Comprehensive Research on Issues Related to Economy, Energy and the Environment in Kazakhstan

March 2016

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Chapter 1

Introduction

Climate change is an imminent global problem, which cannot be solved without global cooperation. Paris Agreement on climate change, adopted at the 21st session of the Conference of the Parties (COP), provides a historic international unity in the global fight against the climate change by keeping temperature rise below 2 °C through low carbon, sustainable and resilient development [1]. Kazakhstan and other Central Asian countries are among the signing nations.

Fighting global climate change is one of the most important tasks for Central Asian republics as it poses complex and serious threats to water, energy, agriculture and industry in the region [2-3]. Environmental Performance Index (EPI) of the republics which is the aggregation of national-level environmental indicators, outlines needs for sound environmental strategies [4]. Development strategies of Central Asian countries based on exploitation of natural reserves without paying attention to environmental degradation may lead to catastrophic outcomes to the fragile ecosystem of the region [2].

Environmental impact assessment considering almost 3 °C increase of mean annual temperature is projected in Kazakhstan by 2050. This will cause frequent weather extremes, recurrence of forest fires and the retreat of glaciers [5]. The consequences of global warming are expected to be devastating for Kazakh economy if no actions are taken.

Expected ratification of Paris agreement by the government of Kazakhstan requires stronger commitments on greenhouse gas (GHG) emissions reduction and low carbon development. The government has already made significant process in developing policies aiming at low carbon development. However, the effectiveness of the policies is questionable as they contradict the development path of Kazakhstan based on energy intense extractive industries with high environmental impact. It is important to understand the incompatibility of current economic system with a green growth strategy of Kazakhstan.

1.1 Background information

The Republic of Kazakhstan is a landlocked country located in the middle of the Eurasian continent. Kazakhstan has strategic location to control energy resources flow to China, Russia and global market as seen in Figure 1.1. The country is divided into 14 regions (oblas) and two cities of state importance (capital Astana and city of Almaty). The territory of Kazakhstan is 2,724,900 square kilometres (1,049,150 square miles) [6], which makes it the 9th largest country in the world. The population of Kazakhstan is 17.5 million people, which represents about 0.2% of world population [6-7]. Hence, the population density (6.3 people/km^2) is one of the lowest in the world[7].

Source: CIA [8]

Figure 1.1 Map of Kazakhstan

Politically, Kazakhstan is a durable autocracy ruled by former communist leader of the republic Nursultan Nazarbayev, president for life [9]. Political system has signs of patrimonial system, where power is in the hands of the president's family and the oligarchs [10]. The extractive economic and political institutions in Kazakhstan emerged due to weak initial qualities of institutions after the collapse of the USSR. The institutional quality and regulatory burden are the main contribution factors to the size of shadow economy in Kazakhstan, which accounts for almost 40% of Gross Domestic Product (GDP) [11-12].

The economy of Kazakhstan is the largest in Central Asia. GDP in 2013 consisted of 231.9 billion US Dollars (USD), which represented around 0.3% of world's economy. The economy is among the upper-middle income with almost 13000 USD per capita [7]. It has been suggested that Kazakh economy has been declining towards state capitalism [13]. The system when the state often acts in the interests of big business against the interests of consumers [14].

The main driver of the Kazakh economic growth is the export of hydrocarbons. The oil export dependence has affected the energy system of Kazakhstan. Crude oil has become a precious commodity for export, and the role of coal in the domestic energy system has become enormous. Over-reliance on fossil fuel production, consumption and exports causes environmental pollution and economic volatility. Additionally, heavy dependence on export of hydrocarbons has created social disparities and a development gap between regions [15]. Therefore, the diversification of economy by development of non-energy intensive industries, measures for energy efficiency and energy saving improvement and development of renewable energy is essential for energy policy in Kazakhstan. Among them the potential of renewable energy, wind power in particular, is estimated to be sufficient for industrial-scale deployment.

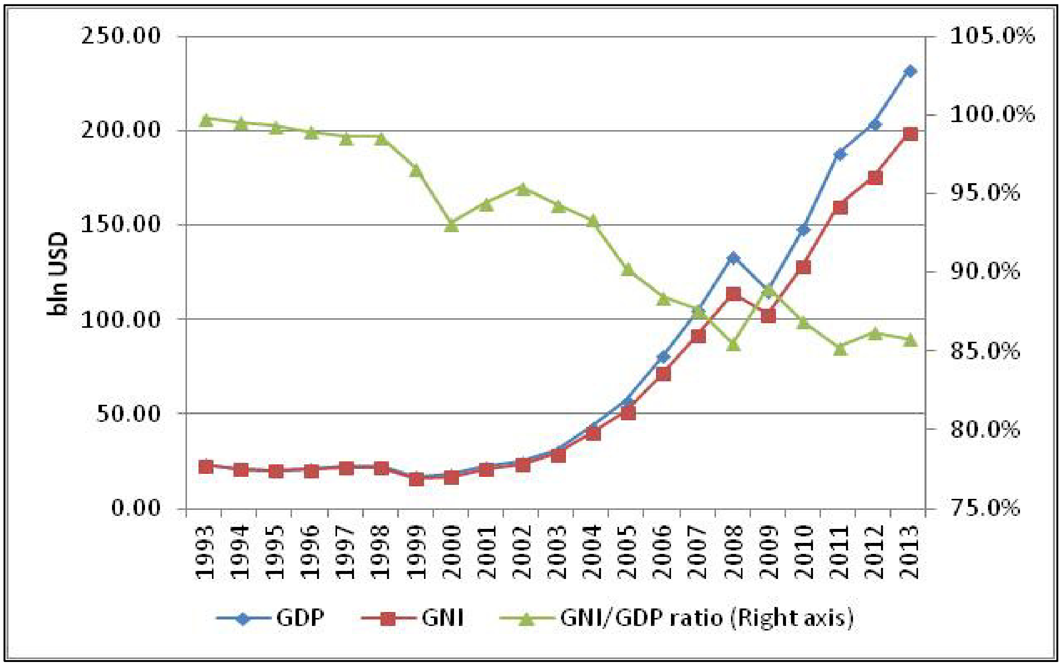
1.2 Scope of the problem

Kazakhstan`s economic growth has been soaring for over a decade due to 2000s commodity boom. However, when it comes to social indicators and the quality of institutions, it has made more limited progress. The model of economic growth, triggered by the commodity boom, without development is unlikely to be sustainable. Despite short-term growth, the economies with an abundance of natural resources are likely to have lower economic growth in a long-term [16].

Due to its development strategy, Kazakhstan is vulnerable to the negative effects of the resource dependence and the Dutch disease. The ongoing decline in commodity prices has negative consequences on economic growth of the country. In 2015, Financial Times named Kazakh Tenge (KZT) as "the world's worst-performing currency" due to over 80% devaluation since the beginning of the year [17]. This in return affects the social stability of the country due to declining income, growing number of non-performing bank loans and high inflation. Furthermore, despite the small government debt compared to most economies, Kazakhstan is listed among the world's riskiest sovereign debt [18].

Unlike global financial crisis in 2009, which had a short-term negative implication on Kazakh economy, the oil price collapse of 2014-2015 calls for structural economic reforms as the longer period of low oil prices is expected [19]. The diversification of Kazakh economy has been a priority policy for the government. However, the current diversification strategy seems to be ineffective and the economy is still dependent on the resource sector due to misaligned economic policies, poor financial regulation and weak institutions [20]. Hence, the mismatch between economic reforms and institutional changes has created unbalanced economic growth.

Furthermore, the commodity-based development causes the outflow of the natural resources toward abroad. The Gross National Income (GNI) measures the total value of goods and services produced by Kazakh nationals and companies, while GDP measures the total value of goods and services produced in Kazakhstan by all nationals and companies. The GNI/GDP is estimated around 1 for most of the countries with insignificant deviations. However, in the case of Kazakhstan, there is a significant separation between GNI and GDP as seen in Figure 1.2. The separation has started since the end of 1990s, when the number of the foreign companies in the resource sectors started to grow. The GNI and GDP comparison indicates that the natural resources in Kazakhstan are declining toward abroad rather than the domestic capital creation.



Source: Author's calculations based on World Bank data

Figure 1.2 GNI and GDP in Kazakhstan

1.3 Research framework

This work is designed to evaluate the causes of policy incompatibility by application of a multi-level system approach research framework. The main objective of the study is to understand the causes of contradictions between national plans on expansion of carbon intense, commodity export-dependent economy and Kazakhstan's green growth strategy. It is important to fully understand the environmental, energy and economic risks in Kazakhstan, as well as contradictions between energy, environmental and economic development strategies of the country.

The structure of research is presented in Table 1.1. The study starts with analysis of interactions of energy, economy and resulting environmental impact in Central Asian republics. Moreover, the regional energy security related to external supply and demand is analyzed.

At the country level, economy, energy and the environment nexus in Kazakhstan is assessed. The relationships between CO_2 emissions, energy, and real GDP are modeled between 1990 and 2012. Furthermore, the mechanisms of the Dutch disease in the period 1993-2013 are tested.

Sector level study explains the contribution of different industries to CO_2 emissions over independence period. The analysis explores the factors affecting emissions of the industry sector. It also helps to define the industry with highest environmental impact.

Study on power industry is carried out at the industry level. The structure of the industry as well as its environmental impact is analyzed using the Life Cycle Assessment methodology. Moreover, the presence of the relationship between coal production and respiratory health is tested.

Resource potential and environmental improving effect of wind power technologies in Kazakhstan are assessed. The cost of wind power production is also estimated. Additionally, candidate sites of wind power systems are assessed by the multi-criteria approach.

Kazakh Emissions Trading Scheme (ETS) is a focus of the policy level research. Principles and approaches of Green Growth Strategy and ETS strategy are described. Furthermore, the impact of ETS on industrial energy intensities is analyzed. Logarithmic Mean Divisia Index (LMDI) technique is used to estimate required energy intensity improvement in order to meet ETS emission targets.

The chapters are organized as follows: Chapter 2 gives an overview of energy profiles of Central Asian republic. Country security on external energy supply and export demand is assessed; in Chapter 3, the aspects and the problems of energy sector, environment and economy are analyzed. In this chapter energy-economy-environment nexus is modeled. Additionally, the mechanisms the Dutch disease are investigated; driving factors of CO_2 emissions from industrial activities are analyzed in Chapter 4; Chapter 5 describes the power system of Kazakhstan and life cycle assessment is performed in order to identify regional environmental impacts of heat and electricity production; Chapter 6 presents the potential assessment of wind power and its environmental improving effect from industrial scale development; in Chapter 7, the Green Growth is described and the effect of Kazakh Emissions Trading Scheme is analyzed; Chapter 8 sums up the results of the study and provides policy recommendations.

To the best knowledge of the author, it is the first attempt to take a comprehensive approach to issues related to economy, energy and the environment in Kazakhstan. Hence, there is no specific chapter with literature review. However, the chapters contain literature surveys or references to previous studies.

