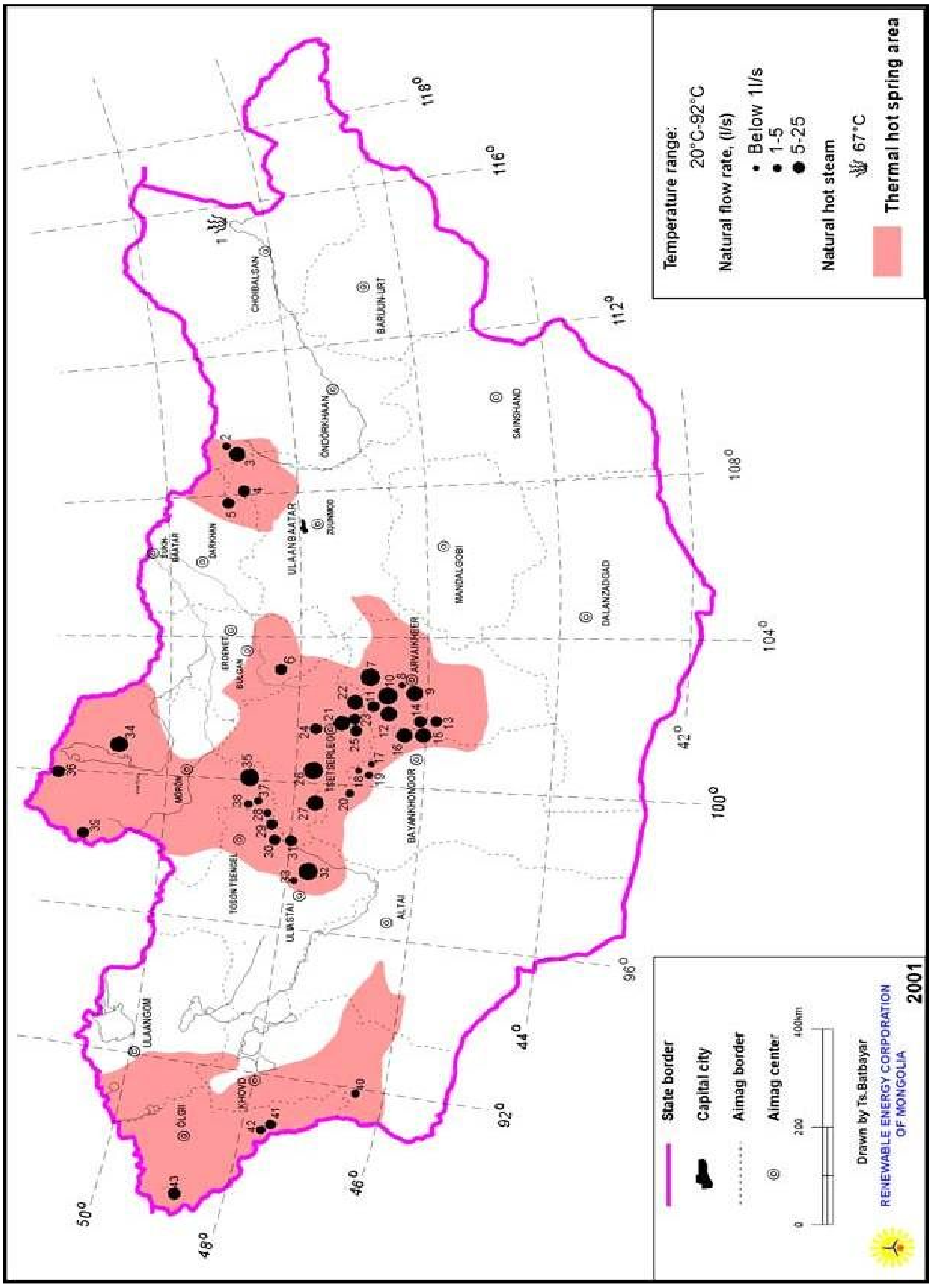


Figure 14: Geothermal Resources in Mongolia

Source: ADB ‘Updating Energy Sector Development Plan (TA No. 7619-MON)’, Ulaanbaatar 201

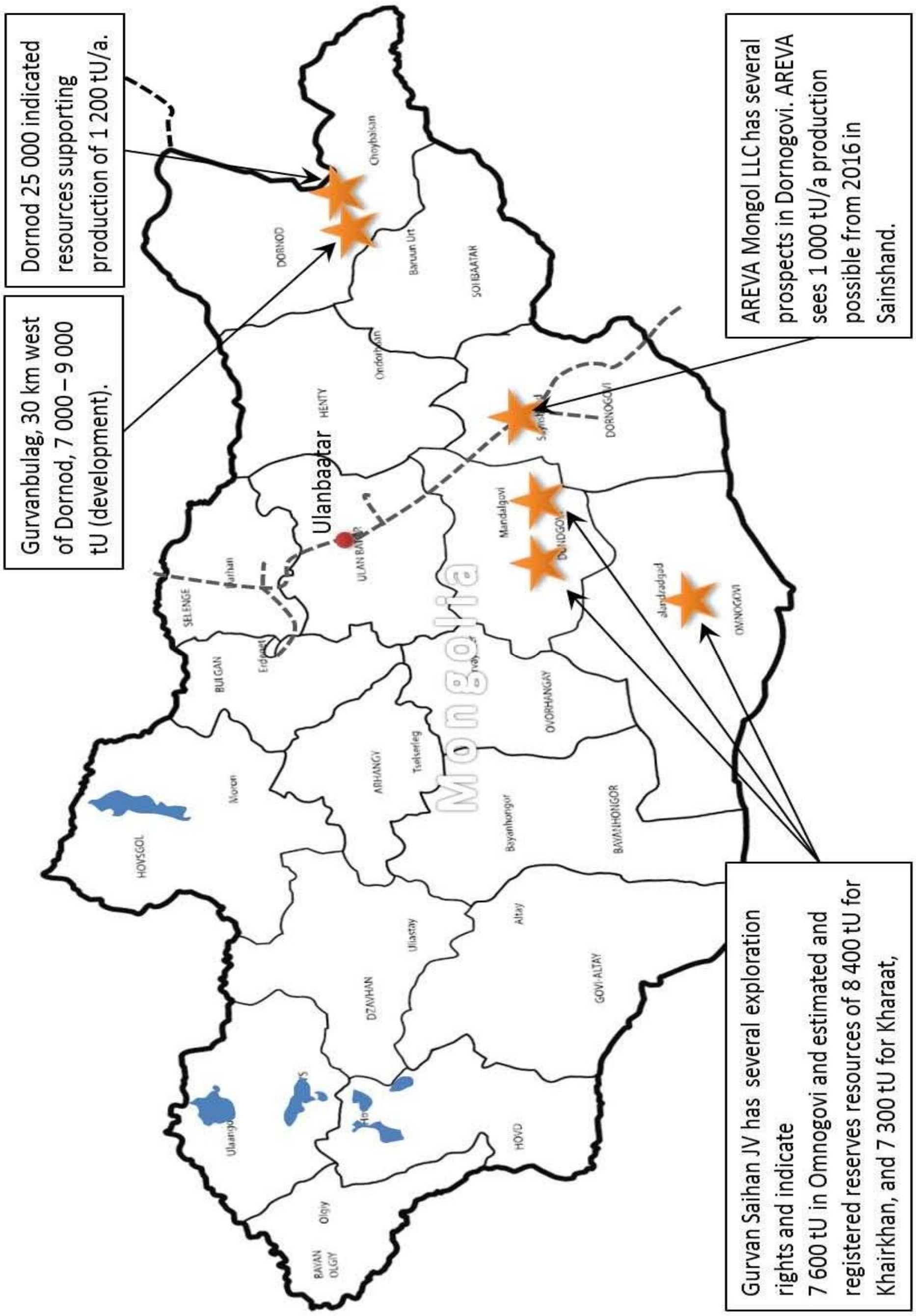


Figure 15: Uranium Resources in Mongolia

Source: ADB 'Updating Energy Sector Development Plan (TA No. 7619-MON)', Ulaanbaatar 2013

2.3 ENERGY SUPPLY AND DEMAND

Mongolia's energy needs are met mainly by domestic generation in coal-fired power plants and for others by hydro powers, small size renewable and diesel generators. Since Mongolia doesn't have own refineries, it is 100 % dependent on imported petroleum products from Russia and China. Total primary supply is dominated by coal (80.7% in 2012), electricity production in the country largely being based on coal. Petroleum products comprise second largest share at 15.1% of TPES. Other sources including combustible renewable have a small share of 4.1% and hydro less than 1 %.

Table 3 shows the structure of Primary Energy Supply by Source in Mongolia, 1,000 TOE and figure 16 shows the Trends of Primary Energy Supply by Source, 1,000 TOE.

Mongolia also experienced a significant structural change in energy demand by source over the last two decades years. This occurred as a result of changing political orientation from centrally planned economy into one that is market-based and private sector driven. Figure 17 shows structure of energy demand and supply in Mongolia.

During the economic transition period from 1990 until 1995 is characterized by significant decrease of TPES and total final consumption (TFC) in the country, followed by a period of modest increase of the energy supply and demand levels till 2005 with a more accelerated raise reaching 8.9 % annual increase of final consumption for the period 2005-2012.

The current structure of TFC is dominated by petroleum products (36.5%) and heat (24.8%), followed by coal (13.7%) and electricity (15.1%). Compared with the first years of transition, there is evidence of substantial more than three-fold decrease in of coal consumption and increase in use of other fuels. Electricity and Oil keep constant absolute levels in the total energy consumption during the years.

Table 4, 5 show Final Energy Demand by Sector in Mongolia, 1,000 TOE and Final Energy Demand by Source in Mongolia, 1,000 TOE respectively.

	1990	1995	2000	2005	2010	2012	Growth rate p.a. (%)			
							’90-’95	’95-’00	’00-‘05	’05-’10
Coal	2,365	1,695	1,798	1,895	2,324	6,884	-6.5%	1.2%	1.0%	4.2%
	63.1%	73.1 %	70.2%	67.7%	65.6 %	80.7 %	-	-	-	-
Oil	1,206	345	472	584	879	1,284	-22.1%	6.5%	4.3%	8.5%
	32.2%	14.9 %	18.4%	20.9%	24.8 %	15.1 %	-	-	-	-
Hydro	0.00	0.00	0.25	0.28	4.73	8.96	0.0%	0.0%	2.1%	76.0 %
	0.00%	0.00 %	0.01%	0.01%	0.13 %	0.11 %	-	-	-	-
Tradit Fuels & Others	175	277	293	321	337	348	9.6%	1.1%	1.8%	1.0%
	4.7%	12.0 %	11.4%	11.5%	9.5%	4.1%	-	-	-	-
Total	3,746	2,317	2,564	2,800	3,545	8,526	-9.2%	2.0%	1.8%	4.8%
	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	-	-	-	-

Table 3: Structure of Primary Energy Supply by Source in Mongolia, 1,000 TOE

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

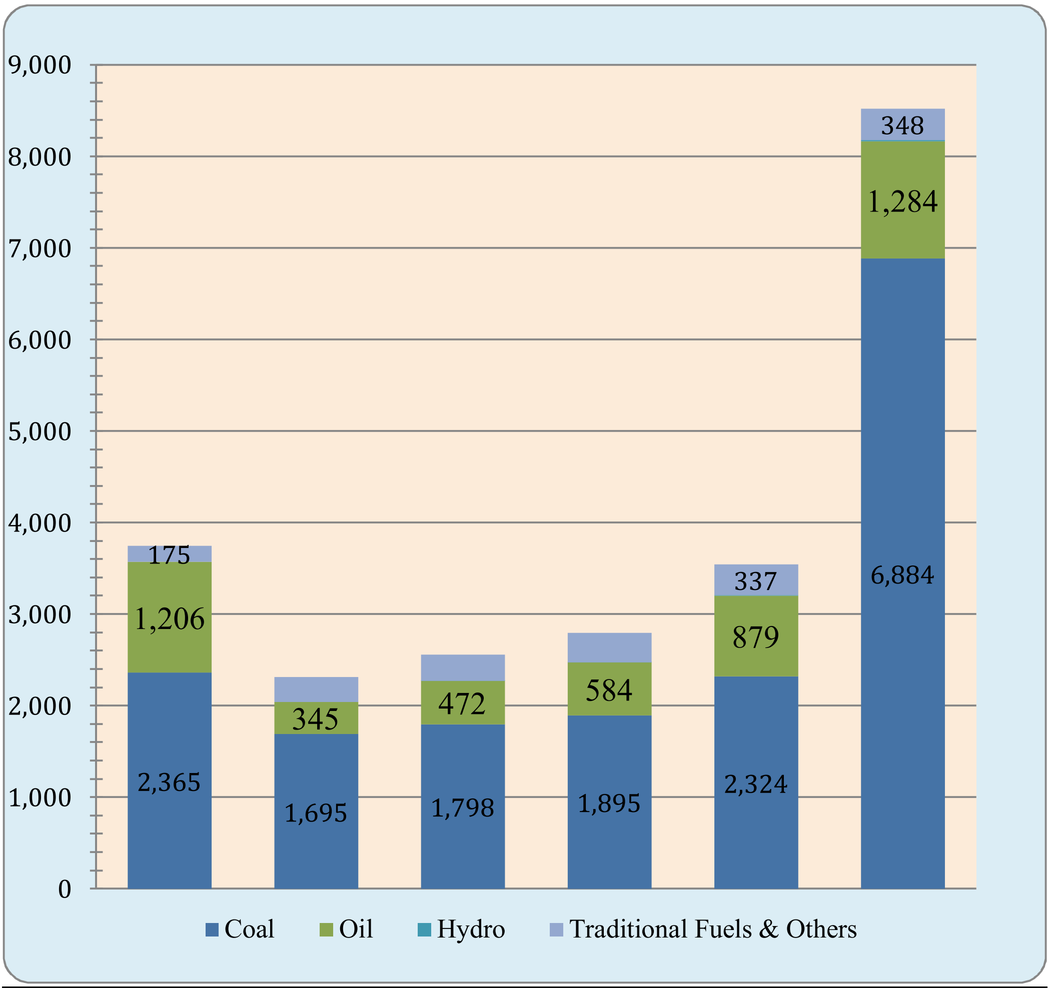


Figure 16: Trends of Primary Energy Supply by Source, 1,000 TOE

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

	1990	1995	2000	2005	2010	2012	Growth rate p.a. (%)			
							'90-'95	'95-'00	'00-'05	'05-'10
Industry	1129	502	464	721	623	937	-15.0%	-1.6%	9.2%	-2.9%
	35.2%	31.9%	26.2%	36.6%	23.9%	26.7%	-	-	-	-
Trans-	258	220	254	248	686	984	-3.2%	3.0%	-0.5%	22.6%
	8.1%	14.0%	14.4%	12.6%	26.3%	28.0%	-	-	-	-
Resid-	425	516	585	548	812	947	4.0%	2.5%	-1.3%	8.2%
	13.3%	32.9%	33.0%	27.8%	31.1%	27.0%	-	-	-	-
Comm/Public/Other	1392	333	467	456	490	644	-24.9%	7.0%	-0.5%	1.4%
	43.4%	21.2%	26.4%	23.1%	18.8%	18.3%	-	-	-	-
Total	3204	1571	1770	1973	2611	3511	-13.3%	2.4%	2.2%	5.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-	-	-	-

Table 4: Final Energy Demand by Sector in Mongolia, 1,000 TOE

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

		1990	1995	2000	2005	2010	2012	Growth rate p.a. (%)			
								'90-'95	'95-'00	'00-'05	'05-'10
Coal		826	201	217	148	326	482	-24.59%	1.52%	-7.43%	17.18%
		25.8%	12.8%	12.3%	7.5%	12.5%	13.7%	-	-	-	-
Oil		1,092	273	443	570	876	1,281	-24.21%	10.18%	5.16%	8.96%
		34.1%	17.4%	25.0%	28.9%	33.5%	36.5%	-	-	-	-
Elect		228	161	154	216	290	531	-6.65%	-0.94%	6.97%	6.14%
		7.1%	10.3%	8.7%	10.9%	11.1%	15.1%	-	-	-	-
Heat		884	658	663	718	782	869	-5.74%	0.16%	1.62%	1.72%
		27.6%	41.9%	37.4%	36.4%	29.9%	24.8%	-	-	-	-
Trad/ Fuels/ Others		174	277	293	321	337	348	9.72%	1.10%	1.85%	0.99%
		5.4%	17.7%	16.5%	16.3%	12.9%	9.9%	-	-	-	-
Total		3,204	1,571	1,770	1,973	2,611	3,511	-13.3%	2.4%	2.2%	5.8%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-	-	-	-