Table 1.1 Research structure

Level	Economy	Energy	Environment
	1. Introduction		
Central Asia	**2. Energy Profiles of Central Asian Countries: Current Status and Future Prospects**		
	2.6 Measuring the Security of External Energy Supply and Energy Export Demand in Central Asia		
Country	**3. Economy, Energy and the Environment in Kazakhstan**		
	3.1 Economy of Kazakhstan		
		3.2 Energy System	
			3.3 Environmental Problems in Kazakhstan
	3.4 Modeling CO2 Emissions, Energy Use, and Economic Growth		
	3.5 The Dutch Disease in Kazakhstan		
Sector	**4. Decomposition Analysis of Industry Sector CO2 Emissions from Fossil Fuel Combustion in Kazakhstan**		
Industry	**5. Power Industry**		
		5.1 Electricity Generation	
		5.2 Commercial Heat Generation	
	5.3 Life Cycle Assessment of Commercial Heat and Electricity Production		
		5.4 Health Effects of Coal: A Long-Run Relationship Assessment of Coal Production and Respiratory Health in Kazakhstan	
Technology	**6. Wind Power in Kazakhstan**		
		6.2 Potential Assessment	
		6.3 Environmental Improving Effect of Wind Energy	
	6.4 Cost of Wind Energy		
	6.5 Multi-Criteria Analysis of Wind Power		
Policy	**7. Green Growth Strategy of Kazakhstan**		
	7.1 Effect of Kazakh Emissions Trading Scheme (ETS) on Industrial Energy Intensities		
	8. Conclusions and Policy Implications		

Chapter 2

Energy Profiles of Central Asian Countries: Current Status and Future Prospects

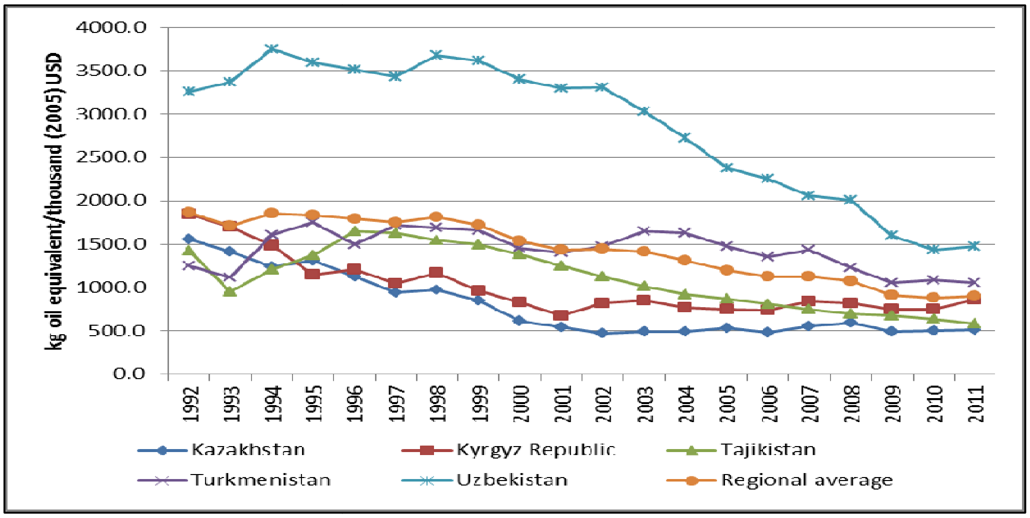
The former soviet Central Asia consists of five landlocked republics, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan, located in the center of Eurasian continent. A total population of the region is about 66 million people corresponding to 0.9% of the world total, and the economy of Central Asia represents around 0.5% of the world economy [7]. After the collapse of the Soviet Union and its planned economy, each republic has pursued its own development path. While energy resource-rich countries such as Kazakhstan, Turkmenistan and Uzbekistan have focused on hydrocarbons export, Kyrgyz Republic and Tajikistan have faced energy shortages that affected their development path. This has resulted in the significant differences among the countries in the levels of income, energy profiles and relative environmental impact as well as contribution to global warming.

For example, GDP of Kazakhstan is the largest in the region and it is almost 26 times larger than that in Kyrgyz Republic, the smallest economy in Central Asia. Whilst total final energy consumption and total CO_2 emissions in Kazakhstan are almost 22 and 94 times larger than in Tajikistan respectively. Hence, there are significant differences in energy intensity and CO_2 emission intensity between the countries of the region.

Kyrgyz Republic and Tajikistan are the most natural disaster prone countries in the region [21]. It is likely that global climate change increase the likelihood of weather-related natural disasters. Although the GHG emissions in Kyrgyz Republic and Tajikistan are significantly lower than those in other countries of the region, the negative impacts of climate change would be the biggest in the republics.

Figure 2.1 shows energy intensities of Central Asian economies from 1990 till 2011 based on total final consumption (TFC). Although all countries have achieved a decline in the energy intensity since 1990, there are noticeable differences between the countries as well as time periods. Energy intensity of Uzbek economy is the highest in the region, almost 1.7 times higher than the regional average, while the indicator of Kazakhstan is almost 70% lower than the average for all countries. Energy intensity has been declining in Kazakhstan and Kyrgyz Republic by 45% and 48% between 1992 and 1999 respectively, while it increased in Tajikistan (5%), Turkmenistan (33%) and Uzbekistan (11%). In 2000-2011, all economies, apart from Kyrgyz Republic, became less energy intensive: Kazakhstan by 17%, Tajikistan by 57%, Turkmenistan by 27% and Uzbekistan by 57%, while energy intensity of Kyrgyz economy increased by 3%.

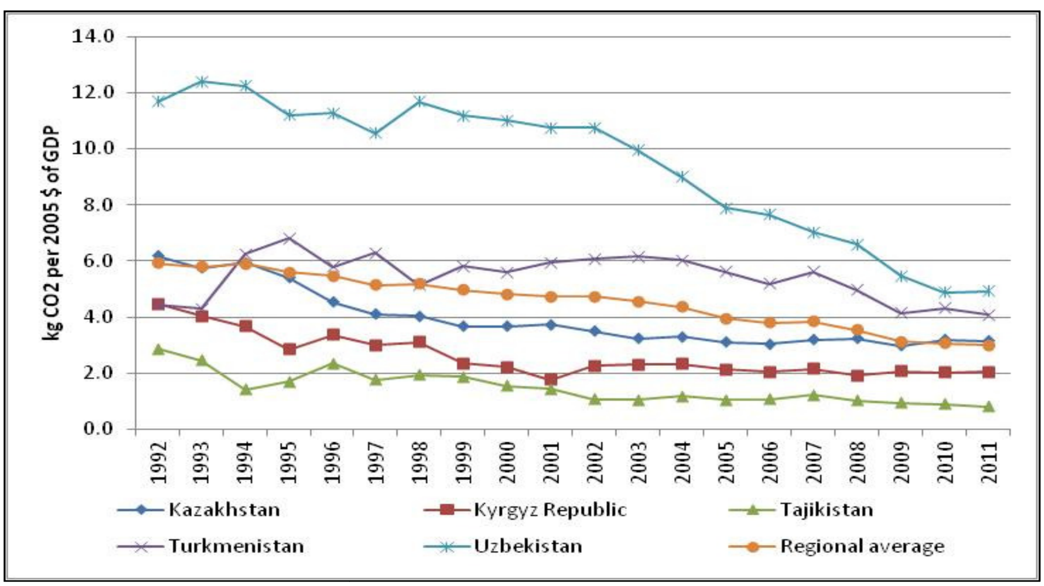
Energy intensity of Kazakh economy is the lowest in the region, despite being the biggest energy consumer in Central Asia. This is due to almost 140% GDP growth since 1992, while energy consumption declined by 35% for the same period. Other countries that achieved energy consumption reduction in 1992-2011 are Kyrgyz Republic by 38% (33% GDP growth) and Tajikistan by 45% (36% GDP growth), while both energy consumption increased in Turkmenistan by 98% (133% GDP growth) and Uzbekistan (136% GDP growth). Variations in energy consumption and fuel mix have resulted in significant differences in CO_2 emission intensities between the countries.



Source: Author`s calculations based on World Bank [7] and IEA data [22]

Figure 2.1 Energy intensity of Central Asian economies

Figure 2.2 displays CO_2 emission intensities of Central Asian republics in 1992-2011. As can be seen, Tajikistan and Kyrgyz Republic, where fuel mix is dominated by hydropower, have significantly lower indicators than other countries of the region. Uzbek economy is the most CO_2 emission intense in Central Asia, followed by Turkmenistan and Kazakhstan. The highest reduction has been achieved by Tajikistan (72%), while in Turkmenistan the indicator has declined only by 8% since 1992.



Source: World Bank[7] data

Figure 2.2 CO_2 emission intensity of Central Asian economies

In order to gain a better understanding of variations in economic development, energy consumption and CO_2 emissions, energy profiles of Central Asian countries need to be studied. Subchapters 2.1 – 2.5 will provide a quick overview of energy profiles of five countries of the region. Furthermore, the forecasted

2.1 Kazakhstan

Kazakhstan is one of the key players in the global energy market due to the combination of affiliate resources of fossil fuels and uranium as well as a very strategic geographic location. While crude oil and natural gas are produced primarily for export, coal is primarily consumed domestically, mainly at the large-scale thermal power plants. The republic is the biggest emitter of CO_2 in the region.

Table 2.1 presents the main socioeconomic, energy and environmental indicators of the country. Data shows slight increase of population, almost doubled GDP and marginally declined TPES, TFC has declined by 35% and CO_2 emissions have barely increased. ADB expects a gradual GDP growth in the next 20 years at slightly over 4% annually, while population is forecasted to grow at 0.4% per year [23].

Table 2.1 Main socioeconomic, energy and environmental indicators of Kazakhstan

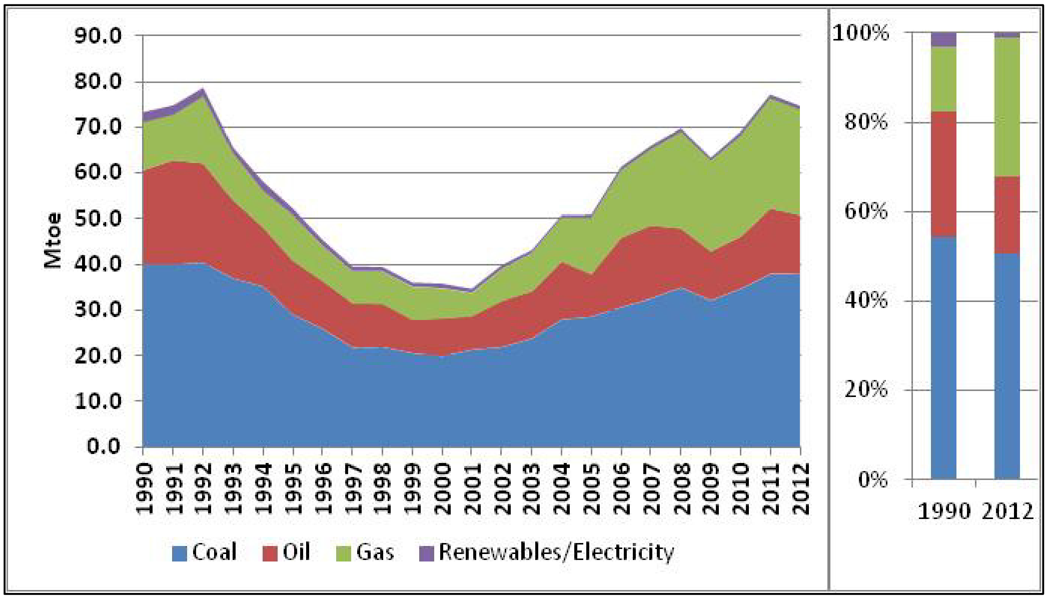
Indicator name	1992	2000	2005	2011
Population, million	16.4	15.8	15.1	16.6
Population density per sq. km	6.1	5.9	5.5	6.1
GDP (billion constant 2005 USD)	42.3	34.9	57.1	83.0
GDP growth (annual %)	-5.3	9.8	9.7	7.5
Total primary energy supply (Mtoe)	78.8	35.7	50.9	77.3
Total final consumption (Mtoe)	65.8	21.6	30.6	42.9
CO_2 emissions (Mt)	261.3	127.8	176.9	261.8
CO_2 emissions (tons per capita)	15.9	8.6	11.7	15.8

Sources: World Bank [7] and IEA [22] data

Total primary energy supply of Kazakhstan is dominated by coal as indicated in Figure 2.3. Its share in the fuel mix has slightly declined since 1990, while the share of oil has almost halved. The share of gas has doubled, while renewable/electricity has declined from 3% till 1%. The total supply surpassed 1990 level, while remains below 1992 level. The time period 1992-2001 was characterized by a sharp decline in energy supply after the dissolution of the USSR, while since 2002 the TPES growth has been averaging around 8% per annum. The vast share of supplied energy, primarily crude oil, was exported and the revenue contributed significantly to the country`s economic growth.

Heavy pricing and universal supply obligation regulations by the government make domestic market unattractive to suppliers. Therefore, while Kazakhstan is a net energy exporter, some parts of the country would have to rely on imported energy sources from the neighboring countries. Hence, it would require energy infrastructure development to supply energy-importing regions with domestically produced energy sources.