Table 5: Final Energy Demand by Source in Mongolia, 1,000 TOE

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

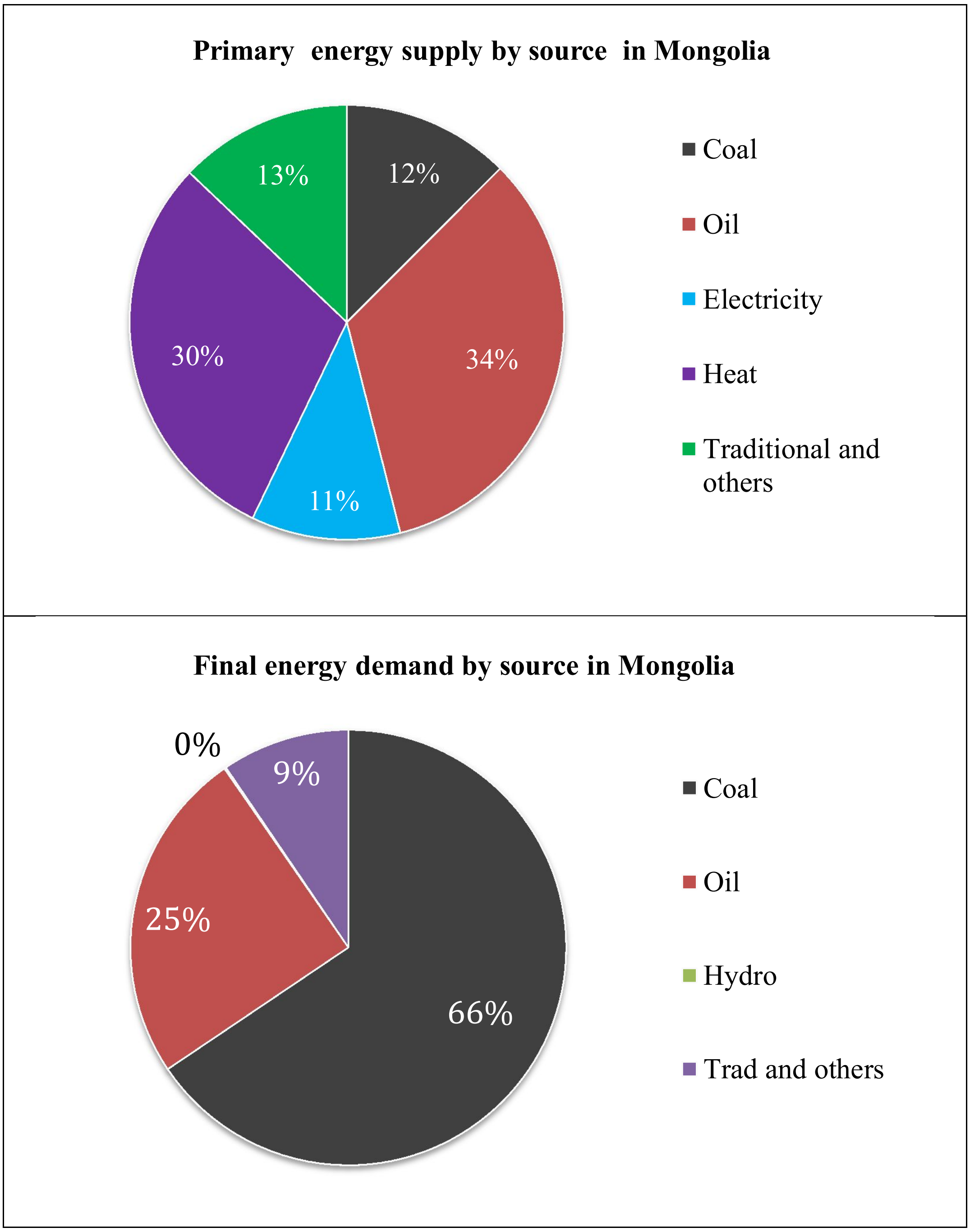


Figure 17: Structure of energy demand and supply in Mongolia

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

2.4 ELECTRICITY SECTOR

The power sector in Mongolia is designed around an integrated system of coal production for the generation, transmission and distribution of power and heat. The overwhelming majority of our heat and electric energy was being generated by coal fired thermo power plants and the remaining small amount by hydro, wind, solar and diesel stations[5].

The power sector consists of three separated electric power systems: the Central Energy System (CES), the Western Energy System (WES), Altai-Uliastai energy system (AUES) and the Eastern Energy System (EES). The Central Energy System is the main system with five generation, one transmission and four distribution companies. It supplies energy to the capital city and 14 aimags in central Mongolia and covers over 97% of the country's total electricity consumption. The CES power supply is comprised of five coal burning generating plants and an interconnection to UES of Russia. With the high increase of the final energy consumption in the recent years and the expectation for further increase, there are preliminary calculations that the peak load of the CES in 2015 could reach 930 MW, with total installed possible capacity of 1176 MW. Figure 18 shows the structure of electricity production in 2013.

In 2013 Major part (97.4%) of electricity is produced in CHPs, 1.2% from hydro, 1.03% from wind and some small solar plants. About 5.8 % of the electricity is imported from Russia during peak load.CES with the poor peaking capability of the essentially base-load plants is unable to properly follow the daily system demand. Therefore CES imports electricity from Russia during the peak periods[6].

Losses in the transmission and distribution systems are high; technical losses were about 14% in distribution and about 3.44% in transmission. District heating is usually provided from 15th September to 15th May each year for all sectors, but to 1st of May for governmental offices. Steam and hot water is provided all year round. The

[5] National Statistical Committee, National Statistical Yearbook, Mongolia, Ulaanbaatar 1999-2012

[6] National Dispatching Center, Mongolia, 2013

major suppliers of coal to the power industry are the Baganuur, Nariinsukhait, Shivee Ovoo and Tavantolgoit mines with annual capacities of 10 million, 3 million, 15 million and 20 thousand tons, respectively. Total coal production is 25 million tons in 2010, of which some 5.5 million is used for power generation. The most recent available data on energy consumption in Mongolia's regional heat and electricity systems shows that they consume about 25 percent of total coal production (25 million tons) used domestically in 2010. In addition to the regional coal-based energy systems, there is an isolated diesel-power generator that accounts for 0.1 % of electricity production. Figure 19 shows the Installed capacity for Electricity and Heat of Mongolia.

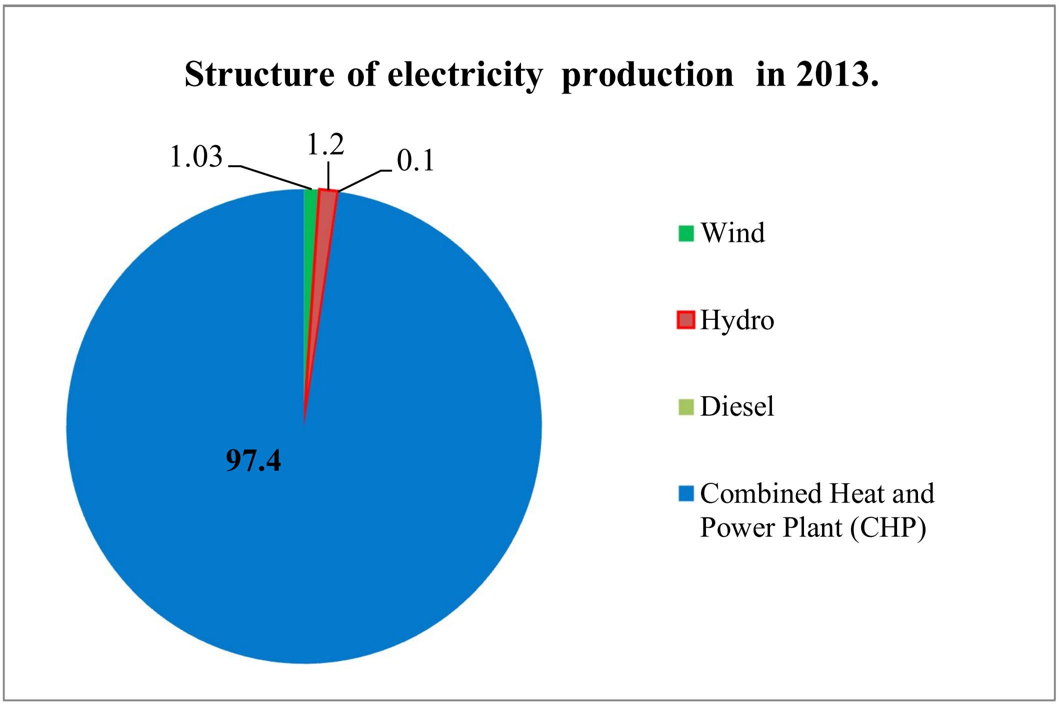
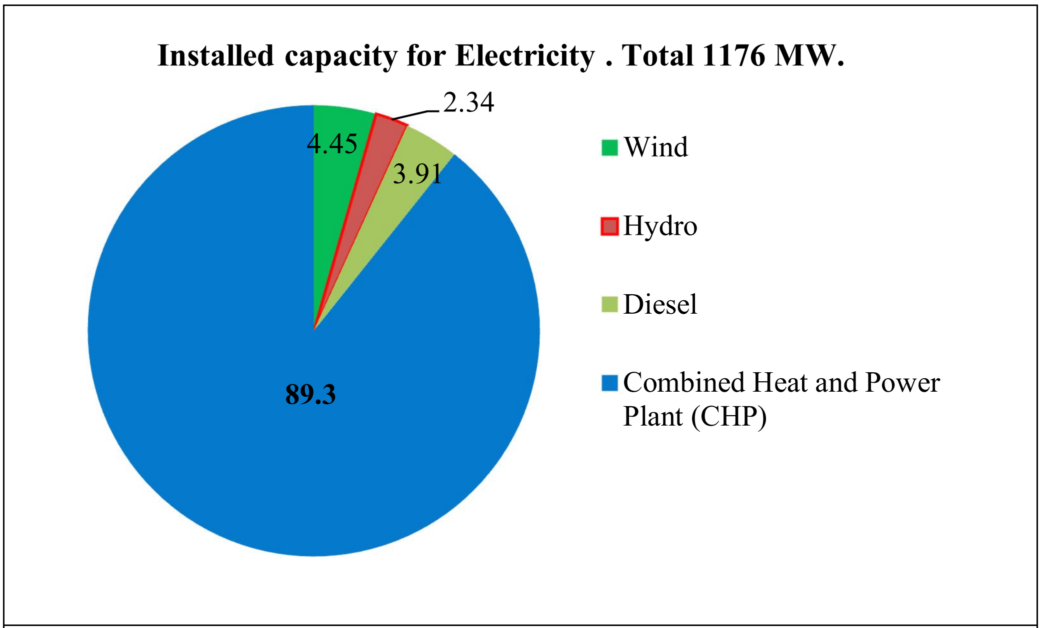


Figure 18. Structure of electricity production in 2013.

Source: Energy regulatory committee statistics, 2014



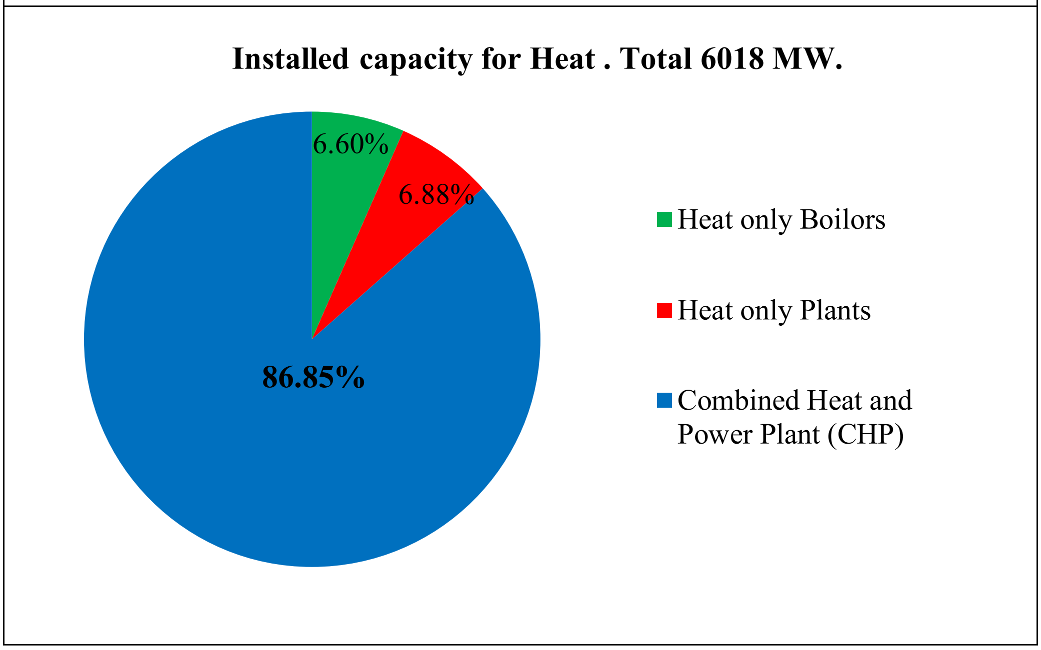


Figure 19: Structure of Power Generation Installed Capacity in 2012

Source: Ministry of Energy, Energy Statistics, Mongolia 2013

Chapter 3. Literature review

This chapter describes main researches on causality between Energy consumption and Economic growth among different countries with different energy sources and economic development in the world. For this study a number of previous literature are reviewed in terms of nexus between the energy consumption and economic growth.

Various researches on causality between Energy consumption and Economic growth of the countries depend on the level of economic development and energy sources as well. But mainly differentiations among them consist from the different variables and time period of that history period.

Depending on energy consumption impact to the economic growth, works can be separated to the long-time period issues and short-time issues. Using results of the researches with clear vision what kind of causality exist between energy consumption and economic growth policy makers can choose applicable policy tools in order to increase positive effects of the energy policy in the area.

These diverse results arise due to the different data set, alternative econometric methodologies and different countries' characteristics. The actual causality is different in different countries and this might be due to different countries' characteristics such as different indigenous energy supplies, different political and economic histories, different political arrangements, different institutional arrangements, different cultures and different energy policies, etc. (Chen et al., 2007, p. 2612).

As pointed out also by Apergis and Payne, 2009a; Ansgar Belke et al., 2010, Chontanawat et al., (2006), Squalli, 2007; Chen et al., 2007;Yoo, 2005; Jumbe, 2004; Shiu and Lam 2004 many others, the directions that the causal relationship between energy consumption and economic growth could be categorized into four types each of which has important implications for energy policy.

1) No causality: No causality between energy consumption and GDP is referred to as **"neutrality hypothesis"**. It implies that energy consumption is not correlated with

GDP, which means that neither conservative nor expansive policies in relation to energy consumption have any effect on economic growth.

Thus, the neutrality hypothesis is supported by the absence of a causal relationship between energy consumption and GDP.

2) The unidirectional causality running from economic growth to energy consumption. It is also called **''conservation hypothesis''**. It suggests that the policy of conserving energy consumption may be implemented with little or no adverse effect on economic growth, such as in a less energy-dependent economy. The conservation hypothesis is supported if an increase in GDP causes an increase in energy consumption.

3) The unidirectional causality running from energy consumption to economic growth. It is also called **''growth hypothesis''**. It implies that restrictions on the use of energy may adversely affect economic growth while increases in energy may contribute to economic growth. 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. Consequently, we may conclude that energy is a limiting factor to economic growth and, hence, shocks to energy supply will have a negative impact on economic growth.

4) Bi-directional causality between energy consumption and economic growth. It is also called **''feedback hypothesis''**. It implies that energy consumption and economic growth are jointly determined and affected at the same time.

In these times, most popular tools for scholars in this area are Granger causality cointegration, vector error correction model, which is used to analyze the causal relationship between energy consumption and economic growth of the country. But before founding Granger test, scholars used to analyze the causality with simple log-linear model and calculated by the ordinary least square (OLS) method and the variables affinities of time series were not concerned.

However, mostly scholars tried to find vector of the causal relation between energy consumption and economic growth for selected countries with different economic development using different tools, although we got different results. Main differentiation between these works is absence or existence of the causality between energy consumption and economic growth.

- Existence of (unidirectional, bidirectional) causal relationship.
- Absence of causal relationship.

3.1 Existence of a (unidirectional, bidirectional) causal relationship.

According to the scholars there are countries, where causality between energy consumption and economic growth exists. Some country's causality goes from the energy consumption to economic growth, and other countries have opposite causality between economic growth and energy consumption. In this chapter will be discussed issues, which consist from the existence of causality between energy consumption and economic growth in different countries.

The causal relationship between energy consumption and GNP in the United States of America in the period 1947-1974 was first found by Kraft and Kraft (1978) which showed unidirectional causality running from GNP to energy consumption. According to this issue, was found that energy conservation measures do not affect the economy negatively. Scholars used cointegration and causality methods as an analytical tool to determine the relationship between energy consumption and economic growth of the country, which was offered by Granger (1969), this method, become most widespread analytical tool in this kind of research areas.

Later same result, but using monthly data Akarca and Long (1979) in the period of 1973-1978 in United States also found unidirectional causality between energy consumption and GNP. They estimated the long-run elasticity of total employment with respect to energy consumption. In case of Asian countries, Asafu-Adjaye (2000) found the causal relationships between energy use and income in four Asian countries. In this issue scholar include except economic growth and energy consumption price as a third variable. In the result researcher conclude that unidirectional Granger causality runs from energy use to income for India and Indonesia, when bidirectional Granger causality runs from energy to income for Thailand and the Philippines.

In the long term perspective for India and Indonesia exist unidirectional Granger causality running from energy consumption and prices to income for India and Indonesia. When for Thailand and Philippines energy consumption, income and price are bidirectional causal. In the casual chain price affect less significant causal chain. In general issue do not support the aspect that energy and income are neutral with respect to each other, with the exception of Indonesia and India where neutrality is observed in short run.

Li and Leung investigated the relationship between coal consumption and real GDP among different regions of China with the use of panel data and indicated that coal consumption and GDP are both I(1) and cointegrated in all regional groupings. The regional causality tests reveal that the coal consumption-GDP relationship is bidirectional in the Coastal and Central regions whereas causality is unidirectional from GDP to coal consumption in the Western region.

Mohanty and Devtosh (2014) investigated relationship between electricity consumption and GDP in period of 1970-2011 for India. Applying, two step Engle-Granger technique and Granger causality/ Block exogeneity Wald test, the study suggests that it is the electricity energy consumption that fuels economic growth both in short run and long run. It rejects the neo-classical hypothesis and empirically proves that electricity consumption is a limiting factor on economic growth.

Masih and Masih (1996) observed cointegration for India, Indonesia and Pakistan and no cointegration for Singapore, Malaysia and the Philippine between GDP and energy consumption with the vector correction model (VECM). And the unidirectional causality was found in India running from energy consumption to GDP, and opposite causality in Indonesia running from GDP to energy consumption, and finally in case of Pakistan bidirectional causality was found. The Philippine, Malaysia and Singapore were tested by VAR method and causality was not found among those countries.

Lei and Li (2014), investigated the relationships between coal consumption and economic growth of the six biggest coal consumption countries: with coal price as a third variable using a common source of data from 2000 through 2010. Then 6 main coal consumption countries are chosen as China, the United States of America, India, Germany, Russia and Japan. The tests show: (1) Bidirectional causal relationships between coal consumption and economic growth exist in Germany, Russia and Japan. (2) Only a unidirectional causality from economic growth to coal consumption exists in China.

Aqeel and Butt (2001) issued the causal relationship between economic growth, employment and energy consumption in Pakistan and found unidirectional causality running from economic growth to energy consumption. Later authors checked relationship between economic growth with several type of energy consumption and found unidirectional causality between from economic growth to petroleum consumption, also no causality between economic growth and gas consumption, and discovered unidirectional causality running from electricity consumption to economic growth.

The causality between energy consumption and economic growth in Singapore and South Korea were issued by Glasure and Lee (1997). Using of VAR model helped to discover unidirectional Granger causality in the case of Singapore running from energy consumption to GDP and no Granger causality in case of South Korea. However bidirectional causality for both countries was found by adopting cointegration and error corrections models (ECMs).

Later Oh, W., Lee, K. (2004) discovered bidirectional causality between energy consumption and economic growth of South Korea in the long term and unidirectional causality running from energy consumption to economic growth in short term for the period 1970-1999. Scholars used the Divisia aggregate instead of the conventional energy aggregate and VECM rather than the VAR model.

The energy and economy relationship issues of the G-7 countries and the top 10 emerging economies were studied by Soytas and Sari (2003). The results showed the existence of unidirectional causalities running from GDP to energy consumption in Italy and South Korea, and from energy consumption to GDP in Germany, France, Japan and Turkey and bidirectional causality for Argentina.

China was not included in previous research, but Lin (2003) discovered unidirectional causality from electricity consumption to GDP within period of 1978-2001. But Shiu and Lam (2004) researched the period of 1971-2000 and found unidirectional causality running from GDP to electricity consumption.

Jumbe (2004) investigated the causality relationship between GDP, agricultural GDP, nonagricultural GDP and electricity consumption in Malawi in the period of 1970-1999. Error correction model showed a bidirectional Granger causality between electricity consumption and GDP and unidirectional Granger causality between electricity consumption and GDP and an unidirectional Granger causality nonagricultural GDP and electricity consumption.

Lee (2005) used panel cointegration and panel-based error correction models to find the causality between the energy consumption of 18 developing countries in period of 1975 - 2001. The results showed long-term and short term causalities running from energy consumption and economic growth. It implied that energy conservation policies could damage the economic growth of most of inspected developing countries.

Lee and Chang, (2005) issues the relationship between energy use and GDP in Taiwan in the period of 1954-2003. Scholars found that different directions of causality exist between GDP and various kinds of energy consumption. The empirical result shows unanimously that in the long run energy acts as an engine for economic growth, and that energy conservation may harm economic growth.

In case of Turkey, Altinay and Karagol (2005) got problems with data providing from the 1970 period, what can be reason of the problems in analyzing part of their work. Therefore, they used different approaches to check causality: the Dolado – Lutkepohl test using the VARs in levels and the Granger causality method for de-trended data. As a result, they obtained unidirectional causality running from electricity consumption to GDP which indicated the importance of electricity supply to contribute to the economic growth in Turkey in the period of 1950 - 2000.

Wolde-Rufael (2005) analyzed the causality between energy consumption and GDP in 19 African countries within the period of 1971-2001. He obtained causal relationships only for 12 countries and long-term connections for 8 countries.

In the case of Bangladesh the causal connections between the electricity consumption per capita and the GDP per capita were studied by Mozumder and Marathe (2007), who applied cointegration and VECM approaches, and found unidirectional causality running from GDP per capita to electricity consumption per capita what means necessity of employment of energy conservation policies to sustain economic growth in Bangladesh.

The analysis for the causal relationship between energy consumption per capita and GDP per capita for 11 OPEC countries was researched by Mehrara (2007). The results obtained the unidirectional and strong causality from GDP to energy consumption for OPEC countries. The governments of most of these countries make the domestic price lower than market price resulting in an increase in energy consumption. Thus, the government's policies on conservation do not harm to the economic growth of these countries.

Chebbi and Boujelbene (2008) examined the causal linkage between energy consumption and agricultural and nonagricultural outputs in Tunisia in period of 1971-2003. In their study, they used ADF and PSS (Kwiatkowski et al 1992), Johansen cointegration test and VECM. The findings showed there is only a unidirectional causality running from agricultural and non- agricultural sectors to energy consumption, which implies that sectoral growth leads to increases in energy consumption.

Zhang-wei (2012) investigated relationship between energy consumption and economic development based on the VAR model using temporal series of China from 1990 to 2009, then uses impulse response function and variance decomposition to portray the correlations between economic growth and energy consumption. The result shows that there exists a unidirectional causality from energy consumption to gross domestic product and energy consumption can observably promote the development of economy.

Hu and Lin (2013) examined relationship between the electric power consumption of 3 major industries of the whole society and GDP growth in Hainan Island from 1988 to 2009. And they discovered some causalities between them. Only the secondary industry's GDP and the electric power consumption aren't in the same order integration, there doesn't exist co-integration relationship between them. It isn't clear that the electric power consumption in the secondary industry influences the GDP growth in Hainan Island.

Belke and Dreger (2010) examined the long-run relationship between energy consumption and real GDP, including energy prices, for 25 OECD countries from 1981 to 2007. The results suggest that energy consumption is price-inelastic. Causality tests indicate the presence of a bi-directional causal relationship between energy consumption and economic growth.

3.2 Absence of a (unidirectional, bidirectional) causal relationship.

In this part described several cases with no causality between energy consumption and economic growth. Researches about no causality between GNP and different kinds of energy consumption have been issued European countries such as United Kingdom, Germany, Italy, Canada, France as well as by Japan.

Yu and Choi (1985) discovered no causal linkages for the USA, UK and Poland. But in case of South Korea they found causality running from GDP to energy consumption and causality for Philippine running from energy consumption to GDP.

Several developed countries were observed by Erol and Yu (1987) in the period of 1950-1982 and causality between energy and output was obtained, but within the years of 1950-1973 no casual connection was found. By using monthly data, Yu and Jin (1992) checked the cointegration between energy and GDP and found no long term connection among them.

Lei and Li (2014), investigated the relationships between coal consumption and economic growth of the six biggest coal consumption countries using a common source of data from 2000 through 2010. Then 6 main coal consumption countries are chosen as China, the United States of America, India, Germany, Russia and Japan. The tests show that there are no causal relationships between coal consumption and economic growth in USA and India. These coincident results with previous research further indicate that each country should form their own coal consuming policies according to their own situations.

Using the multivariate approach instead of bivariate was started by Stern (1993). Energy, GDP, capital and labor was used to check the Granger causality between energy and GDP in the post-war United States. Scholar applied a multivariate vector autoregressive analysis and also used weighing measure of energy (by changing low quality - coal to high quality electricity instead of using the total energy itself). Using the total energy with various causality tests no Granger causality was found but with weighting the Granger causality existed.

After applying the bivariate model no relationship between energy use and income way) in the United States was discovered by Cheng (1995). The same result of no relationship occurred by employing the multivariate model.

3.3 Energy and Economic growth

The direct influence of energy in economic growth still remains an interesting question among researchers. As all economic sector like industrial, mining, transportation, agro-industrial, residential, commercial and public activities increase, the demand for energy similarly increases.

From an economic point of view, the relationship between energy consumption and economic growth lies in two aspects: the growing dependence of economic growth on energy, and on the other hand, economic growth can promote energy technology advances and large-scale development and utilization of energy. There are different views among economists on the role of energy in the economy.

By reviewing the relationship between consumptions of various energy supply and economic growth it is necessary to explain the causality between them. For this reason, the theoretical literature of neoclassical and of ecological economic world views is examined.

3.3.1 Neo-classical views of economic growth

The basic growth model which examines the hypothetical economy is the Solow growth model (1956). In this model, Solow focuses on three variables output (Y), capital (K) and labor (L). The production is Y = f(K,L) which does not include resources at all. Economic growth is achieved by increasing inputs of labor or human capital.

On the other hand, the only cause of continuing economic growth is technological progress. When the level of technological knowledge accumulates the functional relationship between productive inputs and output changes, same quantity and quality of inputs can produce greater quantities and better qualities of output. Intuitively, increases in the state of technological knowledge raise the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth (Stern, 2003).

However, the Solow model just described does not explain how improvements in technology come about and it treats technological progress as an exogenous variable. In endogenous growth models the relationship between capital and output can be written in the form Y = AK. Where the level of technology that is a positive constant (A) and Capital (K), is defined more broadly than in the neoclassical model. According to endogenous growth models, technological knowledge is thought as a form of capital, where it accumulated through research and development and other knowledge creating processes. The technological knowledge through investment in capital exactly offsets the diminishing returns to manufactured capital and the economy can sustain a constant growth rate (Stern, 2003).

In these models, the contribution of energy to economic activity is only considered relative to its cost within production. Therefore, the model consider energy to be an "intermediate good" rather than a "primary input" into the production process. It argues that there are some mechanisms by which economic growth could remain in spite of limited sources of energy resources. Thus, the government can adopt energy conservation policies without having any harmful effect on economic growth (Bartleet and Gounder, 2010).

3.3.2 Ecological views of economic growth

Ecological economic theory on the contrary states that energy consumption is a limiting factor to economic growth, especially in modern economies. Ecological economists judge that technological progress and other physical inputs could not possibly substitute the vital role of energy in the production process. Most importantly, the ecological economists' worldview attempts to account for the laws of thermodynamics. The first law of thermodynamics, the conservation law, implies that the mass of inputs and output must be equal in the production process.

Therefore, there are minimal material input requirements for any production process producing material outputs. The second law of thermodynamics, the efficiency law, implies that a minimum quantity of energy is required to carry out the transformation or movement of matter. All production involves the transformation or movement of matter in some way and all such transformations require energy, and there must be limits to substitution of others factors of production for energy so that energy is also an essential factor of production (Stern, 2003).

This perspective is the so-called "growth hypothesis" and advises that any shock to energy supply will strongly have a negative impact on economic growth. As a result, they are against energy conservation policies.

Without using energy, it is impossible to operate a factory, grow crops, travel, or deliver goods from producer to consumers. Economic growth almost always leads to increased energy use, at least in the early stages of economic development. Energy is included in the production function via empirical analysis conducted by IEA (2004).

This study demonstrates the importance of energy in driving economic growth applied to several developing countries between 1981 and 2000 (IEA, 2004). This function is described as follows:

$$Yt = At*(Kt)\alpha\ (Lt)1-\beta\ (Et)1-\alpha-\beta \quad (1)$$

where,

Yt : Output

At : Economy's total factor productivity

Kt : Stock of capital

Et : Energy use

Lt : Labour

3.4 Previous Research

A number of studies in the literature have focused on the energy consumption and economic growth nexus; however no consensus results are achieved due to different countries characteristics or different times within the same country, and different research methodologies. The pioneering study of Kraft and Kraft (1978) provides evidence in support of a unidirectional long run relationship running from gross domestic product (GDP) to energy consumption for the case of the U.S. over the 1947-1974 period. The results imply that energy conservation policies might be enforced without having any adverse effect on economic growth. On the other hand, Akarca and Long (1980) failed to obtain causality between energy consumption and GDP, so they argued that Kraft and Kraft's study could suffer from temporal time period instability (Belloumi, 2009).

Several researchers have since joined the debate, with some having either confirmed or contradicted Kraft and Kraft's results. Cheng and Lai (1997) found causality running from GDP to energy consumption but not vice versa for Taiwan for the 1955 – 1993 period. They concluded that, for the newly industrializing countries in general, energy is an important ingredient of economic development; which in turn boots employment also. However, Yang (2000) reexamined the causality between energy consumption and GDP for Taiwan using updated data for the 1954–1997 period. The findings of this paper totally deny the findings of Cheng and Lai (1997) of unidirectional causality from GDP to energy consumption. They found evidence of bi-directional causality between energy consumption and GDP.

Masih and Masih (1996) used cointegration analysis of Engle-Granger's version to study this relationship in a group of six Asian economies. Significant cointegration was found between energy consumption and economic growth in India, Pakistan, and Indonesia, but no cointegration in Malaysia, Singapore, and the Philippines.