It is expected that by 2035 the energy mix would not change substantially and coal would remain the dominant fuel (37%), followed by natural gas (30%) and oil (22%), while total primary energy demand is predicted to growth at an annual rate of 1.5% [23]. It is likely that crude oil will remain the main export commodity from Kazakhstan. Hence, it is forecasted that oil production will grow by 80% by 2035 [23].

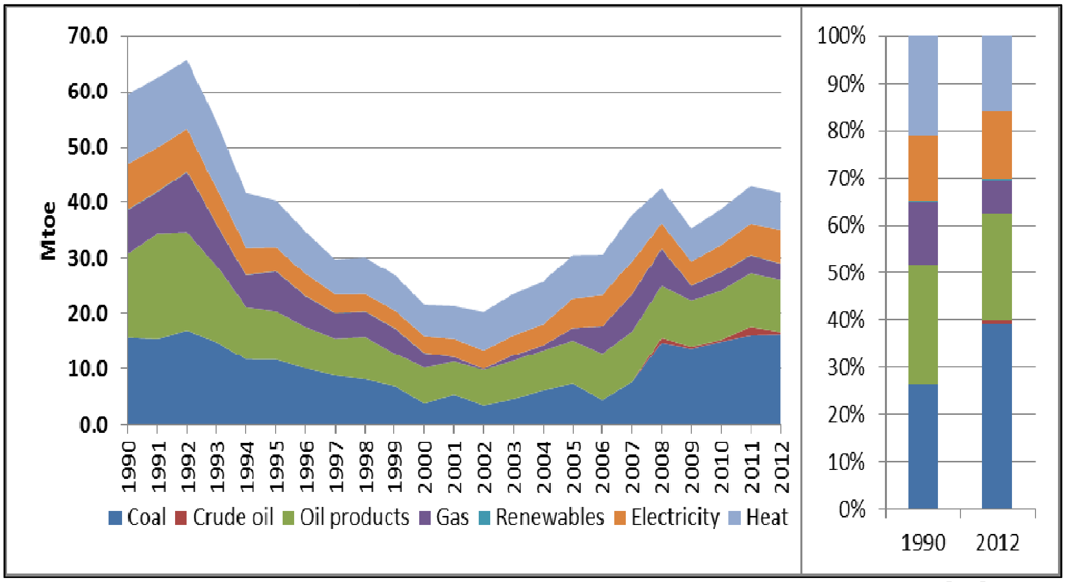


Source: IEA [22] data

Figure 2.3 Total primary energy supply in Kazakhstan

Figure 2.4 displays total final consumption by fuel. Like TPES, coal is the dominant fuel in TFC (almost 40% of fuel mix), followed by crude oil and oil products (22%), heat (16%), electricity (14%) and natural gas (7%). Energy demand has been making positive growth since 1999 as response to economical growth after a substantial setback in 1990s due to the collapse of the Soviet Union. Despite the moderate growth, in 2012 TFC was about 30% below the 1990 level.

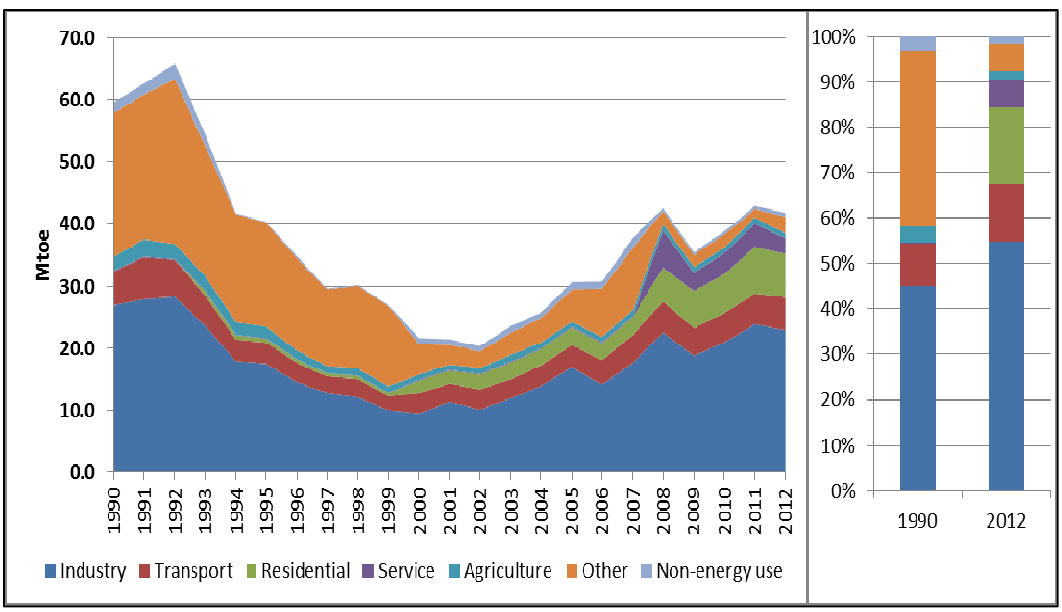
It is forecasted that the total final demand will grow at slightly over 2% annually and faster growth of electricity (3.5%) and natural gas (2.9%) consumptions are expected by 2035 [23]. However, the latter would not significantly affect the TFC energy mix and coal would remain a dominant domestically used fuel. Consequently, it is likely that CO_2 emissions would substantially increase if no actions are taken.



Source: IEA [22] data

Figure 2.4 Total final consumption by fuel in Kazakhstan

The total final consumption is significantly lower than that during the Soviet period as seen in Figure 2.5. Energy consumption of industry, agriculture, transport and all other sectors have declined by 15%, 62%, 3% and 49% respectively. Industry is the biggest energy consumer (55%) followed by residential (17%) and transport (13%). ADB expects almost 3% growth of the transport sector`s demand, while all other industries would grow at slightly over 1.5% through 2035 [23].



Source: IEA [22] data

Figure 2.5 Total final energy consumption by sector in Kazakhstan

The Republic of Kazakhstan intends to achieve a country-wide GHG emissions reduction target of unconditional and conditional targets of 15% and 25% respectively by 2030 compared to base year 1990 [24]. Primarily, the country plans to improve energy efficiency and develop renewable energy projects across the country. It is assumed that the country would enter the low-carbon development path and contribute to global efforts to combat climate change.

2.2 Kyrgyz Republic

Kyrgyz Republic is primarily a mountainous country with rich hydropower resources and insignificant fossil fuel reserves. Two major revolutions took place in the country in 2000s, which hindered economic development and resulted in inconsistent economic growth. According to the World Bank, the republic belongs to the lower-middle-income economies by the level of income. The economy has changed into less industrial and more service-oriented since 1990 and represents around 0.01% of global economy.

Table 2.2 displays the main socioeconomic, energy and environmental indicators of the republic. It is seen that population have increased by almost 1 million, while GDP has grown by 33% since 1990. TPES, TFC and CO_2 emissions have significantly declined for the same period. GDP is forecasted to more than double by 2035, while would increased for almost 1.5 million [23]. Such growth would require significant improvement of the energy system of the country.

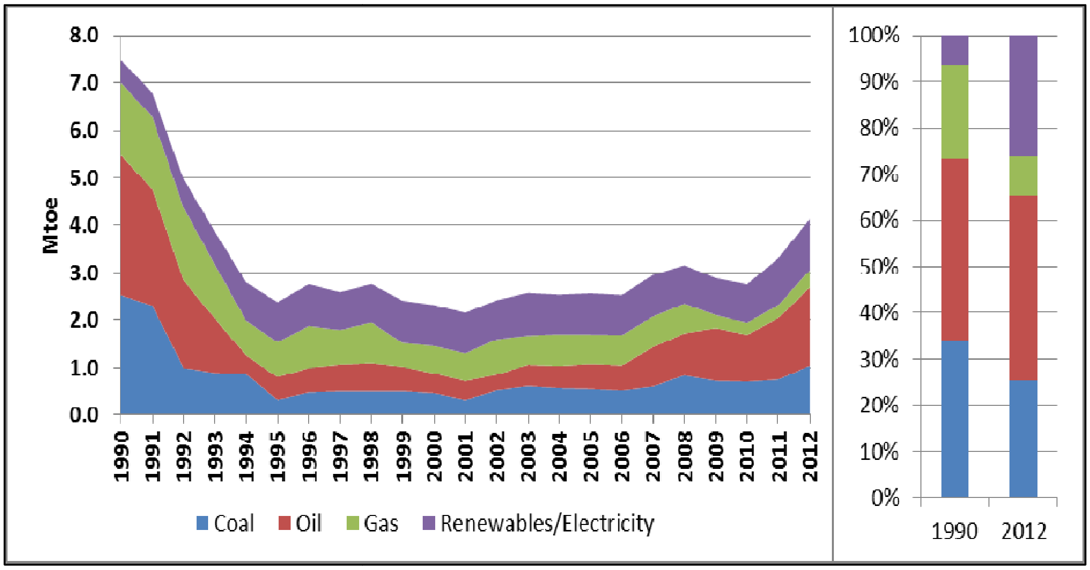
Table 2.2 Main socioeconomic, energy and environmental indicators of Kyrgyz Republic

Indicator name	1992	2000	2005	2011
Population, million	4.5	4.9	5.2	5.5
Population density per sq. km	23.5	25.5	26.9	28.7
GDP (billion constant 2005 USD)	2.4	2.0	2.5	3.2
GDP growth (annual %)	-13.9	5.4	-0.2	6.0
Total primary energy supply (Mtoe)	7.5	2.3	2.6	3.3
Total final consumption (Mtoe)	4.5	1.7	1.8	2.8
CO_2 emissions (Mt)	10.9	4.5	5.2	6.6
CO_2 emissions (tons per capita)	2.4	0.9	1.0	1.2

Sources: World Bank [7] and IEA [22] data

Figure 2.6 presents TPES structure by fuel type in Kyrgyz Republic. The total supply has declined by slightly less than 45% since 1990. The structure has also significantly transformed towards the dominance of oil and hydropower. Particularly, hydropower production has more than doubled since the Soviet times, while the supply of gas has declined by almost 80%. The dependence on hydropower makes the republic dependent on electricity import during the winter season, while increase export in summer. This creates a mismatch between the demand and production peaks. Furthermore, climate change causes melting of mountain glacier, which would result in decline of hydropower production in the long run.

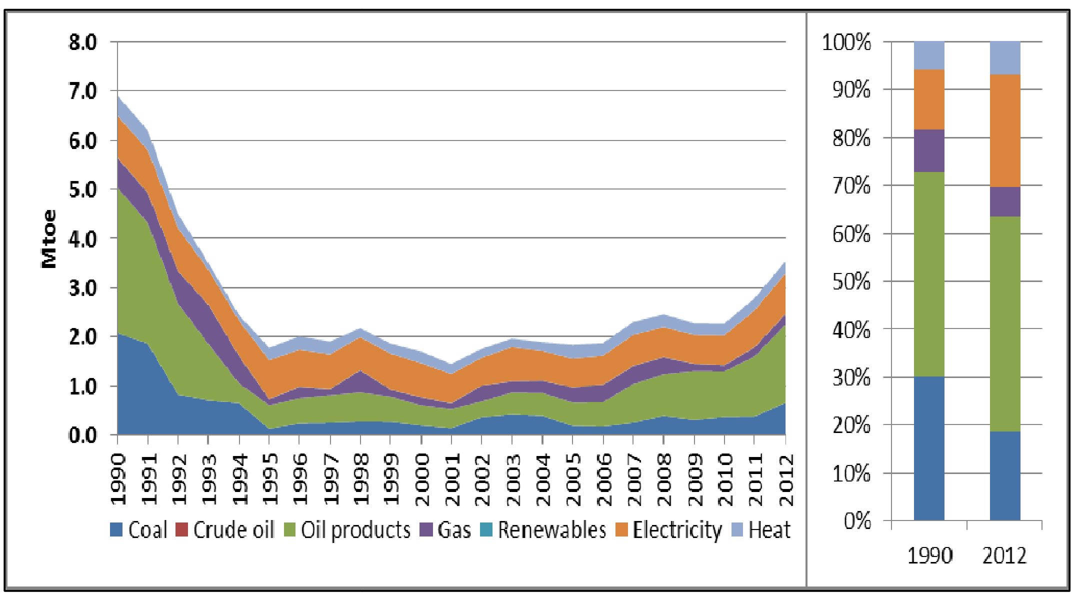
It is expected that the primary energy demand will more than double by 2035 and oil will be a dominant fuel in the energy mix, while share of hydro would decline due to increased share of coal [23]. It is likely that the country will remain dependent on energy import to satisfy its growing demand. Hence, rehabilitation and improvement of the existing hydropower plants and distribution system is crucial for the country.