Glasure and Lee (1997) examined the causality between energy consumption and GDP for South Korea and Singapore and reported different results from different methodologies used. The standard Granger causality tests revealed no causal relationship for South Korea and a unidirectional causal relationship running from energy consumption to GDP for Singapore, while the error correction models (ECM) gave signal of bi-directional causality for both countries.

Asafu-Adjaye (2000) tested the causal relationship between energy use and income in four Asian countries (including India, Indonesia, Thailand and the Philippines) using the ECM models. The test results indicated a unidirectional causality running from energy to income in India and Indonesia, and a bi-directional causality in Thailand and the Philippines.

Chontanawat et al. (2008) investigated for causality between energy and GDP using a consistent data set and Granger test for 30 OECD countries and 78 non-OECD countries. They discovered that causality running from energy to GDP appeared to be more prevalent in the developed OECD countries compared to the developing non-OECD countries (70% in OECD countries compared to 46% in non-OECD countries); implying that a policy to reduce energy consumption aimed at reducing emissions is likely to have greater impact on the GDP of the developed rather than the developing world.

In short, a general judgment is that the results are still mixed: that is, while some studies find causality running from economic growth to energy consumption, others figure out causality running from energy consumption to economic growth and even some studies suggest no causality and/or bi-directional causality between these two variables.

As a conclusion, it is difficult to reach a conclusion on the causal relationship between energy consumption and economic growth. Moreover, from Table 6, it can be concluded that for the most countries involved, almost all types of causality results (unidirectional causality, bidirectional causality and no causality) have been reported in the literature.

There are also some cases when different researchers find different and sometimes controversial results for the specific country that has been researched.

Authors	Period	Country	Methodology	Causality relationship
Kraft and Kraft (1978)	1947–1974	USA	Granger causality	GDP→EC
Akarca and Long (1980)	1950–1970	USA	Sims' technique	No causality
Yu and Hwang (1984)	1947–1979	USA	Sims' technique	No causality
Abosedra and Baghestani (1989)	1947–1987	USA	Cointegration, Granger causality	GDP→EC
Hwang and Gum (1991)	1961–1990	Taiwan	Cointergration, error correction	No causality
Yu and Jin (1992)	1974–1990	USA	Cointegration and Granger causality	No causality
Stern (1993)	1947–1990	USA	Multivariate VAR model	EC→GDP
Cheng (1995)	1947–1990	USA	Cointegration and Granger causality	No 58ausally
Cheng and Lai (1997)	1954–1993	Taiwan	Ganger causality	GDP→EC
Chontanawat et al.	2008	78 non	Cointegration and	EC→GDP

(2008)		OECD country	Granger causality	
Zhang-wei,Zheng (2012)	1990-2009	China	Ganger causality, Var model	EC→GDP
Li Fei et.al., (2011)	1985-2001	China	Cointegration and Granger causality	EC→GDP
Herrerias et.al., (2013)	1995-2009	China	Cointegration and Granger causality	EC→GDP
Hai and Yandong Wang (2015)	1991-2012	China	Cointegration, Granger causality	EC→GDP
Xiaohua Hu (2013)	1990-2009	China, Hainan	Cointegration, Granger causality	EC→GDP
Shohrat Baymuradovich Niyazmuradov (2012)	1992-2010	Turkmen-istan	Cointegration, Granger causality	EC→GDP, GDP → EC
Hoang Buu Quoc (2012)	1984-2010	Vietnam	Cointegration, Granger causality	GDP→EC
Ularbek Ruslanovich Niizaliev (2013)	1990-2011	Kyrgyz republic	Cointegration, Granger causality	EC→GDP, GDP → EC
Ali Aliabadi (2012)	1991-2008	Iran	Cointegration, Granger causality	GDP → EC
Carlo Mario Franchini Irujo (2014)	1971-2010	Peru	Cointegration, Granger causality, Trivariate Analysis	EC→GDP, GDP → EC
Mercy Abrokwah-Koranteng (2013)	1971-2009	Ghana	Cointegration, Granger causality	GDP → EC
Mergenbayev Adil Kayirdinovich (2013)	1990-2010	Kazakhstan	Cointegration, Granger causality	EC→GDP
Ali Mohammed Aziz (2013)	1989-2011	Yemen	Cointegration, Granger causality	EC→GDP
Cheng (1998)	1952-1995	Japan	Hsiao's version of Granger causality	GDP→EC
Cheng (1999)	1952-1995	India	Cointegration, Granger causality	GDP→EC
Stern (2000)	1948-1994	USA	Cointegration, Granger causality	EC→GDP
Soytas et al. (2001)	1960-1995	Turkey	Cointegration, Granger causality	EC→GDP

Aqeel and Butt (2001)	1955–1996	Pakistan	Cointegration and Hsiao's version of Granger causality	GDP→EC
Fatai et al. (2002)	1960–1999	New Zealand	Granger causality, Toda and Yamamoto's and autoregressive distributed lag (ARDL) technique	No causality
Glasure (2002)	1961–1990	South Korea	Cointegration, error-correction, variance decomposition	GDP↔EC
Hondroyiannis et al. (2002)	1960–1996	Greece	Error correction model	GDP↔EC
Altinay and Karagol (2004)	1950-2000	Turkey	Hsiao's version of Granger causality	No causality
Ghali and El-Sakka (2004)	1961–1997	Canada	Cointegration, VEC, Granger causality	GDP↔EC
Paul and Bhattacharya (2004)	1950-1996	India	Cointegration, Granger causality	GDP↔EC
Oh and Lee (2004)	1970–1999	Korea	Granger causality and error correction	EC→GDP
Wolde-Rufael (2004)	1952–1999	Shanghai	A modified version of Granger causality	EC→GDP
Lee and Chang (2005)	1954-2003	Taiwan	Johansen-Juselius, Cointegration, VEC	EC→GDP
Ang (2007)	1960-2000	France	Cointegration, VECM	Energy use→GDP (in the short run)
Lee and Chang (2007 a)	1955-2003	Taiwan	Granger causality, Cointegration, VECM	EC→GDP (only where there is a low level of energy consumption in Taiwan)

Jobert and Karanfil (2007)	1960-2003	Turkey	Granger causality test	No causality
Ho and Siu (2007)	1966-2002	Hong Kong	Cointegration, VEC model	EC→GDP
Zamani (2007)	1967-2003	Iran	Granger causality, Cointegration, VECM	GDP → Total energy
Lise and Montfort (2007)	1970-2003	Turkey	Cointegration test	GDP↔EC
Karanfil (2008)	1970-2005	Turkey	Granger causality test, cointegration test	GDP↔EC No causality (when unrecorded economy is taken into account)
Ang (2008)	1971-1999	Malaysia	Johansen cointegration, VEC model	GDP↔EC
Erdal et al. (2008)	1970-2006	Turkey	Pair-wise granger causality, Johansen cointegration	ELC↔GDP
Bowden and Payne (2009)	1949-2006	USA	Toda-Yamamoto causality test	EC→GDP
Halicioglu (2009)	1960-2005	Turkey	Granger causality test, ARDL, cointegration test	No causality
Payne (2009)	1949-2006	USA	Toda-Yamamoto causality test	No causality
Soytas and Sari (2009)	1960-2000	Turkey	Toda-Yamamoto causality test	No causality
Belloumi (2009)	1971-2004	Tunisia	Granger causality, VECM	GDP↔EC (in the long-run)

Note: EC→GDP means that the causality runs from energy consumption to growth.
GDP→EC means that the causality runs from growth to energy consumption.
GDP↔EC means that bi-directional causality exists between energy consumption and growth
Abbreviations are defined as follows: VAR=vector autoregressive model, VEC=vector error correction model, ARDL=autoregressive distributed lag, EC=energy consumption, GDP=gross domestic product. ECM=error correction model and GMM=generalized method of moments.

Table 6. Summary of empirical studies on energy consumption-growth nexus for country specific cases

Chapter 4. Methodology

This chapter will describe the methodology used in order to find causality between economic growth and energy consumptions in Mongolia, using the unit root test, co-integration test, VECM and Granger causality test.

According to Engle and Granger (1987), 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.

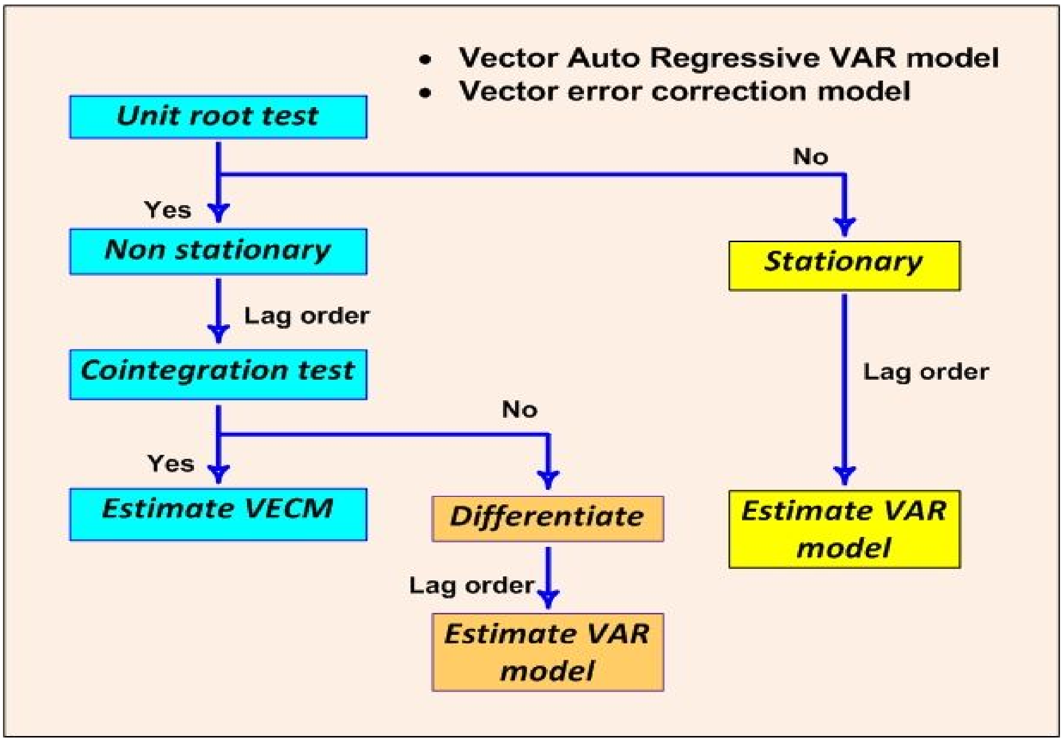
In regards to causality testing, we must check at first hand the stationary of variables to decide whether we can apply the standard Granger causality test or not. If the data sets prove to be stationary, then we can apply the standard vector autoregressive (VAR) Granger causality test, but if they prove 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 shown 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. Figure 20 describes the process of causality testing we use to analyze the relationship between energy consumption and economic growth in Mongolia.

4.1 Data

In our empirical study on cointegration and causality between Mongolia's 3 different energy consumptions and Gross domestic product, we use the time series data of GDP, and oil, primary energy, electricity consumptions for the period from 1985 to 2012 of Mongolia. Data set for real Gross domestic product was obtained from the World Development Indicators (2015) produced by the World development Indicators database, World Bank. Data for net energy sector was obtained from U.S Energy Information Administration web site. In this paper, electricity consumption is expressed in terms of billion kWh, oil consumption is expressed in thousand barrel p.day, primary energy



consumption is expressed in million Btu p.person and GDP is expressed in constant 2005 US$. Only in case of primary energy consumption we used nominal GDP.

Figure 20: Causality testing steps

Empirical analysis has been done by using STATA 12.0 statistical package. The choice of the starting period was constrained by the availability of data electricity consumption. The historical trends of GDP and energy consumptions of Mongolia are represented in Fig.21, Fig.22, Fig.23, Fig.24 respectively.

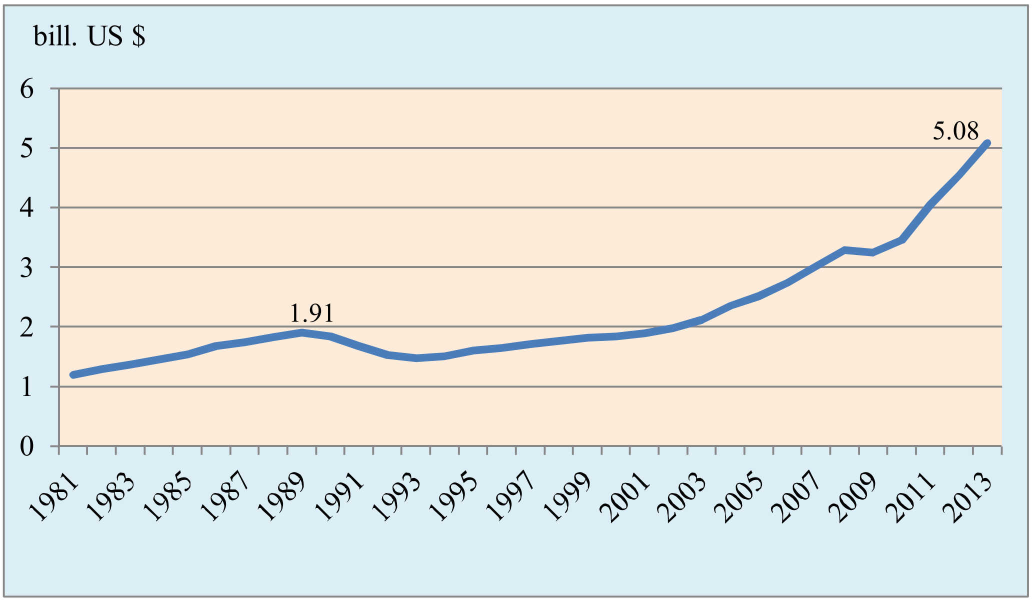


Figure 21. The historical trend of GDP in Mongolia

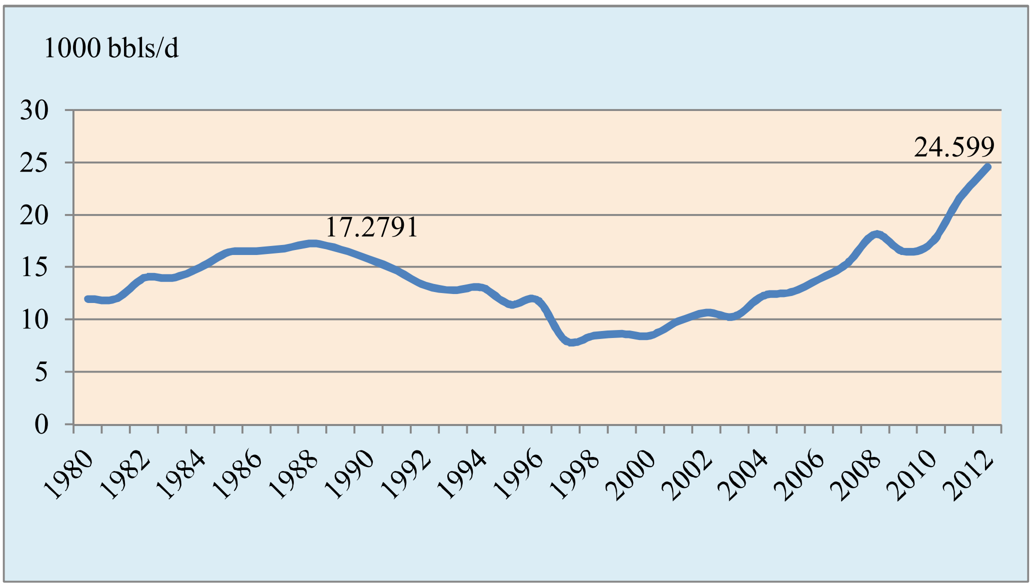


Figure 22. The historical trend of Oil consumption in Mongolia

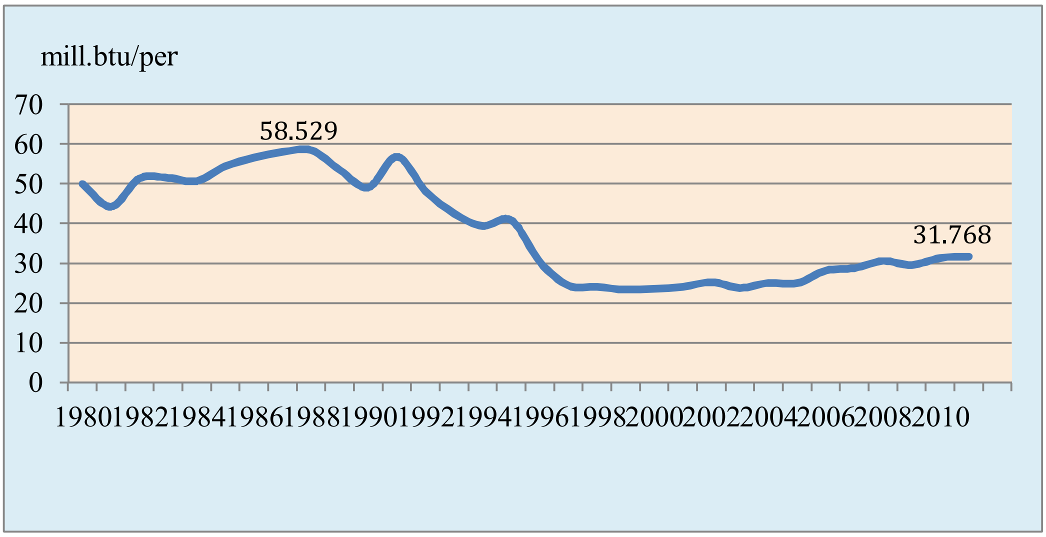


Figure 23. The historical trend of Primary energy consumption in Mongolia

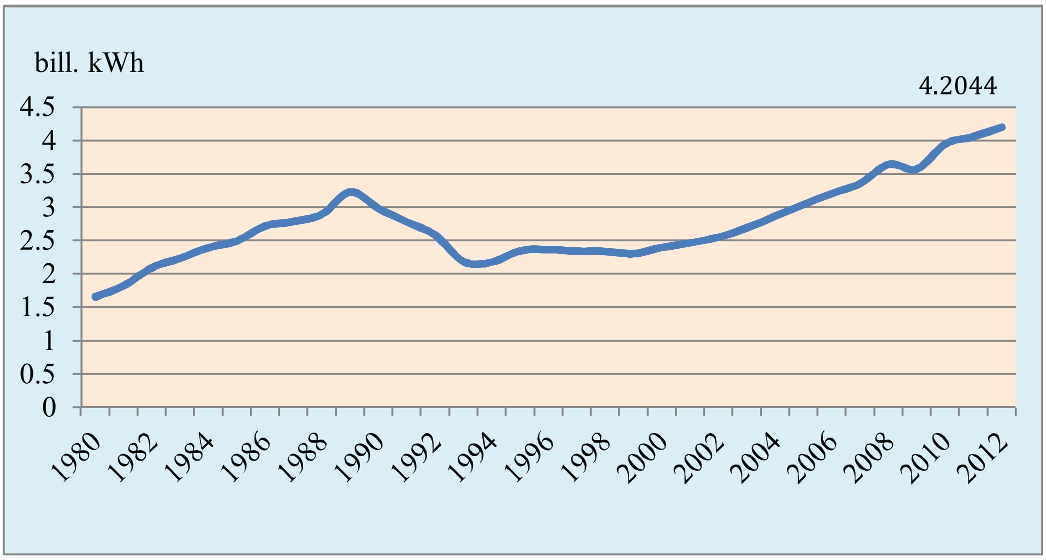


Figure 24. The historical trend of Electricity consumption in Mongolia

Before starting to the analysis we convert variables of GDP, energy consumption into their natural logarithm for to reduce heteroscedasticity while the second is that the logarithm variables have its economic meaning because they are approximated to be viewed as the growth of the respective differenced variables.

4.2 Stationarity and integration

Before the 1970s, the models of econometrics were basically built on the assumption of stationary of time series; however this assumption is obviously too simplistic. But later on Nelson and Plosser (1982), identified that most macro-economic time series are non-stationary therefore coefficients may have different distributions, which may result in non reliable regression.

Stationary requires the Mean, Variance and Auto-covariance of a series to be stationary. A series *xt* is said to be stationary, if it has a constant mean *E(xt)*, and its variance Var(*xt*) does not appear to systematically change over time. In this case, it will tend to fluctuate around the mean *E(xt)* steadily.

Whereas, a series *xt* is said to be non-stationary if it has non-constant mean *E(xt)*, and variance Var(*xt*) appears to be systematically changed over time. If the difference of a nonstationary series is stationary, the series is said to be integrated, i.e. ***I(1)***. If a nonstationary series has to be differenced *d* times to become stationary, then it is said to be integrated of *d* order: i.e. ***I(d)***. Only when two series are integrated of the same order, can it be proceeded to test for the presence of cointegration.

Early in 1976, Dickey and Fuller developed the DF method to test the stationarity of time series. In 1979-1980, they improved the DF method to ADF (Dickey, Fuller, 1979). Because actual series are usually not first order autoregression series, the augmented Dickey-Fuller (ADF) test is broadly applied to examine the unit root and stationarity of series here.

Firstly, set up the regression equation:

$$\Delta x_t = (\rho - 1)x_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta x_{t-j} + \varepsilon_t \qquad (2)$$

Where: ε_t is the residual (the same as follows).

Then test the null hypothesis $H0$: $\rho = 1$ that x_t is nonstationary, against $H1$: < 1, that x_t is stationary.

4.3 Co-integraion test

Co-integration - feature several non-stationary (integrated) time series is the existence of a stationary linear combination. The concept of co-integration was first proposed by Granger in 1981. Later this trend developed Engle, Johansen, Phillips and others.

Co-integration is an important feature of many economic variables, which means that, despite the occasional (slightly predictable) behavior of the individual economic variables, there is a long-run relationship between them, which leads to some joint inter-related changes. Actually it is the correction model (correction) of errors (ECM - Error Correction Model) - when the short-term movements are adjusted according to the degree of deviation from the long-term dependence. Such behavior is co-integrated time series. Another method is one presented by Engle and Grange (1987). They propose co-integration as non-stationary series, integrated in the same procedure, and linear combination between them may be observed which is stationary. This method includes two steps and means if two series *xt* and *yt*, are tested to be non-stationary, but both of them are integrated of the same order, the regression equation can be set up as:

$$xt = \alpha + \beta yt + \varepsilon t \quad (3)$$

As authors said the co-integration between *xt* and *yt* can thereby be tested by examining the stationarity of the residual *εt*. And if *xt* and *yt* are not co-integrated, all of their linear combinations will be non-stationary, consequently the residual *εt* will be also non-stationary. From the other side, if the *εt* is tested to be stationary, then the co-integration between *xt* and *yt* can be justified.

4.4 Vector Auto-regressions (VARs)

Vector auto-regression (VAR) is a dynamics model of multiple time series, in which the current value of the series depends on the past values of a time series. The model proposed by Christopher Sims (1980) as an alternative system of simultaneous equations involves substantial theoretical limitations. VAR-models are free from the limitations of structural models. However, the problem of VAR-models is a sharp increase in the number of parameters while increasing the number of analyzed time series and the number of lags.

The vector auto-regression is used to analyze the dynamic impact of random disturbances on the system of variables and to predict systems of interrelated time series. This is because VAR approach sidesteps the need for structural modeling by treating endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system.

Actually VAR - a system of econometric equations, each of which is a model and autoregressive distributed lag (ADL).

The mathematical representation of a VAR is (3) where *yt*is a *k* vector of endogenous variables, *xt* is a *d* vector of exogenous *A1…Ap* variables, and *B* are matrices of coefficients to be estimated, and is a ε_t vector of innovations.

Since only lagged values of the endogenous variables appear on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates.

Moreover, even though the innovations may be contemporaneously correlated, OLS is efficient and equivalent to GLS since all equations have identical regressors.

Real VAR model have longer lags and more variables. However, compared with the structural models VAR models have fewer options and less stringent restrictions on their values, which makes the VAR model extremely useful when faced with difficulties when collecting baseline information.

For example, suppose that industrial production (IP) and money supply (M1) are jointly determined by a VAR and let a constant be the only exogenous variable. Assuming that the VAR contains two lagged values of the endogenous variables, it may be written as

$$IP_t = a_{11}IP_{t-1} + a_{12}M1_{t-1} + b_{11}IP_{t-2} + b_{12}M1_{t-2} + c_1 + \epsilon_{1t} \qquad (4)$$

$$M1_t = a_{21}IP_{t-1} + a_{22}M1_{t-1} + b_{21}IP_{t-2} + b_{22}M1_{t-2} + c_2 + \epsilon_{2t} \qquad (5)$$

where a_{ij}, b_{ij}, c_i are the parameters to be estimated.

4.5 Vector error correction model

A Vector Error Correction Model (VECM) can lead to a better understanding of the nature of any non-stationarity among the different component series and can also improve longer term forecasting over an unconstrained model.

Consider a bi-variation vector of integrated order one, and assume that is Y_t cointegrated with cointegrating vector $\beta = (1, -\beta_2)'$ hat $\beta' Y_t = y_{1t} - \beta_2 y_{2t}$ is stationary.

According to Engle and Granger (1987), cointegration implies the existence of an Error Correction Model (ECM) of the following equation:

$$\Delta y_{1t} = c_1 + \alpha_1(y_{1,t-1} - \beta_2 y_{2,t-1}) + \sum_j \gamma_{11}^j \Delta y_{1,t-j} + \sum_j \gamma_{12}^j \Delta y_{2,t-j} + \varepsilon_{1t} \qquad \textbf{(6)}$$

$$\Delta y_{2t} = c_2 + \alpha_2(y_{1,t-1} - \beta_2 y_{2,t-1}) + \sum_j \gamma_{21}^j \Delta y_{1,t-j} + \sum_j \gamma_{22}^j \Delta y_{2,t-j} + \varepsilon_{2t} \quad \textbf{(7)}$$

The error correction term (ECT,α_2) denotes the long-run equilibrium with the short-run adjustment mechanism that demonstrates how the variables react when they deviate from the equilibrium. Unlike causality analysis using the VAR model which presents only one causal path, the causality analysis using VECM can present three different paths. The first one is "short-run causality tests" the statistical significance on the two types of hypotheses like in the VAR case (test on γ_{22}^j and γ_{12}^j for above equations), the second one is "long-run causality tests" the hypothesis of both short-run and long-run causality (and for above equations). Kim, Jinsoo (2010).

4.6 Granger causality test

In our study, the Granger Causality test was adopted to examine the causality between two series according to Engle and Grange (1987). When the past information is collected to forecast variable *yt*, we can use only the past information of both *xt* and *yt* . According to the Granger Causality test, there is causality from *xt* to *yt* if the past information of *xt* can help us to forecast *yt* more precisely.

When applying to the Granger Causality test, we first set up the bivariable autoregression model:

$$y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i y_{t-i} + \sum_{i=1}^{m} \beta_i x_{t-i} + \varepsilon_t \quad (8)$$

$$x_t = \alpha_0 + \sum_{i=1}^{m} \alpha_j x_{t-j} + \sum_{i=1}^{m} \beta_j y_{t-j} + \varepsilon_t \quad (9)$$

Then the F test is carried out to test the null hypothesis H_0:β_i (i = 1, 2,…, m) = 0, which is equal to the hypothesis that "x_t has no Granger Causality to y_t". If H_0:β_i (i = 1, 2,…, m)

= 0, is rejected, then we can also reject the hypothesis "x_t has no Granger Causality to y_t", and thereby conclude that x_t has no Granger causality to y_t. Similarly, the hypothesis H_0:β_j (j = 1, 2,…, m) = 0, can be tested to verify whether there is Granger causality from y_t to x_t .

Chapter 5. Empirical analysis

In this empirical study on the cointegration and causality between Mongolia's consumption of its three major forms of energy and economic indicators, the time series data of the real GDP and of the consumption of different forms of energy (i.e., oil, primary energy, and electricity) for the period 1985-2012 in Mongolia were used. Before starting the analysis, GDP and electricity consumption were converted into natural logarithms to reduce the heteroscedasticity. Also, the logarithm variables had an economic meaning because they were approximated to represent the growth of the different variables.

5.1 Unit root test.

Data were obtained from the World Development Indicators (2015) produced by the World Bank, and from the U.S. Energy Information Administration website. Moreover, despite the fact that Mongolia's energy industry and industrialization started earlier than those of the USSR, there are insufficient data on such for analysis in this study. In addition, at that time, Mongolia did not have a market economy but a centrally planned economy.

A necessary but insufficient condition for cointegration is that each of the variables should be integrated into the same order (more than zero), or that both series should contain a deterministic trend (Granger, 1988). To determine if this preliminary condition was fulfilled, times series data on the consumption of electricity, oil, and primary energy and on the GDP of Mongolia were tested for a unit root via various testing procedures, as required by the augmented Dickey-Fuller (ADF) and Phillips Perron tests (Dickey & Fuller, 1979). Table 7 reports the results of the ADF tests on the integration properties of GDP and of the consumption of different forms of energy (i.e., primary energy, oil, and electricity) for Mongolia. The results of both tests indicate that the four series are non-stationary in their levels and first differences but become stationary in their second differences, or unit roots are discovered. This indicates that the Lngdp and Lnelc, Lnoc, and Penc and gdpn variables are individually integrated into order 2 or I (2).

Variables		Model	Test statistics	Critical value		
				1%	5%	10%
GDP	Level	ADF	2.779*	-3.746	-2.994	-2.628
		PP	1.886	-3.736	-2.994	-2.628
	1st difference	ADF	-2.010	-3.743	-2.997	-2.629
		PP	-2.136	-3.743	-2.997	-2.629
	2nd difference	ADF	-4.528***	-3.750	-3.000	-2.630
		PP	-4.511***	-3.750	-3.000	-2.630
Electricity	Level	ADF	0.418	-3.736	-2.994	-2.628
		PP	-0.054	-3.736	-2.997	-2.629
	1st difference	ADF	-3.514**	-3.743	-2.997	-2.629

		PP	-3.512**	-3.743	-2.997	-2.629
	2nd difference	ADF	-7.246***	-3.750	-3.000	-2.630
		PP	-7.762***	-3.750	-3.000	-2.630
Oil	Level	ADF	0.684	-3.736	-2.994	-2.628
		PP	0.249	-3.736	-2.994	-2.628
	1st difference	ADF	-3.591**	-3.743	-2.997	-2.639
		PP	-3.609**	-3.743	-2.997	-2.629
	2nd difference	ADF	-8.703***	-3.750	-3.000	-2.630
		PP	-10.403***	-3.750	-3.000	-2.630
Primary energy	Level	ADF	-0.314	-3.736	-2.994	-2.628
		PP	-0.508	-3.736	-2.994	-2.628
	1st difference	ADF	-2.626*	-3.743	-2.997	-2.629
		PP	-2.728*	-3.743	-2.997	-2.639
	2nd difference	ADF	-6.038***	-3.750	-3.000	-2.630
		PP	-6.084***	-3.750	-3.000	-2.630
GDP nom	Level	ADF	3.272	-3.736	-2.994	-2.628
		PP	3.311	-3.736	-2.994	-2.628
	1st difference	ADF	-2.791**	-3.743	-2.997	-2.629
		PP	-2.759**	3.743	-2.997	-2.629
	2nd difference	ADF	-7.474***	-3.750	-3.000	-2.630
		PP	-8.588***	-3.750	-3.000	-2.630

, * indicates rejection of null hypothesis at the 10%, 5%, 1% level

Table 7. Unit root test. (Energy consumptions and GDP)