Source: IEA [22] data

Figure 2.6 Total primary energy supply in Kyrgyz Republic

Figure 2.7 displays the structure of TFC by fuel in the republic. The consumption has dropped almost twice since 1990. The mix remains oil products dominant, while share of coal has dropped by more than 10% in favor of electricity. ADB expects the energy demand to grow more than 3% annually through 2035.

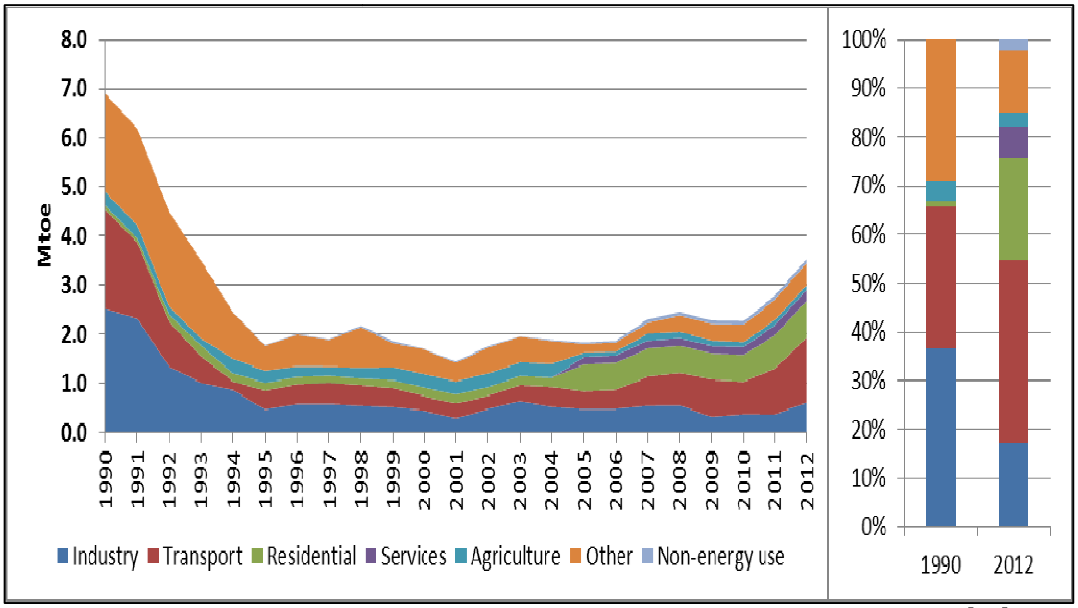


Source: IEA [22] data

Figure 2.7 Total final consumption by fuel in Kyrgyz Republic

There has been a significant transformation in TFC by sector since 1990. Consumptions by industry, transport, agriculture and other sectors have declined by 76%, 34%, 66% and 78% respectively, while residential, residential and non-energy use have grown by 774%, 100% and 100% respectively as seen in Figure

2.8. It is forecasted that share of transport will increase from 38% till almost 42% through 2035, industry from 17% till slightly over 35%, non-energy use will remain unchanged, while all other sectors will account for slightly over 20% [23].



Source: IEA [22] data

Figure 2.8 Total final energy consumption by sector in Kyrgyz Republic

According to the Intended Nationally Determined Contribution of Kyrgyz Republic, the country intends to reduce GHG emissions by 11.49% - 13.75% below 2010 base level [25]. The target variations depend on population growth. The republic plans to mobilize domestic efforts and attract international funds to achieve the targets.

2.3 Tajikistan

Tajikistan is the smallest of the five Central Asian countries, endowed with water resources. Tajik economy is among the lower-middle-income economies. Economic downturn in the 1990s after the collapse of the USSR was significantly faster than in other countries due to a civil war that lasted for 5 years. Major factors of the economic growth in the 2000s are exports of aluminum and cotton as well as remittances from the Tajik workers in the Russian Federation.

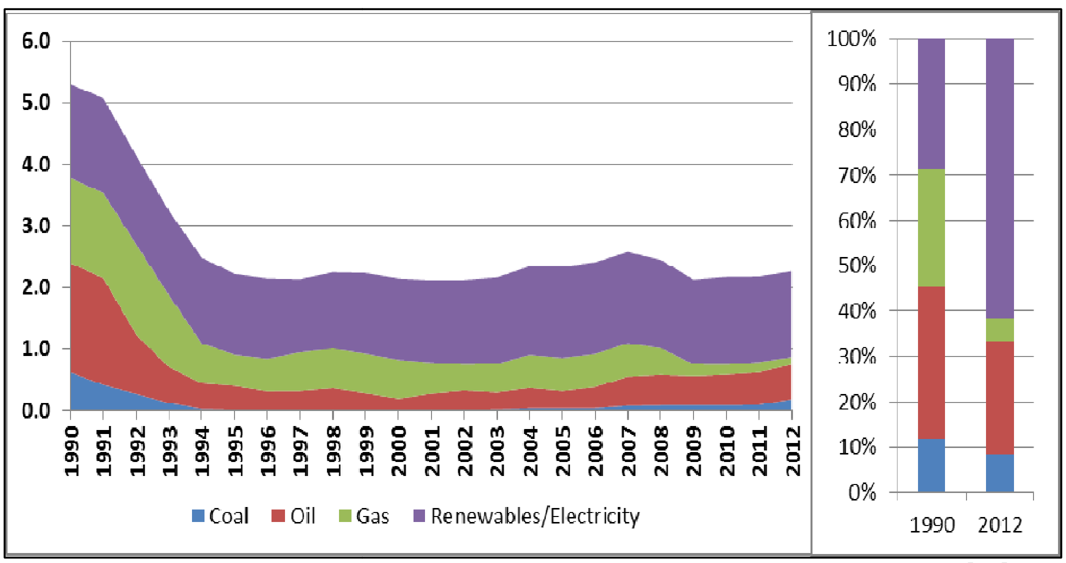
As shown in Table 2.3 population and GDP have increased since 1992 by 42% and 36% respectively, while TPES, TFC and CO_2 emissions have declined by 46%, 44% and 61% respectively over the same period of time. ADB forecasts almost 6% annual average growth rate of GDP through 2035, while population is expected to grow moderately at slightly over 1% annually [23]. This will likely exacerbate existing energy security problems.

Table 2.3 Main socioeconomic, energy and environmental indicators of Tajikistan

Indicator name	1992	2000	2005	2011
Population, million	5.5	6.2	6.8	7.8
Population density per sq. km	39.5	44.2	48.6	55.4
GDP (billion constant 2005 USD)	2.5	1.4	2.3	3.4
GDP growth (annual %)	-29.0	8.3	6.7	7.4
Total primary energy supply (Mtoe)	4.1	2.1	2.3	2.2
Total final consumption (Mtoe)	3.6	1.8	1.9	2.0
CO_2 emissions (Mt)	7.2	2.2	2.4	2.8
CO_2 emissions (tons per capita)	1.3	0.4	0.4	0.4

Sources: World Bank [7] and IEA [22] data

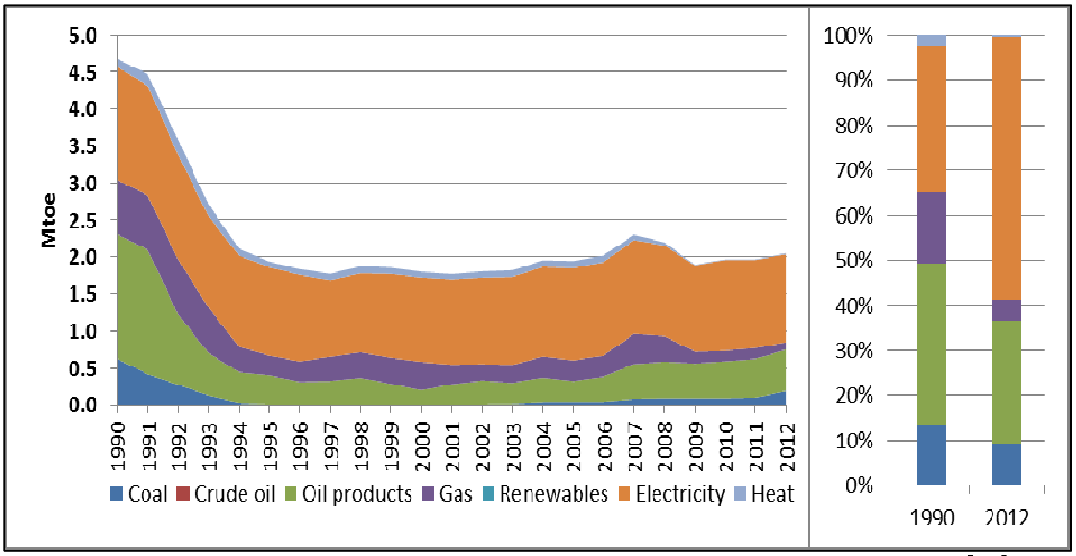
Tajik TPES is dominated by hydropower as seen in Figure 2.9. There was slightly more than two times decline of the total supply from 1990 till 2012. TPES of all fuel types have reduced since 1990. The highest decrease was recorded in supply of gas (91%), followed by coal (70%), oil (68%) and renewable/electricity (8%). It is expected that the total supply will more than double and hydropower will be the dominant fuel, while the shares of coal and oil will likely increase due to decline in natural gas supply.



Source: IEA [22] data

Figure 2.9 Total primary energy supply in Tajikistan

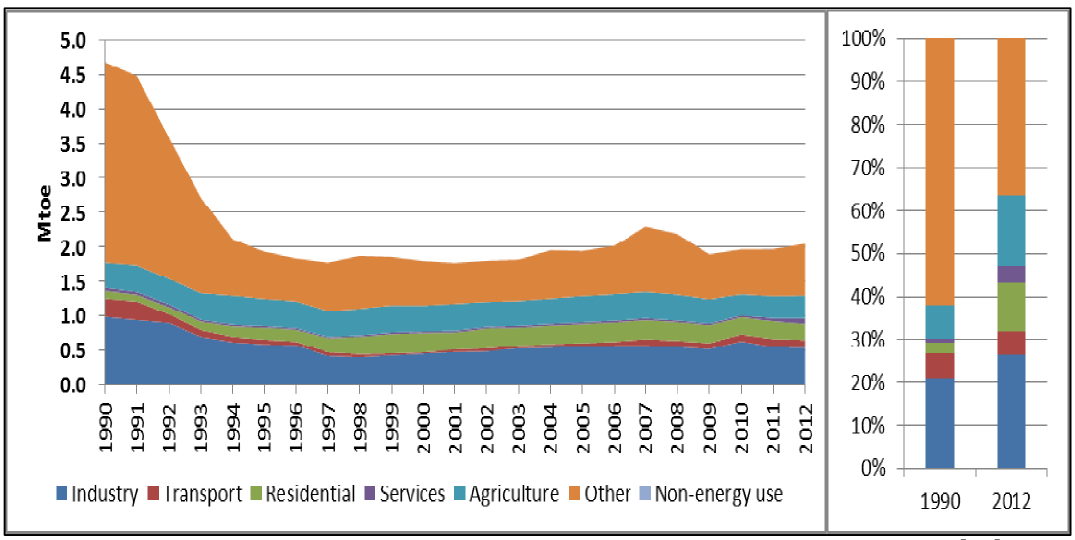
Figure 2.10 displays TFC by fuel in Tajikistan. The total consumption has declined more than more than twice since 1990, while the energy mix have also transformed significantly for the same period. Electricity accounts for almost 60% of the mix, followed by oil products (27%), coal (9%) and natural gas (5%). Electricity consumption is slightly lower than in 1990, while gas consumption has dropped by almost 7.5 times since the Soviet period. It is projected that oil consumption will grow faster than other fuel types [23].



Source: IEA [22] data

Figure 2.10 Total final consumption by fuel in Tajikistan

Figure 2.11 shows TFC by sectors in Tajikistan. There has been a significant decline in consumption by other sectors (74%), transport (59%), industry (45%) and agriculture (9%), while energy uses by residential and service sectors have increased by 104% and 81% respectively. Industry sector`s share is expected to expand almost 1.5 times, primarily by increasing electricity consumption.



Source: IEA [22] data

Figure 2.11 Total final energy consumption by sector in Tajikistan

The government of Tajikistan plans to not exceed its GHG emissions by 80-90% without international funds and 65%-75% with international funds of the base 1990 level by 2030 [I26]. The country requires additional funds and technology transfer to achieve its goals. Furthermore, Tajikistan will need to introduce climate change measures due to adverse effects of climate change on its economy.

2.4 Turkmenistan

Turkmenistan is an upper-middle-income country, located between the Caspian Sea in the west and Amudarya River in the east. Country is the largest producer of natural gas in the region. Until recently, the government of Turkmenistan provided natural gas, electricity and gasoline free of charge for the citizens. This led to inefficient use of the energy resources and increased emissions.

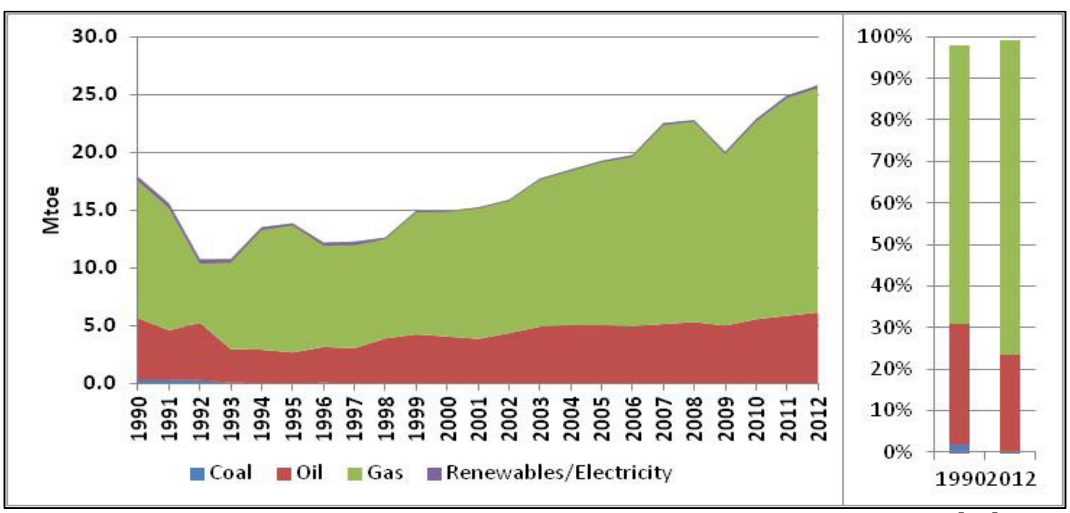
A double-digit economic growth in the 2000s was based on utilization of its vast natural gas reserves, which doubled country's real GDP as shown in Table 2.4. TPES have increased almost 2.5 times, while both energy consumption and CO_2 emissions have almost doubled since 1990. The real GDP is expected to increase almost four times by 2035,while population will grow moderately, resulting almost more than triple increase in per capita GDP.

Table 2.4 Main socioeconomic, energy and environmental indicators of Turkmenistan

Indicator name	1992	2000	2005	2011
Population, million	3.9	4.5	4.7	5.1
Population density per sq. km	8.3	9.6	10.1	10.9
GDP (billion constant 2005 USD)	6.5	6.3	8.1	15.2
GDP growth (annual %)	-15.0	5.5	13.0	14.7
Total primary energy supply (Mtoe)	10.4	14.9	19.2	24.7
Total final consumption (Mtoe)	8.1	9.2	12.0	16.1
CO_2 emissions (Mt)	29.0	35.4	45.5	62.2
CO_2 emissions (tons per capita)	7.5	7.9	9.6	12.2

Sources: World Bank [7] and IEA [22] data

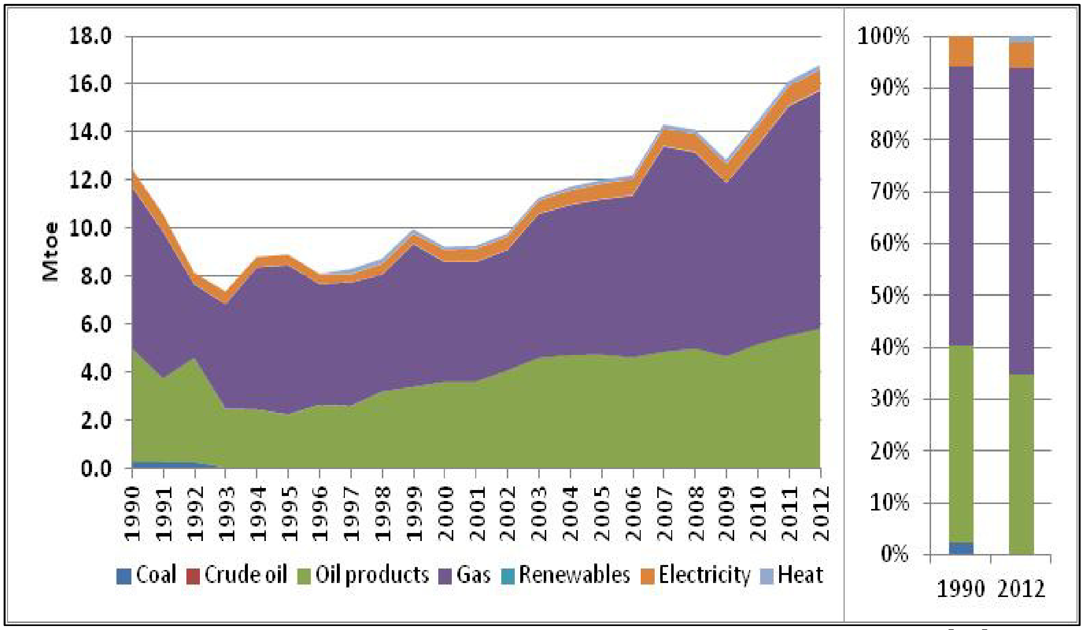
TPES of Turkmenistan has increased almost 1.5 times since 1990. Gas has been a dominant fuel, while oil production has grown moderately as shown in Figure 2.12. Gas production is expected to increase more than three times, while oil production is projected to increase more than 100,000 barrels per day by 2035 [23]. Larger growth in hydrocarbons production is limited by existing pipeline capacity.



Source: IEA [22] data

Figure 2.12 Total primary energy supply in Turkmenistan

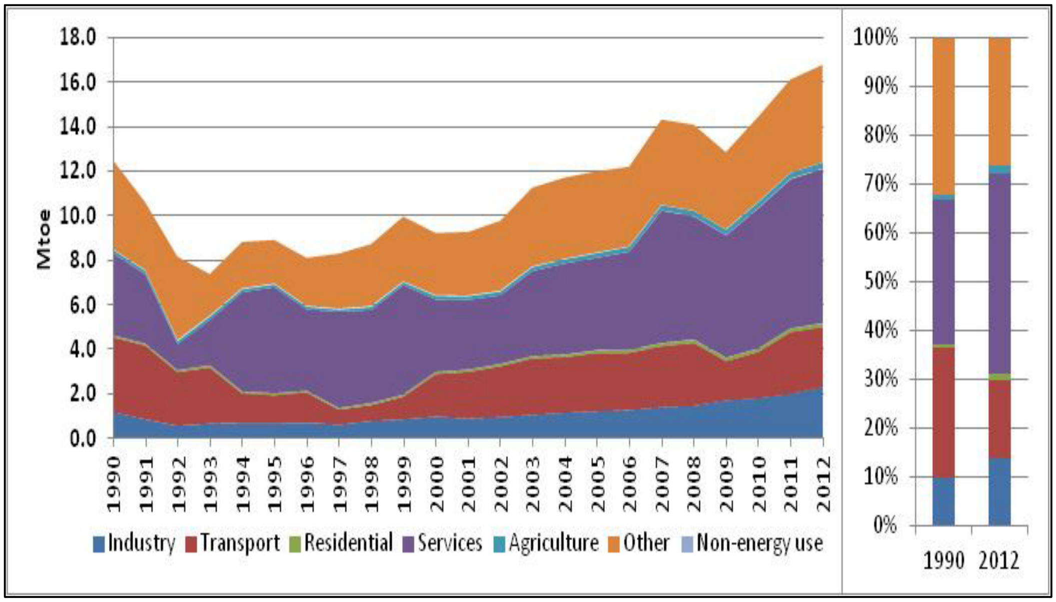
Turkmen TFC has increased by 34% since 1990 as seen in Figure 2.13. The highest growth was recorded in gas consumption (47%), followed by oil products (23%) and electricity (15%). TFC is predicted to moderately grow at slightly more than 1% annually by 2035 and gas will remain a dominant fuel despite increased consumption of oil products.



Source: IEA [22] data

Figure 2.13 Total final consumption by fuel in Turkmenistan

Services have emerged as the biggest final energy consumer in Turkmenistan, overtaking the other industries as seen in Figure 2.14. Transport is the only sector that decreased its energy consumption. However, the sector's consumption is expected to grow moderately through 2035 along with moderate growth of total energy demand [23].



Source: IEA [22] data

Figure 2.14 Total final consumption by sector in Turkmenistan

Turkmenistan plans to stabilize or begin GHG emissions comparing to base year 2000 by 2030 [27]. The target is feasible only by combination of domestic efforts and international support. Furthermore, the country needs to its climate change adaptation measures.

2.5 Uzbekistan

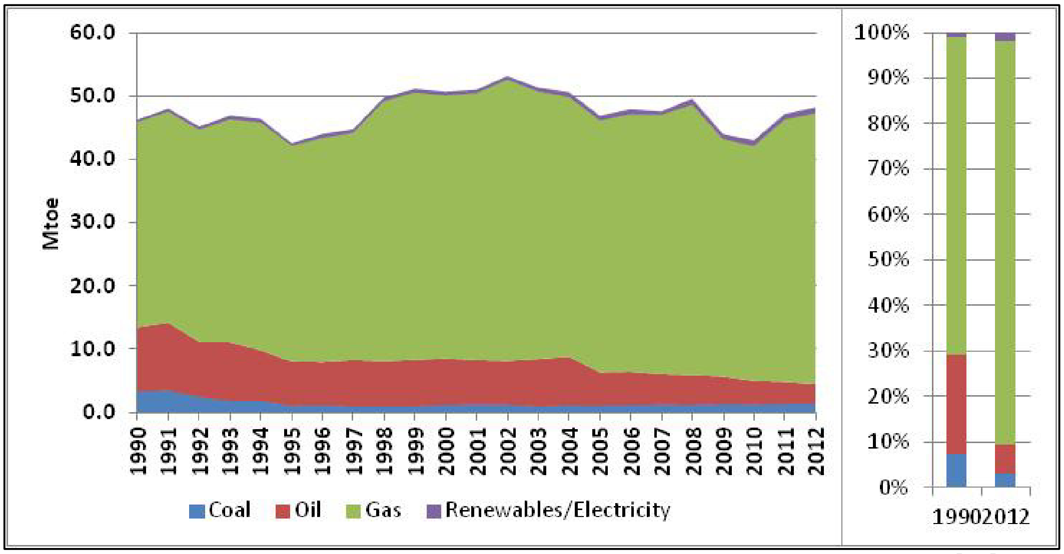
The Republic of Uzbekistan is a landlocked country, located in the valley between Amudarya and Syrdarya rivers. The country is the most populous in Central Asia. Uzbek GDP have more than doubled since 1990, population have grown by almost 8 million people. The country belongs to the group of lower-middle-economies. Energy supply and consumption have not increased significantly as indicated in Table 2.5. Hence, CO_2 emissions are below the pre-independence volume. ADB projects more than 6% growth of GDP, while population is expected to be slightly below than 35 million by 2035.