5.2 Cointegration test.

To find a long-term co-integrating relationship between the consumption of different forms of energy and GDP, the Johansen test was adopted in this dissertation. Graphs 25-27 show the results of the lag selection process, which is required for the next cointegration test.

```
. varsoc lnoc lngdp

  Selection-order criteria
  Sample:  1989 - 2012                          Number of obs      =        24
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-64.8301				.898994	5.56918	5.59522	5.66735
1	3.52705	136.71	4	0.000	.004224	.206079	.284214	.500593
2	7.81034	8.5666	4	0.073	.004166	.182472	.312696	.673328
3	18.6551	21.69*	4	0.000	.002408*	-.387929*	-.205615*	.299269*
4	20.876	4.4417	4	0.350	.002913	-.239666	-.005263	.643874

```
  Endogenous:  lnoc lngdp
   Exogenous:  _cons
```

* indicates lag order selected by the criterion

Figure 25. Lag selection result for cointegration test. Oil

```
. varsoc lnelc lngdp

  Selection-order criteria
  Sample:  1989 - 2012                          Number of obs      =        24
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	21.0043				.000704	-1.58369	-1.55765	-1.48552
1	85.0122	128.02	4	0.000	4.7e-06	-6.58435	-6.50622	-6.28984*
2	87.67	5.3156	4	0.256	5.4e-06	-6.4725	-6.34228	-5.98165
3	96.9102	18.48*	4	0.001	3.5e-06*	-6.90918*	-6.72687*	-6.22198
4	98.4298	3.0393	4	0.551	4.5e-06	-6.70249	-6.46808	-5.81895

```
  Endogenous:  lnelc lngdp
   Exogenous:  _cons
```

* indicates lag order selected by the criterion

Figure 26. Lag selection result for cointegration test. Electricity

```
. varsoc penc gdpn

   Selection-order criteria
   Sample:  1989 - 2012                         Number of obs      =        24
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	.293379				.003952	.142218	.168263	.24039
1	46.5596	92.532	4	0.000	.000117*	-3.37996	-3.30183*	-3.08545*
2	47.9231	2.727	4	0.604	.000147	-3.16026	-3.03003	-2.6694
3	51.9451	8.0441	4	0.090	.00015	-3.16209	-2.97978	-2.4749
4	59.057	14.224*	4	0.007	.000121	-3.42142*	-3.18702	-2.53788

```
   Endogenous:  penc gdpn
    Exogenous:  _cons
```

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

Figure 27. Lag selection result for cointegration test. Primary energy

The cointegration rank r of the time series was tested using two test statistics. The trace test was calculated under H_0: $r_0 \leq r$ and against H_1: $r_0 > r$. By indicating the number of cointegrating vectors as r_0, the maximum eigenvalue (λ_{max}) test was calculated under the null hypothesis H_0: $r_0 = r$ and against the alternative hypothesis H_1: $r_0 > r$. Figure 28-30 show the results of the Johansen maximum likelihood cointegration tests. It was determined that there is a cointegration between the consumption of different forms of energy and GDP.

```
. vecrank lnoc lngdp, lags(3) max levela

                       Johansen tests for cointegration
Trend: constant                                        Number of obs =      25
Sample:  1988 - 2012                                            Lags =       3
-------------------------------------------------------------------------------
maximum                                     trace    5% critical  1% critical
  rank    parms       LL       eigenvalue  statistic      value        value
    0      10      5.2800566                15.6064*1     15.41        20.04
    1      13      12.626761     0.44442     0.9130*5      3.76         6.65
    2      14      13.083258     0.03586
-------------------------------------------------------------------------------
maximum                                      max     5% critical  1% critical
  rank    parms       LL       eigenvalue  statistic      value        value
    0      10      5.2800566                14.6934       14.07        18.63
    1      13      12.626761     0.44442     0.9130        3.76         6.65
    2      14      13.083258     0.03586
-------------------------------------------------------------------------------
```

Figure 28. Cointegration test of oil with GDP

```
. vecrank lnelc lngdp, trend(none) lags(3) max levela

                       Johansen tests for cointegration
Trend: none                                            Number of obs =      25
Sample:  1988 - 2012                                            Lags =       3
-------------------------------------------------------------------------------
maximum                                     trace    5% critical  1% critical
  rank    parms       LL       eigenvalue  statistic      value        value
    0      8       87.873884                16.6684       12.53        16.31
    1      11      95.215941     0.44421     1.9843*1*5    3.84         6.51
    2      12      96.208069     0.07630
-------------------------------------------------------------------------------
maximum                                      max     5% critical  1% critical
  rank    parms       LL       eigenvalue  statistic      value        value
    0      8       87.873884                14.6841       11.44        15.69
    1      11      95.215941     0.44421     1.9843        3.84         6.51
    2      12      96.208069     0.07630
-------------------------------------------------------------------------------
```

Figure 29. Cointegration test of electricity with GDP