Table 2.5 Main socioeconomic, energy and environmental indicators of Uzbekistan

Indicator name	1992	2000	2005	2011
Population, million	21.4	24.6	26.2	29.3
Population density per sq. km	50.4	57.9	61.5	69.0
GDP (billion constant 2005 USD)	9.9	11.0	14.3	23.4
GDP growth (annual %)	-11.2	3.8	7.0	8.3
Total primary energy supply (Mtoe)	45.3	50.8	47.0	47.2
Total final consumption (Mtoe)	32.3	37.4	34.0	34.4
CO_2 emissions (Mt)	115.7	121.1	112.9	114.9
CO_2 emissions (tons per capita)	5.4	4.9	4.3	3.9

Sources: World Bank [7] and IEA [22] data

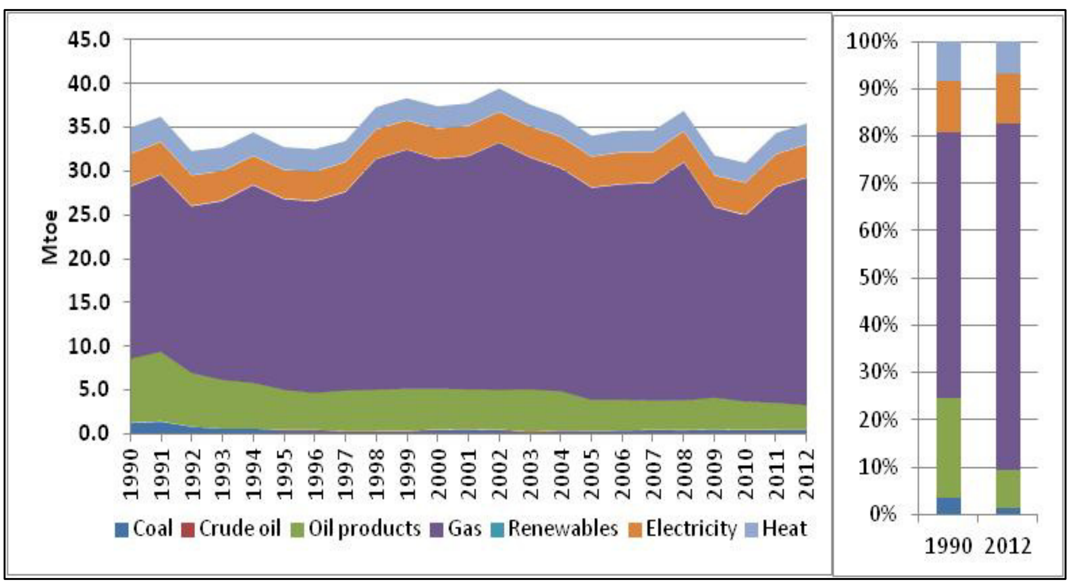
TPES have slightly increased since 1990 and have transformed significantly towards the dominance of natural gas as seen in Figure 2.15. Supplies of coal and oil have declined by 59% and 69% respectively. 1% annual increase of TPES is expected through 2035 and natural gas will remain the type of energy [23].



Source: IEA [22] data

Figure 2.15 Total primary energy supply in Uzbekistan

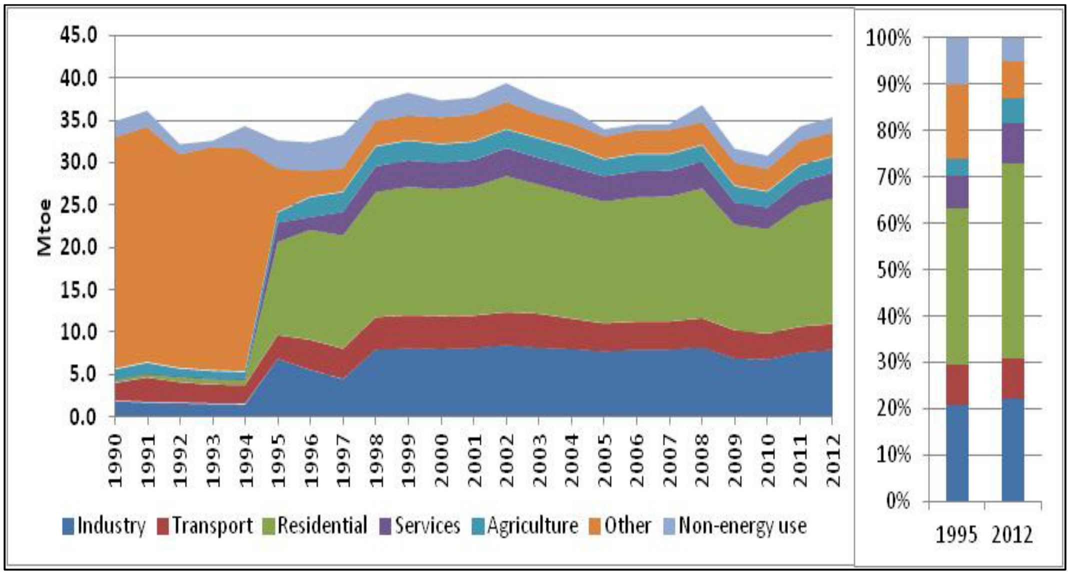
Uzbek TFC have not changed significantly since the Soviet period as seen in Figure 2.16. However, the share of natural gas has increased significantly, while the shares of coal and oil products have declined significantly. It is predicted that final energy demand will surpass 40 Mtoe by 2035 and natural gas will be a dominant fuel in the mix.



Source: IEA [22] data

Figure 2.16 Total final consumption by fuel in Uzbekistan

Residential sector accounts for over 40% of total final energy consumption, followed by industry (22%), while all other sectors together account for 36% as presented in Figure 2.17. It is likely that the reporting on sectors final energy consumption until 1995 was poor. Hence, FY 1995 was used to compare the shares of the sectors in TFC. Energy consumption by agriculture, residential sector, services, industry and transport have increased by 55%, 35%, 34%, 16% and 9% respectively, while both non-energy use and consumption by other non-defined sectors have declined by slightly more than 45%. It is projected that TFC by sector will not change significantly by 2035 [23].



Source: IEA [22] data

Figure 2.17 Total final consumption by sector in Uzbekistan

The country has strategic aspirations to transit to a low-carbon development path. This resulted in the highest number of Clean Development Mechanisms (CDM), which issued 3.5 megatons of Certified Emission Reductions (CERs) [28]. It is likely that without stronger mitigation efforts and international support, GHG emissions reduction of Uzbekistan would be hard to achieve.

2.6 Measuring the Security of External Energy Supply and Energy Export Demand in Central Asia

The variations in energy profiles affect the self-sufficiency rates of Central Asian republics and create different energy security agenda for Central Asian countries as seen Table 2.6. While Kazakhstan and Turkmenistan are endowed with enormous reserves of hydrocarbons and their economic growth is based on the export of crude oil and gas, energy systems of Kyrgyz Republic and Tajikistan are largely dependent on energy imports. Despite being a net natural gas exporter, it is likely that Uzbekistan will transform into net energy importing country due to combination of increasing domestic demand and depleting reserves of hydrocarbons. This subchapter aims to quantitatively measure the security of energy export demand and supply for all countries of the region and compare the results with the

European Union (EU) and the Organization of Petroleum Exporting Countries (OPEC).

Table 2.6 Energy self-sufficiency rates of Central Asian countries by type

	Coal		Crude oil		Oil products		Natural gas		Electricity	
	1995	2012	1995	2012	1995	2012	1995	2012	1995	2012
KZ	128%	139%	176%	477%	102%	149%	47%	122%	90%	99%
KG	55%	40%	0%	100%	0%	5%	4%	7%	111%	113%
TJ	59%	95%	100%	120%	6%	4%	6%	8%	96%	104%
TM	0%	N/A	100%	136%	141%	143%	259%	286%	126%	118%
UZ	67%	98%	106%	100%	101%	107%	116%	119%	103%	100%

Notes: KZ-Kazakhstan, KG–Kyrgyz Republic, TJ-Tajikistan, TM-Turkmenistan, UZ-Uzbekistan.

Source: Author's calculations based on IEA [22] data

The total reserves of crude oil, natural gas and coal in the region are 2%, 11% and 8% of total world proved reserves, respectively. However, the reserves are unequally distributed among the nations as seen in Table 2.7. Kazakhstan, Turkmenistan and Uzbekistan possess majority of hydrocarbon reserves in the region, while Kyrgyz Republic and Tajikistan rely on energy import to satisfy their domestic demand. Despite the significant coal resources in Kyrgyz Republic, it has only four small mines due to high cost of production [29].

Table 2.7 Fossil fuel reserves in Central Asia

Country	**Crude oil, billion barrels**	**Natural gas, trillion m^3**	**Coal, billion tons**
Kyrgyz Republic	<0.1	<0.1	31.0
Tajikistan	<0.1	<0.1	4.0
Turkmenistan	0.6	17.5	<0.1
Uzbekistan	0.6	1.1	2.4
Total	**31.2**	**20.1**	**71.0**

Sources: BP Statistical Review of World Energy 2015 [30], EIA [31], Eurasian Coal Portal [29], Kabutov (2008) [32], USGS (1997) [33]

The proved hydrocarbon reserves made Kazakhstan, Turkmenistan and Uzbekistan the center of geopolitical interests for different countries who want to address their own energy security issues [34-39]. Meanwhile, Kyrgyz Republic and Tajikistan heavily rely on their hydropower that accounts for about 90% of the regional potential, and this creates heated political water-food-energy disputes with downstream countries of Kazakhstan, Turkmenistan and Uzbekistan [40-41]. Attempts to create a regional water management structure in the form of barter for oil and gas for increased water discharge to downstream countries have not been very successful [42]. The water-energy disputes have been at the core of the rivalry and competition for regional dominance [37-38]. The regional cooperation in energy and water could produce huge gains for energy importers by improving their energy security, while energy exporters could increase their irrigated agriculture.

Oil and gas export income has been a backbone of the economy in energy exporting Central Asian countries. The governments of Central Asia address their concern for the security of external demand by exploring different pipeline routes and markets. Pipeline routes have become an extremely important bargaining chip used in negotiations with interested parties [44]. Ensuring income generated through the export of hydrocarbons is the main factor for economic and political stability of oil exporting countries, where the government revenues significantly depend on the oil and gas price and export volumes [45].

The 2008 Central Asia energy crisis, triggered by the severe winter and high food and fuel prices, required humanitarian assistance from the United Nations [47]. Disruptions of the external energy supply to Kyrgyz Republic and Tajikistan not only affect the functioning of the regional energy sector, but also impact the socio-economic development, stability and progress of the countries [48]. Furthermore, the households in relatively poorer Kyrgyz Republic and Tajikistan are vulnerable to energy insecurities due to shortage of energy, under-investment in infrastructure and growing electricity tariffs [49]. The security of external energy supply has been one of the most important agenda for the governments of Kyrgyz Republic and Tajikistan since the collapse of the Soviet Union. Increasing electricity tariffs was one of the main causes that triggered the Kyrgyz Revolt of 2010.

Therefore, it is important to assess the security levels of both external energy supply for energy-importing countries and energy exports demand for energy exporters of the region. Understanding the energy export and supply risks facing Central Asian countries could help develop policies that address possible shocks to the economies of the region from both energy export and import disruptions. Given the fact that this is the first attempt to quantitatively measure the risks related to external energy supply and energy exports demand, comparing the results with other countries and regions will be beneficial.

2.6.1 Methodology

This study uses methodologies developed to measure the security of external supply in the EU and the security of energy exports demand in the OPEC in order to compare the results with Central Asian countries. The methods aim to provide qualitative measurement of energy securities on supply and external exports demand. The proposed indexes measure the energy securities at the country level and contribution of each country to Central Asian risk exposure.

Le Coq and Paltseva (2009) developed a set of indexes to measure the risks related to the external supply of coal, oil and gas for all EU member states and the resulting contribution to EU risk exposure [50]. The methodology combines the measures of import diversification, political risks in supplying countries, transportation and economic risks. Meanwhile, the methodology to measure the risks of energy exports demand developed by Dike (2013) puts together the estimates of energy export diversification, economic dependence on export, transportation disruption risk and share of energy in export profile of the OPEC countries. Indexes measure country risks related to energy exports demand for all countries and the resulting contribution to OPEC risk exposure [51].

The security of external energy supply is measured using the six-factor Risky External Energy Supply (REES) index for each Central Asian country for the period 2010-2012 [50] as indicated by the following equation for a kind of fuel, *a*:

$$\mathrm{REES_a} = \mathrm{M_a} \times \mathrm{F_a} \times \mathrm{R_a} \times \mathrm{D_a} \times \mathrm{NID_a} \times \mathrm{SF_a} \tag{2.1}$$

where $\mathrm{M_a}$ is the supply monopsony factor of fuel *a* (coal, crude oil and oil products, gas), F_a is the import fungibility of fuel *a*, R_a is the political risk index of the supplier of fuel *a*, D is the indicator of transaction costs, NID_a is the net import dependency of fuel a and SF_a is the share of fuel *a* in the total energy consumption.

M_a reflects the share of exporting countries in the import of fuel *a*:

$$M_a = \sum_i \left(\frac{NPI_{ai}}{NPI_a}\right)^2 \tag{2.2}$$

where NPI_{ai} is the net positive import of fuel *a* from a country *i* in USD, NPI_a is the total net positive import of fuel *a* in USD.

R_a measures the political risk in the supplier country as follows:

$$R_a = \sum_i \frac{100 - PRI_i}{100} \tag{2.3}$$

where PRI_i is the political risk index in an exporting country *i* produced by the PRS Group [52].

The net import dependency index NID_a is calculated as follows:

$$NID_a = \frac{NPI_a}{C_a} \tag{2.4}$$

where NPI_a is the net positive import of fuel *a* in ktoe and C_a is the total fuel *a* consumption in the country in ktoe.

As for the security of demand the objective fuel, *b* is focused on crude oil and gas. The security of energy exports demand is calculated using the Risky Energy Exports Demand (REED) index for each Central Asian country during the period 1995-2012 [51]:

$$REED_b = X_b \times M_b \times D_b \times E_b \tag{2.5}$$

where X_b is the fuel *b* (crude oil and gas) export dependence, M_b is the import monopsony and E_b is the economic impact of fuel *b* export.

The energy export dependence represents the share of crude oil and gas export in total export from the country:

$$X_b = \frac{EE_b}{TE} \tag{2.6}$$

where EE_b is the export value of fuel *b* and TE is the total export value from the country, both in USD.

The monopsony index of energy export to a country j is calculated as follows:

$$M_b = \left(\frac{EX_{bj}}{EX_b}\right)^2 \tag{2.7}$$

where EX_{bj} is the net export of fuel *b* to a country *j* and EX_b is the total export of fuel *b*, both in USD.

The economic impact of fuel *b* export is estimated as the rate of fuel export to the GDP:

$$E_b = \frac{EX_b}{GDP} \quad (2.8)$$

D_a and D_b represent transaction cost factors for energy import and export respectively:

$$D_a = \sum_i d_i \quad (2.9)$$

$$D_b = \bar{d_j} \quad (2.10)$$

where d is an index obtained from a measurable distance between the capitals of two countries of energy import origin (*i*) and energy export destination (*j*). According to Le Coq and Paltseva (2009) and Dike (2013) all country pairs are classified according to the distance between their capitals and indexes assigned as follows [51-52]:

$$D = \begin{cases} 1, & \text{if } d < 1500\ km \\ 2, & \text{if } 1500 \le d < 4000\ km \\ 3, & \text{if } d \ge 4000\ km \end{cases} \quad (2.11)$$

Given the size of Kazakhstan and the fact that the major oil and gas field are located in the western part of the country, Atyrau instead of Astana is used to measure the distance between the countries. Furthermore, the export destination of hydrocarbons from Central Asia to China is Xinjiang. Hence, Urumqi, the capital city of Xinjiang, is used to estimate the factor of distance.

After calculation of REES and REED indexes for all countries of the region, the relative impact of each state on the aggregate regional risk of energy supply and demand is estimated by the Central Asia Risk Exposure of Supply (CARES) and the Central Asia Risk Exposure of Export (CAREX) respectively. The CARES is estimated as follows:

$$CARES_a = \frac{REES_a \times SI_a}{\sum(REES_a \times SI_a)} \quad (2.12)$$

where SI_a is the share of each country in net regional imports of fuel *a*.

The CAREX is expressed as follows:

$$CAREX_b = \frac{REED_b \times SE_b}{\sum(REED_b \times SE_b)} \quad (2.13)$$

where SE_b is the share of the individual country in total regional crude oil and gas exports.

The higher values of REES and REED indexes indicate the bigger risks. On the final stage of assessment, the REES and REED indexes of Central Asian countries are compared with the indexes of the EU [50] and OPEC [51] countries respectively. Furthermore, import origins and export destinations are estimated.

2.6.2 Data

The time intervals under investigation range from 1990 to 2012 for energy export and from 2010 to 2012 for energy import due to data availability. Bilateral energy import and export data in monetary terms are acquired from Hausman et al. (2011) [53] and Simoes and Hidalgo (2011) [54]. Data on energy consumption as well as import on a fuel in ktoe are originated from the International Energy Agency [22]. GDP data of Uzbekistan and Turkmenistan are derived from the World Bank [7], while GDP of Kazakhstan is taken from the Committee of Statistics of the Republic of Kazakhstan [6].

Political risk index produced by PRS Group represents political risk in 100 countries with values between 1 and 100, where a higher number indicates a lower risk. If there is no political risk data for exporting country, the average value of regional data is used. The fungibility index represents the ease of switching suppliers in case of disruptions. Oil and gas imports transported by pipeline have a fungibility index of 2, while other means of transportation are associated with a fungibility index of 1.

2.6.3 Results and Policy Implications

The results of external energy supply risk calculations are presented in Tables 2 .8 and 2.9. Appendix I provide full details of calculations.

Table 2.8 REES indexes of coal, oil and gas external supply for the period 2010-2012

Fuel	Kyrgyz Republic			Tajikistan			Uzbekistan		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
Coal	0.989	0.705	0.289	0.004	0.000	0.004	0.002	0.002	0.004
Oil	70.807	191.065	263.837	39.266	53.707	17.782	0.000	0.001	0.000
Gas	0.943	0.373	1.444	0.195	0.290	0.065	0.000	0.000	0.000

Notes: Only crude oil accounted for Uzbekistan. No coal import to Tajikistan in 2011.

Table 2.9 CARES indexes, in percentage

Country	Coal	Oil	Gas
	2010		
KG	99.99	76.32	88.59
TJ	0.00	23.68	11.41
UZ	0.01	0.00	0.00
	2011		
KG	99.98	89.29	69.14
TJ	0.00	10.71	30.86
UZ	0.01	0.00	0.00
	2012		
KG	99.91	97.74	98.54
TJ	0.02	2.26	1.46
UZ	0.07	0.00	0.00

Notes: KG – Kyrgyz Republic, TJ – Tajikistan, UZ – Uzbekistan.

Kazakhstan has emerged as the main supplier of coal to other Central Asian countries, while the shares of Russia and other countries are declining. The coal REES indexes are lower than both the gas and oil indexes in Kyrgyz Republic and Tajikistan. The index indicates that the coal import dependency is significantly larger in Kyrgyz Republic as seen in Table 2.10. Although the index has been declining in the country due to lower transaction costs and political risk, Kyrgyz Republic has the biggest contribution to the regional exposure to external coal supply risk. This is due to its coal-based power sector and relatively cheaper cost of Kazakhstani coal. Although Uzbekistan is increasing its coal import, its contribution to CARES is insignificant. The average coal REES index in Central Asia is lower than in the EU, and the coal REES index of Kyrgyz Republic is comparable to Estonia and Hungary as displayed in Figure 2.18.

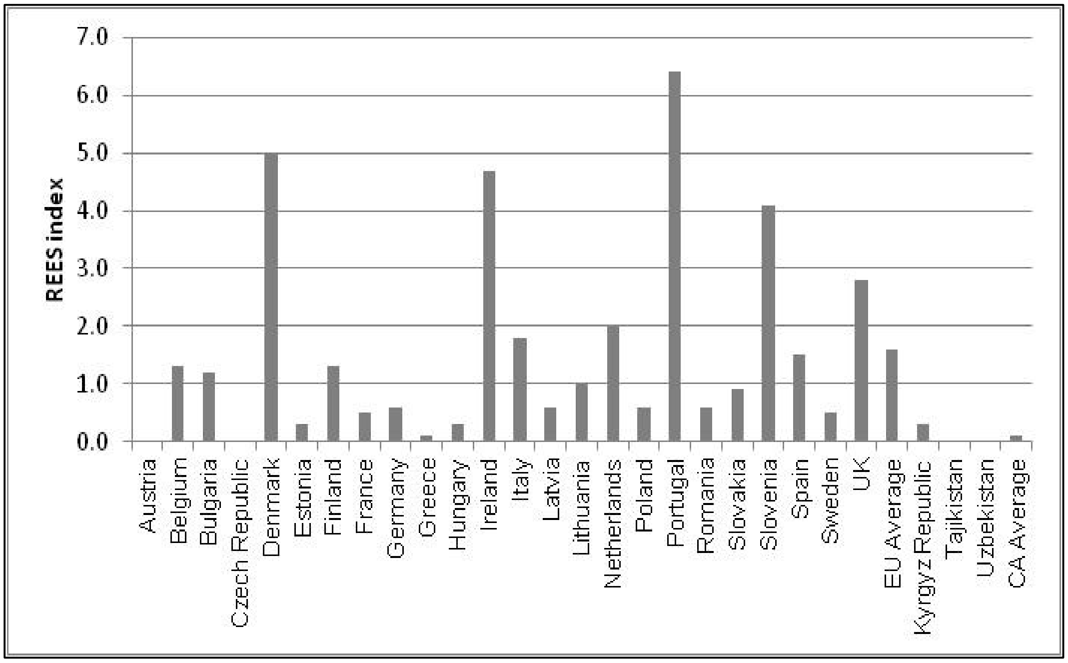


Figure 2.18 Comparison of the coal REES indexes for EU and Central Asia in 2012

Table 2.10 Coal REES indexes of Central Asian republics

	KG			TJ		UZ		
	2010	2011	2012	2010	2012	2010	2011	2012
M	0.930	0.999	1.000	0.347	0.684	0.335	0.388	0.664
D	6	5	3	6	2	6	8	6
NID	0.703	0.597	0.596	0.034	0.053	0.022	0.015	0.023
SF	0.255	0.225	0.253	0.041	0.084	0.030	0.029	0.029
F	1	1	1	1	1	1	1	1
R	0.990	1.050	0.640	1.470	0.680	1.430	1.810	1.390
REES	0.989	0.705	0.289	0.004	0.004	0.002	0.002	0.004

The results of the oil REES indexes and comparison with the EU are provided in Figure 2.19 and Table 2.11. The supply of oil to Central Asian countries imposes the bigger risk than gas and coal supplies to Kyrgyz Republic and Tajikistan. The oil products are dominant fuel in total fuel consumption in Kyrgyz Republic and Tajikistan where almost 90% of consumption is imported, while Uzbekistan imports 0.3% of total crude oil consumption to be processed at its refineries. The main origin of oil import to Kyrgyz Republic and Tajikistan is Russia, while Uzbekistan imports crude oil from Kazakhstan.

The oil REES index of Kyrgyz Republic has been rapidly increasing since 2010 due to poorer monopsony, bigger dependence on energy import and substantial transaction costs factor. Meanwhile, Tajikistan has improved the security of external oil supply mainly by diversification of the import. This had effect on the countries' contribution to the regional oil supply security. The oil CARES index of Kyrgyz Republic has increased by 21% since 2010 due to the decreased oil REES in Tajikistan.

The average oil REES index of Central Asia is higher than the EU average. Kyrgyz Republic's risk of external oil supply is 60 times higher than the EU average one, while Tajikistan's oil REES index is similar to one in Hungary. The Central Asian dependence on external gas supply is lower than the EU.