```
. vecrank penc gdpn,  lags(4) max levela

                        Johansen tests for cointegration
Trend: constant                                          Number of obs =      24
Sample:  1989 - 2012                                              Lags =       4
-------------------------------------------------------------------------------
maximum                                       trace    5% critical  1% critical
  rank    parms       LL       eigenvalue   statistic      value        value
    0       14     49.434486                 19.2451*1    15.41        20.04
    1       17     59.033657     0.55064      0.0468*5     3.76         6.65
    2       18     59.057039     0.00195
-------------------------------------------------------------------------------
maximum                                        max     5% critical  1% critical
  rank    parms       LL       eigenvalue   statistic      value        value
    0       14     49.434486                 19.1983      14.07        18.63
    1       17     59.033657     0.55064      0.0468       3.76         6.65
    2       18     59.057039     0.00195
-------------------------------------------------------------------------------
```

Figure 30. Cointegration test of Primary energy with GDP

Variables	Trace statistic	5% critical value	1% critical value	Lags
Electricity – GDP	**16.6684**	**12.53**	**16.31**	**3**
Oil –GDP	**15.6064**	**15,41**	**20.04**	**3**
Primary energy –GDP	**19.2451**	**15.41**	**16.31**	**4**

Table 8. Combined cointegration test results of 3 variables

Table 8 shows the combined results of the trace tests for three links. As a result of the trace test, it can be seen that the null hypothesis of "no cointegration" was also rejected at the 1% significance level because its trace statistic equaled 16.6684, which is greater than the 1% critical value of 16.31 for electricity and GDP.

For the maximum eigenvalue test, the null hypothesis of "no cointegration equation" was rejected at the 5% significance level because the maximal eigenvalue statistic was 14.6841, which is greater than the critical value of 11.44.

In the case of oil consumption and GDP, as with the previous H0 hypothesis, such hypothesis was rejected at the 5% significance level. Therefore, it can be concluded that both the Lnoc and Lngdp series have one co-integrating equation; in other words, there must be a long-term relationship between the two. Next, in the case where there is a link between primary energy consumption and economic growth for Mongolia, the results show that the primary energy consumption and GDP series also have a cointegration equation. Thus, in other words, there are long-term causal relationships between the consumption of the aforementioned different forms of energy (oil, primary energy, and electricity) and GDP in the case of Mongolia.

5.3 Granger Causality test.

The cointegration test can show the existence only of a long-term causality. To find another study perspective, the Granger causality test was used because the above cointegration that was found does not reveal any information about the direction of causality or the short-term perspective results. To identify all these, there is a need to use VECM-(vector error correction model)-based causality tests.

	Null hypothesis	Short term		Long term
		Chi^2	Prob>Chi^2	Prob>z
1.	Lngdp does not cause Lnoc	7.65	0.0219**	0.000***
	Lnoc does not cause Lngdp	0.89	0.6416	0.044**
	Lngdp does not cause Lnelc	9.56	0.0084***	0.267
	Lnelc does not cause Lngdp	0.22	0.8955	0.038**
	gdpn does not cause penc	17.87	0.0005***	0.000***
3.	penc does not cause gdpn	0.21	0.9769	0.008***

*, **, *** indicates rejection of null hypothesis at the 10%, 5%, 1% level

Table 9. Granger causality test result from VECM model (energy consumptions and GDP)

According to Table 9, in the long term, the causality running from GDP to oil consumption is less than 1% (0.000); as such, there is a long-term causality between GDP and oil consumption. Also, the long-term causality running from oil consumption to GDP is less than 5% (0.044), which proves that oil consumption and GDP have a bidirectional causal relationship in the long term. In the short term, there is no short-term causality that runs from oil consumption to GDP, but there is a short-term causality that runs from GDP to oil consumption because a less than 5% (0.0219) causality was detected running from GDP to oil consumption.

In the case of electricity consumption and GDP, the causality running from electricity consumption to GDP is less than 5% (0.038); as such, there is a long-term causality between electricity consumption and GDP. Adversely, there is no long-term causality that runs from GDP to electricity consumption. Also, the causality running from GDP to electricity consumption is less than 1% (0.0084); as such, there is a short-term causality between GDP and electricity consumption. Conversely, there is no causality running from electricity consumption to GDP, which proves that electricity consumption and GDP have a unidirectional causality in the long term, as in the short term. Finally, in the case of primary energy consumption and GDP, the causality running from primary energy consumption to GDP is less than 1% (0.008); as such, there is a long-term causality between GDP and primary energy consumption. Also, there is a long-term causality (less than 1%, 0.000) running from GDP to primary energy consumption, which proves that primary energy consumption and GDP have a bidirectional causality in the long term. Additionally, in the short term, there is a causality running from GDP to primary energy consumption, which proves that primary energy consumption and GDP have a unidirectional causality in the long term.

In other words, two bidirectional causalities were determined: one unidirectional causality running from energy consumption to economic growth on the selected energy links in the long term, respectively. Also, three unidirectional causalities were indicated in the short term, running from GDP to energy consumption in Mongolia's main energy nexuses.

Chapter 6. Policy Implication and conclusion

Using the fabricated model, a couple of long- and short-term causal relationships were found between the consumption of different forms of energy and the gross domestic product (GDP) in Mongolia. Understanding the nature of the relationship between energy consumption and economic growth is a key issue that both the energy and environmental policymakers have to take into consideration to develop effective policies.

Energy is very much needed for every economic activity; consequently, the results of this study have important policy implications and can help determine the extent to which economic growth can be sustained under various energy availability scenarios.

6.1 Policy implications

When energy consumption leads to economic growth in the long term, as in the case of electricity, primary energy, and oil consumption in Mongolia, then the said country can be said to have a primary-energy-dependent economy, and more primary energy is required to encourage economic development. Moreover, electricity consumption directly affects economic growth, and increasing electricity consumption increases economic growth.

The applications of strong energy conservation policies especially in terms of electricity can totally negatively affect economic growth, but energy and electricity efficiency policies can be implemented. Additionally, the implications listed below can be inferred from the study results.

1. From the point of view of sustainability, to realize growth and development in Mongolia, policy intervention is required to change the country's economic

structure into a more efficiency-oriented and less resource-depleting one. Also, the investment in energy development technologies and research should be increased, and at the same time, the transformation of the economic structure into an energy-intensive one should be accelerated to further ensure Mongolia's sustainable economic development.

2. Mongolia's energy supply structure and the development of renewable energy resources or other clean energies should be diversified and optimized. The country has a huge potential of going renewable, and certainly, the use of renewable energy will play an important role in the future. Moreover, developing Mongolia's capacity for distributed generation based on the smart grid system using clean technology can guarantee energy security for the country as well as environmental protection in the region.
3. Energy efficiency policies should be formulated and implemented in all sectors, especially in the power sector, mines, communal apartments, households, transportation modes, services, etc. Actually, the major energy consumers are the industrial sector, the communal apartments, the buildings, and the power plants that were mainly built during the time when Mongolia was under the rule of the Soviet Union, which employ costly and outdated technologies. There is a significant potential to save energy by employing energy efficiency policies in this case. This would mean upgrading the existing equipment to new ones that use energy-saving technologies, simultaneously increasing the energy efficiency, and decreasing all types of energy loss. Also, the overall efficiency of energy utilization and seasonal efficiency on the part of the individual residents and energy consumers should be improved. Consequently, low energy utilization efficiency, high internal energy use, and high T&D loss are among the limiting factors of the economic growth of Mongolia as energy consumption boosts economic growth.
4. Economic growth causes the expansion of the industrial sector, which is the most energy-intensive main economic sector. Production in industries such as

manufacturing, construction, and transportation as well as the residential sector demand a huge amount of energy (Cheng & Lai, 1997; Ozturk et al., 2010). This view is supported by the recent economic growth seen in Mongolia, which has led to tremendous changes in the industrial, construction, and service sectors. With the economic growth, the people's incomes have increased, and consequently, the households have been using more energy-consuming goods and services, circumstances that stimulate further energy consumption. One possible explanation of the results that were obtained in this study is that in the short run, an increase in GDP leads to the expansion of the industrial and commercial sectors, which require energy as a basic input into the production process. Also, higher disposable incomes increase the individuals' demand for electronic gadgets for entertainment purposes and the households' demand for greater comfort, as well as for more services (Mishra et al., 2009).

5. The electricity use subsidization policy for the population and industrial and commercial consumers should continue to be implemented. Moreover, with regard to electricity consumption, to promote economic growth, the energy policy should be focused on the price level of electric energy, or directly on its demand side. In this case, a low price level or a high demand can promote economic growth (Shahbaz et al., 2012). The expansion of the industrial and commercial sectors, where electricity is used as a basic energy input due to its clean and efficient nature, stimulates economic growth. The industrial and services sectors' share in the GDP are the highest, and they consume maximum electricity compared to the others under the category of consumers. The household sector uses electricity as the cheapest form of energy; this adds to their financial savings. The household sector is the major contributor to the total savings of the Mongolian economy, and these savings are used to finance capital formation, which further accelerates the country's economic growth.
6. Mongolia practically reformed its power electric market and legislation, but some problems in the implementation of the market rules, competitive possibilities, and

functions and types of energy companies remain unresolved. Therefore, further changes in the legislation and regulation are needed, along with technologies that are well suited to the specific nature of the Mongolian power electric system, with a good fit to the market economy. Moreover, the future energy demand must be met. The legacy of the centrally planned economy, where the artificially inappropriate energy prices encouraged the wasteful use of electricity, together with the inefficient infrastructure, has burdened the transition countries with a weak starting point on the path towards a sustainable energy supply. Still, in some of these countries, the legacy of a centrally planned economy, with its absence of market signals and reliance on energy-intensive industries, persists (European Bank for Reconstruction and Development, 2010).

7. The bidirectional causal relationship that was found to exist between oil and primary energy consumption and GDP indicates that the feedback hypothesis with regard to such variables. This suggests that energy consumption and economic growth are interrelated. It is thus recommended that raw-coal conservation policies be carefully formulated and implemented as there is a need to reduce the amount of raw-coal usage through the implementation of appropriate energy policies to minimize their drawbacks in terms of economic growth.

   To ease the trade-off between energy consumption and economic growth, the energy policies targeted at reducing the country's greenhouse gas emissions should emphasize the use of alternative energy sources rather than exclusively try to reduce the overall energy consumption. The shift from less efficient and more polluting energy sources to more efficient energy options may establish a stimulus rather than an obstacle to economic development (Costantini & Martini, 2010).

8. In an economic sense, all services and products or goods in Mongolia are produced (directly or indirectly) with the use of coal and electricity. Thus, an increase in the GDP (or income) will be associated with an increase in coal or electricity consumption. The income elasticity estimates obtained herein support such a relationship. This positive causal relationship does not require a strong and

prosperous coal-intensive sector in Mongolia. As economic growth leads to higher coal consumption, if the Mongolian economy keeps growing at a fast rate in the future, more greenhouse gas emissions will follow, and the policymakers will continue to grapple with the economic growth-carbon emissions dilemma. As coal is the main contributor to Mongolia's greenhouse gas emissions, cutting the consumption of coal seems to be an effective way to curb the greenhouse gas emissions. On the other hand, the reduction of coal consumption may hinder economic growth. Additionally, the adoption of more advanced carbon capture technologies and modern primary energy transformation and transmission technologies as well as the revitalization of the existing equipment may lead to a rise in the cost of coal usage and ultimately to a decrease in the attractiveness of the resource. The gradual diversification of the energy sources utilized, however, may actually be able to enhance the country's energy supply and security in the long run.

9. A secure, integrated power electric system and electric grids connected by a transmission line capable of providing a back-up supply between adjacent grids under conditions of first contingency supply loss should be constructed. To ensure sustainable economic growth, a sufficient energy supply must be ensured. The critical heat and power infrastructure should be urgently renewed, and the investment in the expansion and modernization of the electricity facilities in the central energy system and heating facilities in Ulaanbaatar, where 90% of the heat and electricity in Mongolia is produced, should be the top priorities to sustain the people's lives and economic activities and to reduce the urban air pollution in Ulaanbaatar.

The formulation and implementation of an energy policy that will ensure energy security and will encourage the creation of new energy sources is the challenging task for Mongolia's policymakers (Mohanty & Devtosh, 2014).

6.2 Conclusion and limitation of the study

In this study, the causal relationship between the consumption of different forms of energy and the economic indicators of Mongolia during the period 1985-2012 was examined through several empirical steps. Several methods were used for testing the said relationship, such as co-integration, the vector error correction model, Granger causality, and the unit root test. The augmented Dickey-Fuller (ADF) and Phillips Perron tests were first performed (Dickey & Fuller, 1979) to check the data to be used in the research on stationary datasets. The test results showed that the times series of the consumption of different forms of energy (i.e., electricity, oil, and primary energy) and of the GDP of Mongolia have a unit root at their levels and first differences, but become stationary at their second differences, namely I(2).

Then through the Johansen cointegration test, it was found that the variables are cointegrated in the long run. Finally, the vector error correction model was used for the Granger causality test and the F-test, to find out the causality direction and the joint significance of the consumption of different forms of energy and of the GDP of Mongolia.

As a result of the use of the vector error correction model, a couple of long- and short-term causal relationships were found between the consumption of different forms of energy and GDP: a long-term unidirectional causality from electricity to GDP, and long-term bidirectional causalities between GDP and oil consumption and also between primary energy consumption and GDP. Furthermore, short-term unidirectional causalities were discovered from GDP to electricity consumption, from GDP to oil consumption, and from GDP to primary energy consumption. Therefore, the case of the causality relationship between the consumption of different forms of energy and the GDP of Mongolia supports the "growth hypothesis" in the long term.

The growth hypothesis suggests that energy consumption plays an important role in economic growth, both directly and indirectly in the production process, complementing labor and capital. Consequently, it may be concluded that Mongolia has a primary-energy-dependent economy and more primary energy is required to encourage its economic development. This also implies that the increase of electricity consumption as well primary energy consumption will positively affect the country's economic growth, and that the implementation of energy conservation policies can negatively affect the country's economic growth. As such, energy and electricity efficiency policies can be implemented. Also, various special programs and policies for the encouragement of efficiency improvement by the industries and residential consumers can be implemented.

The initial aim of this study was to investigate the causal relationship between energy use and the economic indicators of Mongolia from the time of the centrally planned economy to the present. The main problem that was encountered in this study was the limited data that were available, due to which the time series variables were insufficient to obtain more precise outcomes. Moreover, a further comparative or multivariate analysis can be conducted on the energy consumption breakdown level of any specific sector in Mongolia, as well as on the multi-country level, such as the energy-resource-abundant countries.

Bibliography

[1] Asit and Devtosh (2014). Relationship between Electricity Energy Consumption and GDP: Evidence from India. International Journal of Economics and Finance; Vol. 7, No. 2; 2015

[2] Akarca, A.T., Long, T.V (1979). Energy and employment: a time-series analysis of the causal relationship. Resources and Energy, Elsevier, vol. 2(2-3), 151-162.

[3] ADB. (2013). Updating Energy Sector Development Plan of Mongolia. e.Gen, Mon Energy consult.

[4] Aliabadi, A.,(2013). Energy consumption and economic growth in Iran, International Energy Policy program, College of Engineering, Seoul National University.

[5] Altinay, G., Karagol, E. (2005). Electricity consumption and economic growth: evidence from Turkey. Energy Economics 27, 849–856. 52

[6] Aqeel, A., Butt, M.S. (2001). Relationship between energy consumption and economic growth in Pakistan. Asia Pacific Development Journal 8, 101–110.

[7] Asafu-Adjaye, J., (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics 22, 615–625.

[8] Carlo M.F.I, (2014), The Role of Energy in Economic Growth in Peru. International Energy Policy Program, College of Engineering, Seoul National University.

[9] Cheng, B. (1995). An investigation of cointegration and causality between energy consumption and economic growth. Journal of Energy Development 21, 73–84.

[10] Cheng, S.B., Lai, W.T. (1997). An investigation of cointegration and causality between energy consumption and economic activity in Taiwan, province of China. Energy Economics 19, 435–444.

[11] Chontanawat, J., Hunt, L. C., Pierse R. (2006). Surrey Energy Economics Centre (SEEC) Department of Economics, SEEDS 113,11SN 1749-8384

[12] Dickey, D., Fuller, W. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of American Statistical Association 74, 427–431.

[13] Engle, R.F., Granger, C.W.J. (1987). Cointegration and error correction: representation, estimation and testing. Econometrica 55, 251–276.

[14] Energy Authority, M. (2012). Energy Authority Statistic Data.

[15] Energy Charter Secretariat. (2011). In-Depth Review of Energy

[16] Energy Regulatory Committee, Mongolia. (2013). *Energy*

[17] Erol, U., Yu, E.S.H. (1987a). On the causal relationship between energy and income for industrializing countries. Journal of Energy and Development 13, 113–122.

[18] Erol, U., Yu, E.S.H. (1987a). Time series analysis of the causal relationships between US energy and employment. Resources Energy 9, 75-89.

[19] Ghali, K.H., El-Sakka, M.I.T. (2004). Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Economics 26, 225–238.

[20] Glasure, Y.U., Lee, A.R. (1997). Cointegration, error correction and the relationship between GDP and energy: the case of South Korea and Singapore. Resource and Energy Economics 20, 17–25.

[21] Granger CWJ. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37: 424-438.

[22] Johansen, S. (1988). Statistical analysis of cointegrating vectors. Journal of Economic Dynamics Control 12, 231–254.

[23] Jinsoo Kim, (2010) The Relationship between Energy Consumption and Economic growth: Theoretical and Empirical Issues. College of Engineering, Seoul National University. Ph.D. dissertation

[24] Jose A. S, (2012), Energy consumption and economic growth. MS Thesis, Seoul.

[25] Jumbe, C.B.L. (2004). Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. Energy Economics 26, 61–68.

[26] Hang, S., (2012), Electricity in Cambodia: fuzzy forecasting affect to policy improvement. MS Thesis, Seoul.

[27] Hoang B.Q, (2012), The relationship between energy consumption and economic growth in Vietnam. MS Thesis, Seoul

[28] Kraft, J., Kraft, A., (1978). On the relationship between energy and GNP. Journal of Energy and Development 3, 401–403.

[29] Kwiatkowski, D., Phillips, P., Schmidt, P., Shin, Y. (1992): Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root, Journal of Econometrics, 54, 159-178, North-Holland.

[30] Lee, C.C. (2005). Energy consumption and GDP in developing countries: a cointegrated panel analysis. Energy Economics 27, 415–427.

[31] Li and Leung, (2012). Coal consumption and economic growth in China, Energy policy 40, 438-443.

[32] Zhang-wei, Zheng., 2012, Study on Relationship of Energy Consumption and Economic Growth in China. Physics Procedia 24, 313 – 319

[33] Lin, B., (2003). Structural change, efficiency improvement and electricity demand forecasting (in Chinese). Economic Research 5, 57–65.

[34] Masih, A.M.M., Masih, R., 1996. Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error- correction modeling techniques. Energy Economics 18, 165–183.

[35] U.S Energy Information Administration, International Energy statistics http://www.eia.gov/cfapps/ipdbproject/IEDI,

[36] Ministry of Mineral Resources and Energy, Energy Balances of Mongolia, Ulaanbaatar 2010, 2011, 2012

[37] Ministry of Energy of Mongolia. Statistics 2012.

[38] Belke et al., (2010) Energy Consumption and Economic Growth –New Insights into the Cointegration Relationship, Ruhr economic papers, #190

[39] Mergenbayev A. K., (2013), Electricity Use and Economic Growth in Kazakhstan. International Energy Policy Program, College of Engineering, Seoul National University.

[40] Mozumder, P., Marathe, A. (2007). Causality relationship between electricity consumption and GDP in Bangladesh. Energy Policy 35, 395–402.

[41] Niyazmuradov, S.B., (2013), The relationship between electricity consumption and economic growth in Turkmenistan, International Energy Policy Program, College of Engineering, Seoul National University.

[42] National Statistical Committee, National Statistical Yearbook, Mongolia, Ulaanbaatar 1999-2012

[43] Nelson, C.R., Plosser, C.I., 1982. Trends and random walks in macroeconomic time series. Journal of Monetary Economics 10, 139–162.

[44] Oh, W., Lee, K., (2004). Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999. Energy Economics 26, 51–59.

[45] Ozturk I, (2010). A literature survey on energy–growth nexus. Energy Policy 38, 340–349.

[46] Phillips, P.C.B., Perron, P. (1988). Testing for a unit root in time series regression. Biometrika 75, 335–346.

[47] Mehrara, M. (2007). Energy consumption and economic growth: the case of

oil exporting countries. Energy Policy 35, 2939–2945.

[48] Pesaran, H. Shin, Y. and Smith, R. (2001). Bound testing approaches to the analysis of level relationships. Journal of applied econometrics. 16, 289-32.

[49] Sims, C.A. (1972). Money, income and causality. American Economic Review 62, 540–552.

[50] Shiu, A., Lam, P.-L. (2004). Electricity consumption and economic growth in China. Energy Policy 32 (1), 47–54.

[51] Soytas, U., Sari, R. (2003). Energy consumption and GDP: causality relation--ship in G7 countries and emerging markets. Energy Economics 25,33–37.

[52] Stern, D.I. (1993). Energy and growth in the USA: a multivariate approach. Energy Economics 15, 137–150.

[53] Stern, D., 2000. A multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics 22, 267–283.

[54] Squalli ,J., Wilson, K. (2006). A Bound Analysis of Electricity Consumption and Economic Growth in the GCC . EPRU, Zayed University ,WP-06-09.

[55] Ularbek R.N, (2012), Energy consumption and economic growth in Kyrgyz Republic. International Energy Policy Program, College of Engineering, Seoul National University.

[56] Yang, H.Y. (2000). A note on the causal relationship between energy and GDP in Taiwan. Energy Economics 22, 309–317.

[57] Yandong, L. (2013). The relationship between energy consumption and GDP growth in China., International Energy Policy program, College of Engineering, Seoul National University.

[58] Yu and Choi, (1985). The causal relationship between energy and GNP: an international comparison. Journal of Energy and Development 10, 249–272.

[59] Lei and Li (2014), Study on the relationships between coal consumption and economic growth of the six biggest coal consumption countries: with coal price as a third variable, Energy Procedia 61, 624-634

[60] National Dispatching Center, Energy Balances, Mongolia, 2013

[61] Wolde-Rufael, Y. (2005). Energy demand and economic growth: the African experience. Journal of Policy Modeling 27, 891–903.

[62] World Bank (2011). World Development Indicators (WDI). Available at: http://data.worldbank.org/country/mongolia, retrieved on July 24, 2015

[63] Hu and Lin (2013), A Study of the Relationship between Electricity Consumption and GDP Growth in Hainan International Tourism Island of China, Research in world economy ,vol-4, 2013

[64] Mishra, V., Smyth, R. and Sharma, S., 2009. The energy-GDP nexus: Evidence from a panel of Pacific Island countries. Resource and Energy Economics, 31, 210-220.

[65] Shahbaz et al., (2012), Revisiting the relationship between electricity consumption, capital and economic growth: Cointegration causality analysis in Romania, Romanian Journal of Economic Forecasting – 3/2012

[66] Sabolić, D., Grćić, B., 2010. Electricity sector reform in South-East European countries in transition. Post-Communist Econ. 22, 367–385.

[67] Abosedra, S. and H. Baghestani (1989). New evidence on the causal relationship between US energy consumption and Gross National Product. Journal of Energy Development 14, 285–292.

[68] Apergis, N., Payne, J.E., 2011. A dynamic panel study of economic development and the electricity consumption-growth nexus. Energy Econ. 33, 770–781.

[69] Mudarissov and Lee (2014). The Relationship between energy consumption and economic growth in Kazakhstan, Geosystem Engineering, 2014

[70] Costantini, V. and C. Martini (2010). The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data. Energy Economics 32(3), 591–603.

[71] European Bank for Reconstruction, Development, 2010. Securing sustainable energy in transition economies. http://www.ebrd.com/downloads/research

Appendix A: Data set

	bill kWh	*thous bar/d*	*bill. Us $*	*quadtril btu*	*1 bill. US $*
Year	Lnelc	lnoc	Lngdp	Penc	gdpn
1985	0.915490	16.446430	0.432109	0.104010	2.186505
1986	1.001367	16.548630	0.521721	0.111060	2.896179
1987	1.024607	16.827480	0.555723	0.116970	3.020612
1988	1.064366	17.279100	0.605541	0.121200	3.204462
1989	1.173410	16.716270	0.646473	0.115630	3.576967
1990	1.093265	15.804880	0.614111	0.109010	2.560786
1991	1.022091	14.688140	0.523162	0.129170	2.379018
1992	0.949339	13.283060	0.426029	0.111710	1.317612
1993	0.782073	12.822740	0.393828	0.100460	0.768402
1994	0.779325	13.100410	0.414947	0.094800	0.925817
1995	0.854415	11.477260	0.476761	0.100030	1.452165
1996	0.862890	11.864020	0.498866	0.075720	1.345719
1997	0.851859	7.986580	0.537093	0.062110	1.180934
1998	0.851432	8.487010	0.569947	0.062210	1.124440
1999	0.835081	8.661750	0.600189	0.061540	1.057409
2000	0.875469	8.495330	0.611584	0.063130	1.136896
2001	0.903157	9.862410	0.640684	0.065170	1.267998
2002	0.937394	10.671780	0.686927	0.069550	1.396556

2003	0.990474	10.348250	0.754629	0.066460	1.595297
2004	1.054316	12.275490	0.855609	0.071020	1.992067
2005	1.113727	12.631210	0.925636	0.071760	2.523472
2006	1.166106	13.881560	1.007734	0.082140	3.414056
2007	1.211771	15.375620	1.105296	0.085130	4.235000
2008	1.293274	18.163950	1.190559	0.091840	5.623217
2009	1.274413	16.525480	1.177792	0.090060	4.583850
2010	1.373852	17.355530	1.239500	0.097050	7.189482
2011	1.401774	21.585590	1.398986	0.099540	10.409797
2012	1.436142	24.599040	1.515166	0.162250	12.292771

Appendix B: Summary of variables

. sum

Variable	Obs	Mean	Std. Dev.	Min	Max
year	28	1998.5	8.225975	1985	2012
lnelc	28	1.039031	.1913305	.7793249	1.436142
lnoc	28	14.06304	4.010897	7.98658	24.59904
lngdp	28	.7473786	.3201483	.3938282	1.515166
penc	28	.0925261	.024673	.06154	.16225
gdpn	28	3.09491	2.797993	.768402	12.29277

Appendix C: Empirical results of Oil consumption and GDP

```
. dfuller lnoc

Dickey-Fuller test for unit root                   Number of obs   =        27

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              0.684            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9895

. dfuller d.lnoc

Dickey-Fuller test for unit root                   Number of obs   =        26

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.591            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0059

. dfuller d2.lnoc

Dickey-Fuller test for unit root                   Number of obs   =        25

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -8.703            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. pperron lnoc

Phillips-Perron test for unit root                 Number of obs   =        27
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)           0.753          -17.336           -12.564           -10.240
 Z(t)             0.249           -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9749

. pperron d.lnoc

Phillips-Perron test for unit root                 Number of obs   =        26
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -19.962          -17.268           -12.532           -10.220
 Z(t)            -3.609           -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0056

. pperron d2.lnoc

Phillips-Perron test for unit root                 Number of obs   =        25
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -34.575          -17.200           -12.500           -10.200
 Z(t)           -10.403           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. dfuller  lngdp

Dickey-Fuller test for unit root                   Number of obs   =        27

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             2.779           -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

. dfuller d.lngdp

Dickey-Fuller test for unit root                   Number of obs   =        26

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -2.010           -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2824

. dfuller d2.lngdp

Dickey-Fuller test for unit root                   Number of obs   =        25

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -4.528           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0002
```

```
. pperron  lngdp

Phillips-Perron test for unit root              Number of obs   =        27
                                                Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)           2.345          -17.336           -12.564           -10.240
 Z(t)             1.886           -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9985

. pperron d.lngdp

Phillips-Perron test for unit root              Number of obs   =        26
                                                Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -9.060          -17.268           -12.532           -10.220
 Z(t)            -2.136           -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2302

. pperron d2.lngdp

Phillips-Perron test for unit root              Number of obs   =        25
                                                Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -20.905          -17.200           -12.500           -10.200
 Z(t)            -4.511           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0002
```

```
. varsoc lnoc lngdp

   Selection-order criteria
   Sample:  1989 - 2012                         Number of obs      =        24
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-64.8301				.898994	5.56918	5.59522	5.66735
1	3.52705	136.71	4	0.000	.004224	.206079	.284214	.500593
2	7.81034	8.5666	4	0.073	.004166	.182472	.312696	.673328
3	18.6551	21.69*	4	0.000	.002408*	-.387929*	-.205615*	.299269*
4	20.876	4.4417	4	0.350	.002913	-.239666	-.005263	.643874

```
   Endogenous:  lnoc lngdp
    Exogenous:  _cons
```

```
. vecrank lnoc lngdp, lags(3) max levela

                       Johansen tests for cointegration
Trend: constant                                         Number of obs =      25
Sample:  1988 - 2012                                             Lags =       3
```

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value	1% critical value
0	10	5.2800566		15.6064*1	15.41	20.04
1	13	12.626761	0.44442	0.9130*5	3.76	6.65
2	14	13.083258	0.03586			

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value	1% critical value
0	10	5.2800566		14.6934	14.07	18.63
1	13	12.626761	0.44442	0.9130	3.76	6.65
2	14	13.083258	0.03586			

```
. vec  lnoc lngdp, lag(3) rank(1)

Vector error-correction model

Sample:  1988 - 2012                              No. of obs      =        25
                                                  AIC             =  .0298591
Log likelihood =  12.62676                        HQIC            =  .2056526
Det(Sigma_ml)  =  .0012484                        SBIC            =  .6636746

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_lnoc               6     1.19526   0.6197   30.96106   0.0000
D_lngdp              6     .041342   0.7325   52.02473   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_lnoc       |
        _ce1 |
         L1. |  -.1223458   .0320036    -3.82   0.000    -.1850717      -.05962
             |
        lnoc |
         LD. |  -.3602907    .213336    -1.69   0.091    -.7784216     .0578403
        L2D. |  -.0553933   .2250822    -0.25   0.806    -.4965462     .3857596
             |
       lngdp |
         LD. |    14.9792   7.121776     2.10   0.035     1.020776     28.93762
        L2D. |  -17.16317   6.805994    -2.52   0.012    -30.50267    -3.823662
             |
       _cons |  -.0003085   .3176705    -0.00   0.999    -.6229312     .6223142
-------------+----------------------------------------------------------------
D_lngdp      |
        _ce1 |
         L1. |  -.0022298   .0011069    -2.01   0.044    -.0043994    -.0000602
             |
        lnoc |
         LD. |  -.0069041   .0073789    -0.94   0.349    -.0213664     .0075583
        L2D. |  -.0027041   .0077851    -0.35   0.728    -.0179627     .0125545
             |
       lngdp |
         LD. |   .8334882    .246328     3.38   0.001     .3506942     1.316282
        L2D. |  -.4291484   .2354058    -1.82   0.068    -.8905353     .0322384
             |
       _cons |   .0169257   .0109876     1.54   0.123    -.0046095      .038461
------------------------------------------------------------------------------
```

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	1	18.95908	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
lnoc	1	.	.	.	.	.
lngdp	-44.49038	10.2178	-4.35	0.000	-64.5169	-24.46385
_cons	16.01313	.	.	.	.	.

```
. test ([D_lnoc]: LD.lngdp L2D.lngdp)

 ( 1)  [D_lnoc]LD.lngdp = 0
 ( 2)  [D_lnoc]L2D.lngdp = 0

           chi2(  2) =    7.65
         Prob > chi2 =    0.0219

. test ([D_lngdp]: LD.lnoc L2D.lnoc)

 ( 1)  [D_lngdp]LD.lnoc = 0
 ( 2)  [D_lngdp]L2D.lnoc = 0

           chi2(  2) =    0.89
         Prob > chi2 =    0.6416
```

Appendix D: Empirical results of the Electricity consumption and GDP

```
.  dfuller lnelc

Dickey-Fuller test for unit root                   Number of obs   =        27

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              0.418            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9822

. dfuller d.lnelc

Dickey-Fuller test for unit root                   Number of obs   =        26

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.514            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0076

. dfuller d2.lnelc

Dickey-Fuller test for unit root                   Number of obs   =        25

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -7.246            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. pperron lnelc

Phillips-Perron test for unit root                 Number of obs   =        27
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)           -0.091           -17.336           -12.564           -10.240
 Z(t)             -0.054            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9538

. pperron d.lnelc

Phillips-Perron test for unit root                 Number of obs   =        26
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -17.029           -17.268           -12.532           -10.220
 Z(t)             -3.512            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0077

. pperron d2.lnelc

Phillips-Perron test for unit root                 Number of obs   =        25
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -31.598           -17.200           -12.500           -10.200
 Z(t)             -7.762            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. varsoc lnelc lngdp
```

Selection-order criteria
Sample: 1989 - 2012 Number of obs = 24

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	21.0043				.000704	-1.58369	-1.55765	-1.48552
1	85.0122	128.02	4	0.000	4.7e-06	-6.58435	-6.50622	-6.28984*
2	87.67	5.3156	4	0.256	5.4e-06	-6.4725	-6.34228	-5.98165
3	96.9102	18.48*	4	0.001	3.5e-06*	-6.90918*	-6.72687*	-6.22198
4	98.4298	3.0393	4	0.551	4.5e-06	-6.70249	-6.46808	-5.81895

Endogenous: lnelc lngdp
Exogenous: _cons

```
. vecrank lnelc lngdp, trend(none) lags(3) max levela
```

Johansen tests for cointegration

Trend: none Number of obs = 25
Sample: 1988 - 2012 Lags = 3

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value	1% critical value
0	8	87.873884		16.6684	12.53	16.31
1	11	95.215941	0.44421	1.9843*1*5	3.84	6.51
2	12	96.208069	0.07630			

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value	1% critical value
0	8	87.873884		14.6841	11.44	15.69
1	11	95.215941	0.44421	1.9843	3.84	6.51
2	12	96.208069	0.07630			

```
. vec lnelc lngdp, trend(none) lags(3) rank(1)

Vector error-correction model

Sample:  1988 - 2012                              No. of obs      =         25
                                                  AIC             =  -6.737275
Log likelihood =  95.21594                        HQIC            =  -6.588527
Det(Sigma_ml)  =  1.69e-06                        SBIC            =   -6.20097

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_lnelc              5      .051896   0.4720   17.87669   0.0031
D_lngdp              5      .042477   0.7027   47.28023   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_lnelc      |
        _ce1 |
         L1. |   .0052993   .0047708     1.11   0.267    -.0040513    .0146498
             |
       lnelc |
         LD. |  -.3005721   .2624995    -1.15   0.252    -.8150618    .2139175
        L2D. |  -.4235012   .2783647    -1.52   0.128    -.9690859    .1220835
             |
       lngdp |
         LD. |   .7534516   .3105968     2.43   0.015      .144693     1.36221
        L2D. |   .7016633    .418699     1.68   0.094    -.1189716    1.522298
-------------+----------------------------------------------------------------
D_lngdp      |
        _ce1 |
         L1. |  -.0081087   .0039049    -2.08   0.038    -.0157622   -.0004553
             |
       lnelc |
         LD. |   .0832279    .214856     0.39   0.698    -.3378822     .504338
        L2D. |  -.0345749   .2278416    -0.15   0.879    -.4811364    .4119865
             |
       lngdp |
         LD. |   .7451425   .2542237     2.93   0.003     .2468732    1.243412
        L2D. |  -.3853609   .3427054    -1.12   0.261    -1.057051    .2863293
------------------------------------------------------------------------------
```

```
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   1   28.19981   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
       lnelc |          1          .        .       .            .           .
       lngdp |  -5.690706   1.071626    -5.31   0.000    -7.791054   -3.590358
------------------------------------------------------------------------------


. test ([D_lnelc]: LD.lngdp L2D.lngdp)

 ( 1)  [D_lnelc]LD.lngdp = 0
 ( 2)  [D_lnelc]L2D.lngdp = 0

           chi2(  2) =    9.56
         Prob > chi2 =    0.0084

. test ([D_lngdp]: LD.lnelc L2D.lnelc)

 ( 1)  [D_lngdp]LD.lnelc = 0
 ( 2)  [D_lngdp]L2D.lnelc = 0

           chi2(  2) =    0.22
         Prob > chi2 =    0.8955
```

Appendix E: Empirical results of the Primary energy consumption and GDP

```
. dfuller penc

Dickey-Fuller test for unit root                   Number of obs   =        27

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -0.314            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9235

. dfuller d.penc

Dickey-Fuller test for unit root                   Number of obs   =        26

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.626            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0878

. dfuller d2.penc

Dickey-Fuller test for unit root                   Number of obs   =        25

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -6.038            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. pperron penc

Phillips-Perron test for unit root                 Number of obs   =        27
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)           -2.057           -17.336           -12.564           -10.240
 Z(t)             -0.508            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8905

. pperron d.penc

Phillips-Perron test for unit root                 Number of obs   =        26
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -24.454           -17.268           -12.532           -10.220
 Z(t)             -2.728            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0693

. pperron d2.penc

Phillips-Perron test for unit root                 Number of obs   =        25
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -33.950           -17.200           -12.500           -10.200
 Z(t)             -6.084            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. dfuller gdpn

Dickey-Fuller test for unit root                   Number of obs   =        27

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              3.272            -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

. dfuller d.gdpn

Dickey-Fuller test for unit root                   Number of obs   =        26

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.791            -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0596

. dfuller d2.gdpn

Dickey-Fuller test for unit root                   Number of obs   =        25

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -7.474            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. pperron gdpn

Phillips-Perron test for unit root                 Number of obs   =        27
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)            6.736         -17.336           -12.564           -10.240
 Z(t)              3.311          -3.736            -2.994            -2.628
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

. pperron d.gdpn

Phillips-Perron test for unit root                 Number of obs   =        26
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -13.535         -17.268           -12.532           -10.220
 Z(t)             -2.759          -3.743            -2.997            -2.629
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0644

. pperron d2.gdpn

Phillips-Perron test for unit root                 Number of obs   =        25
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -31.529         -17.200           -12.500           -10.200
 Z(t)             -8.588          -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. varsoc penc gdpn

   Selection-order criteria
   Sample:  1989 - 2012                         Number of obs      =        24

  +---------------------------------------------------------------------------+
  |lag |    LL      LR      df    p      FPE       AIC       HQIC      SBIC    |
  |----+----------------------------------------------------------------------|
  |  0 |  .293379                       .003952   .142218   .168263   .24039   |
  |  1 |  46.5596  92.532    4  0.000  .000117* -3.37996  -3.30183* -3.08545*  |
  |  2 |  47.9231   2.727    4  0.604  .000147  -3.16026  -3.03003   -2.6694   |
  |  3 |  51.9451  8.0441    4  0.090   .00015  -3.16209  -2.97978   -2.4749   |
  |  4 |   59.057  14.224*   4  0.007  .000121  -3.42142* -3.18702  -2.53788   |
  +---------------------------------------------------------------------------+
   Endogenous:  penc gdpn
    Exogenous:  _cons
```

```
. vecrank penc gdpn,  lags(4) max levela

                       Johansen tests for cointegration
Trend: constant                                        Number of obs =      24
Sample:  1989 - 2012                                            Lags =       4
-------------------------------------------------------------------------------
maximum                                      trace    5% critical   1% critical
  rank    parms       LL       eigenvalue  statistic     value          value
    0      14     49.434486                 19.2451*1    15.41         20.04
    1      17     59.033657     0.55064      0.0468*5     3.76          6.65
    2      18     59.057039     0.00195
-------------------------------------------------------------------------------
maximum                                       max     5% critical   1% critical
  rank    parms       LL       eigenvalue  statistic     value          value
    0      14     49.434486                 19.1983      14.07         18.63
    1      17     59.033657     0.55064      0.0468       3.76          6.65
    2      18     59.057039     0.00195
-------------------------------------------------------------------------------
```

```
. vec penc gdpn,  lags(4) rank(1)

Vector error-correction model

Sample:  1989 - 2012                               No. of obs      =        24
                                                   AIC             = -3.502805
Log likelihood =  59.03366                         HQIC            = -3.281424
Det(Sigma_ml)  =   .000025                         SBIC            =  -2.66835

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_penc               8     .008615   0.8007   64.27288   0.0000
D_gdpn               8     .878802   0.5692   21.13598   0.0068
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_penc       |
        _ce1 |
         L1. |  -.4435894   .1148586    -3.86   0.000    -.6687081   -.2184707
             |
        penc |
         LD. |   .1621208   .2317196     0.70   0.484    -.2920414    .6162829
        L2D. |  -.3131894   .2155467    -1.45   0.146    -.7356532    .1092743
        L3D. |   .2917025   .2257071     1.29   0.196    -.1506754    .7340803
             |
        gdpn |
         LD. |   -.008891   .0042554    -2.09   0.037    -.0172314   -.0005507
        L2D. |  -.0000364   .0043399    -0.01   0.993    -.0085424    .0084695
        L3D. |  -.0157611   .0044265    -3.56   0.000    -.0244369   -.0070853
             |
       _cons |  -.0035478   .0020802    -1.71   0.088     -.007625    .0005293
-------------+----------------------------------------------------------------
D_gdpn       |
        _ce1 |
         L1. |  -31.10605   11.71626    -2.65   0.008     -54.0695   -8.142608
             |
        penc |
         LD. |  -1.812882   23.63678    -0.08   0.939    -48.14012    44.51436
        L2D. |   7.768923   21.98705     0.35   0.724    -35.32489    50.86274
        L3D. |   -6.72895   23.02347    -0.29   0.770    -51.85412    38.39622
             |
        gdpn |
         LD. |  -.5549042   .4340721    -1.28   0.201     -1.40567    .2958616
        L2D. |  -.6849949   .4426909    -1.55   0.122    -1.552653    .1826632
        L3D. |  -.0755595   .4515301    -0.17   0.867    -.9605422    .8094231
             |
       _cons |   .0000506   .2121933     0.00   1.000    -.4158407    .4159419
------------------------------------------------------------------------------
```

```
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   1   40.87953   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
        penc |          1          .        .       .            .           .
        gdpn |  -.0216678   .0033889    -6.39   0.000    -.0283099   -.0150256
       _cons |  -.0493535          .        .       .            .           .
------------------------------------------------------------------------------


. test ([D_penc]: LD.gdpn L2D.gdpn L3D.gdpn)

 ( 1)  [D_penc]LD.gdpn = 0
 ( 2)  [D_penc]L2D.gdpn = 0
 ( 3)  [D_penc]L3D.gdpn = 0

           chi2(  3) =   17.87
         Prob > chi2 =    0.0005

. test ([D_gdpn]: LD.penc L2D.penc L3D.penc)

 ( 1)  [D_gdpn]LD.penc = 0
 ( 2)  [D_gdpn]L2D.penc = 0
 ( 3)  [D_gdpn]L3D.penc = 0

           chi2(  3) =    0.21
         Prob > chi2 =    0.9760
```