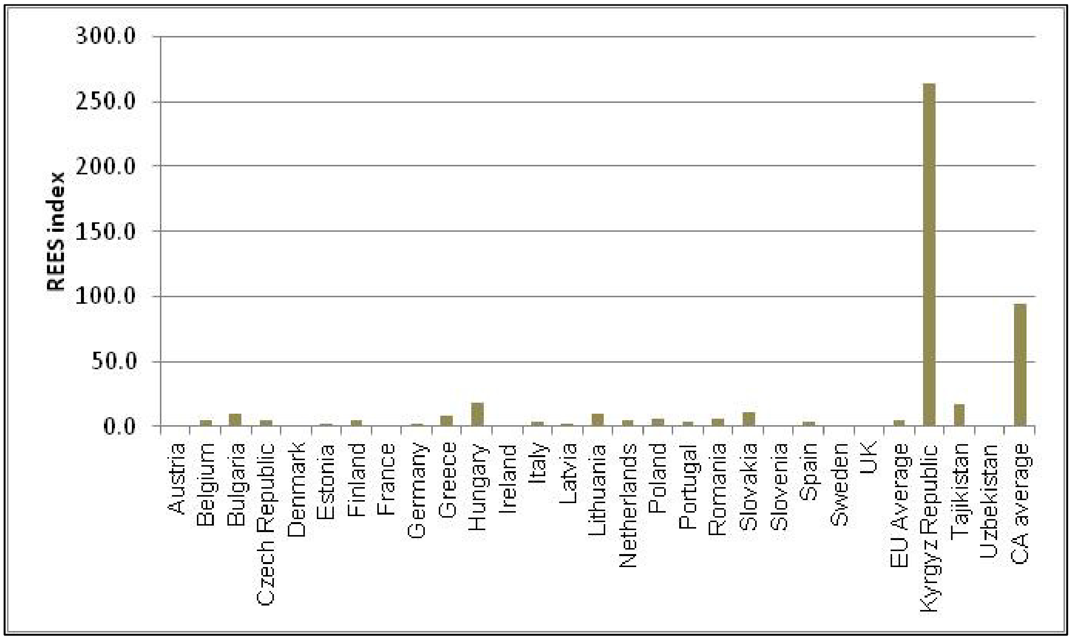


Figure 2.19 Comparison of the oil REES indexes for EU and Central Asia in 2012

Table 2.11 Oil REES indexes of Central Asian republics

	KG			TJ			UZ		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
M	0.59	0.559	0.874	0.94	0.78	0.411	1	0.996	1
D	61	99	89	39	48	40	1	2	1
NID	0.82	0.872	0.904	0.907	0.909	0.908	0.002	0.002	0.003
SF	0.361	0.392	0.399	0.231	0.243	0.248	0.092	0.079	0.069
F	1	1	1	1	1	1	2	2	2
R	6.650	10.110	9.400	5.110	6.490	4.800	0.350	0.720	0.330
REES	70.81	191.07	263.84	39.27	53.71	17.78	0	0.001	0

The results of the gas REES indexes and comparison with the EU are displayed in Figure 2.20 and Table 2.12.The natural gas supplies from Uzbekistan, the main supplier since Soviet times, to Kyrgyz Republic and Tajikistan have had frequent disruptions due to political disputes over water resources. The gas REES index of Kyrgyz Republic is higher mainly due to its dependence on pipeline, while Tajikistan primarily imports liquefied petroleum gas from Kazakhstan.

Furthermore, Tajikistan has addressed the security of gas supply by decreasing its gas consumption by 36% since 2010. Hence, contribution of Kyrgyz Republic to the regional security has increased by more than 10%, while the gas CARES index of Tajikistan has become lower than the oil CARES index.

The average gas REES index of Central Asia is twenty times lower than that of the EU. The gas REES index of Kyrgyz Republic is comparable to an index of France, while Tajikistan's index is similar to that of Belgian.

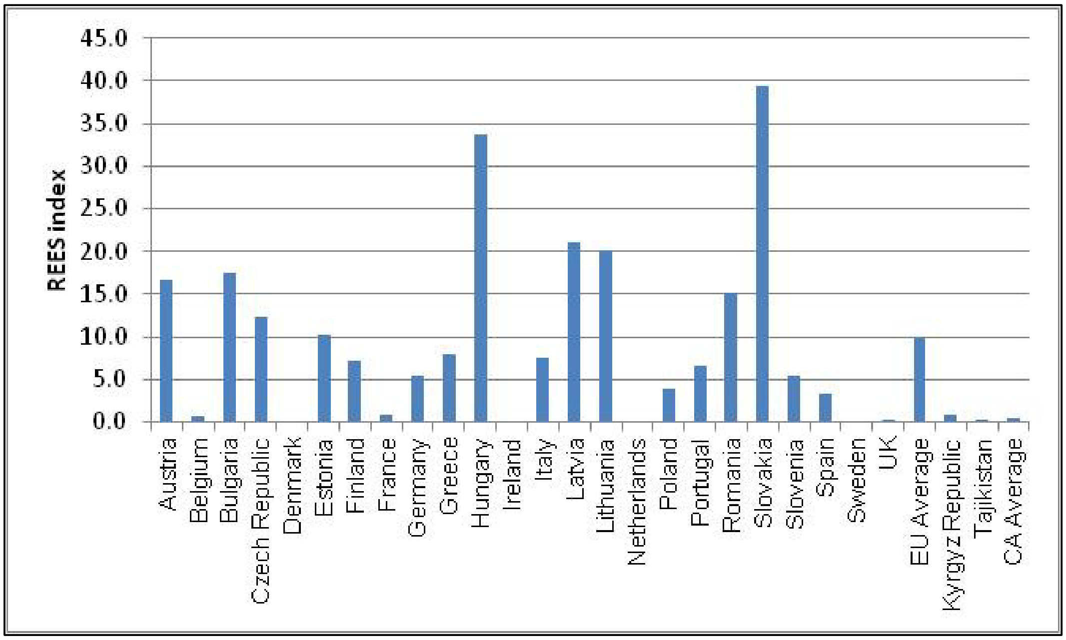


Figure 2.20 Comparison of the gas REES indexes for EU and Central Asia in 2012

Table 2.12 Gas REES indexes of Central Asian republics

	KG			TJ		
	2010	2011	2012	2010	2011	2012
M	0.656	0.543	0.698	0.698	0.996	0.999
D	7	4	8	4	4	2
NID	0.923	0.921	0.933	0.882	0.907	0.924
SF	0.090	0.084	0.086	0.074	0.074	0.052
F	2	2	2	1	1	1
R	1.240	1.110	1.610	1.070	1.080	0.680
REES	0.943	0.373	1.444	0.195	0.290	0.065

In general, the REES indexes of Central Asian countries are lower for coal and gas, while the average REES index for oil is significantly higher than in the EU. It may indicate that securing the external supply of oil is the main priority for the governments of Kyrgyz Republic and Tajikistan. Meanwhile, Uzbekistan has been transforming from net energy exporter to energy importer, affecting the energy policy of the republic.

The results of external energy demand risk calculations are presented in Tables 2.13 and 2.14. Appendix I provide full details of calculations.

Table 2.13 REED indexes of crude oil and gas export for the period 1995-2012

Year	Crude oil				Gas			
	KZ	TM	UZ	Average	KZ	TM	UZ	Average
1995	0.0000	0.0008	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
1996	0.0043	0.0001	0.0000	0.0014	0.0000	0.0226	0.0000	0.0075
1997	0.0055	0.0000	0.0000	0.0019	0.0000	0.4024	0.0000	0.1341
1998	0.0046	0.0005	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000
1999	0.0072	0.0040	0.0000	0.0038	0.0000	0.1167	0.0001	0.0389
2000	0.0386	0.0002	0.0000	0.0129	0.0000	0.2044	0.0009	0.0684
2001	0.0258	0.0005	0.0000	0.0088	0.0000	0.4103	0.0019	0.1374
2002	0.0392	0.0009	0.0000	0.0134	0.0001	0.3728	0.0004	0.1244
2003	0.0150	0.0005	0.0000	0.0052	0.0001	0.3121	0.0011	0.1044
2004	0.0141	0.0001	0.0000	0.0047	0.0002	0.2530	0.0008	0.0847
2005	0.0218	0.0005	0.0000	0.0074	0.0001	0.2895	0.0016	0.0971
2006	0.0191	0.0002	0.0000	0.0064	0.0001	0.3271	0.0023	0.1099
2007	0.0153	0.0002	0.0000	0.0051	0.0002	0.4203	0.0017	0.1407
2008	0.0180	0.0002	0.0000	0.0061	0.0003	0.2990	0.0229	0.1074
2009	0.0133	0.0004	0.0000	0.0046	0.0004	0.0159	0.0156	0.0106
2010	0.0216	0.0002	0.0000	0.0073	0.0002	0.0184	0.0002	0.0062
2011	0.0238	0.0000	0.0000	0.0080	0.0003	0.1328	0.0011	0.0447
2012	0.0255	0.0000	0.0000	0.0085	0.0003	0.2793	0.0001	0.0932

Notes: KZ – Kazakhstan and TM – Turkmenistan

Table 2.14 CAREX indexes, in percentage

Year	Crude Oil			Gas		
	KZ	TM	UZ	KZ	TM	UZ
1995	8.0	92.0	0.0	100	0.0	0.0
1996	100	0.0	0.0	0.0	100	0.0
1997	100	0.0	0.0	0.0	100	0.0
1998	99.8	0.2	0.0	0.0	100	0.0
1999	96.4	3.6	0.0	0.0	100	0.0
2000	100	0.0	0.0	0.0	99.9	0.1
2001	100	0.0	0.0	0.0	99.9	0.1
2002	100	0.0	0.0	0.0	100	0.0
2003	100	0.0	0.0	0.0	100	0.0
2004	100	0.0	0.0	0.0	99.9	0.1
2005	100	0.0	0.0	0.0	99.9	0.1
2006	100	0.0	0.0	0.0	99.9	0.1
2007	100	0.0	0.0	0.0	99.9	0.1
2008	100	0.0	0.0	0.0	97.1	2.8
2009	100	0.0	0.0	1.7	31.8	66.5
2010	100	0.0	0.0	1.7	98.1	0.3
2011	100	0.0	0.0	0.2	99.7	0.1
2012	100	0.0	0.0	0.1	99.9	0.0

Kazakhstan is the main crude oil exporter in the region with a net export of 44 billion USD or 99.7% of total crude oil export from Central Asia. Hence, the contribution to the CAREX index is affected from Kazakhstan. Crude oil has become the dominant exported commodity from Kazakhstan, and its share in total export has increased from 3.6% in 1995 till 55.3% in 2012. Hence, the economic impact of crude oil export has increased from 0.2% till 22.7% for the same period. The crude oil REED index has decreased since 2000 due to improved monopsony factor by diversification of export destinations. China has emerged as the main crude oil importing country from Kazakhstan, while the share of the EU import has been declining since 2005. China's crude oil import from Kazakhstan has increased from 4 million USD in 1997 to 8 billion USD in 2012.

Unlike natural gas, crude oil export from Turkmenistan is insignificant, and its share in total export has never exceeded 5%. Hence, the crude oil REED index of Turkmenistan has been low. The EU countries are the main importers of crude oil from Turkmenistan. Due to insufficient domestic production and growing domestic consumption, Uzbekistan has become a net crude oil importer since 2001.

Kazakhstan has become a net gas exporter since 2001 and its export reached 3.6 billion USD in 2012. However, the amount of gas export from Kazakhstan is twelve times lower than the export of crude oil. Due to combination of diverse export destinations, low export dependence and economic impact of gas export, the gas REED index is the lowest in the region. Kazakhstan's gas CAREX index has not exceeded 2% since 2000.

Turkmenistan is the main gas exporter in the region with a net export of 7.6 billion USD or 66% of total Central Asian gas export. Turkmenistan's gas export sharply declined by 86% in 2009 following the "Lehman" shock and recovered in 2011. The gas REED index is lower than in the pre-crisis period due to lower economic impact of gas export. During the crisis the gas export dependence has almost halved and the economic impact of gas export has reduced by seven times. The contribution of Turkmenistan to the regional risk exposure has been almost 100% except for 2009 when the gas export declined. China has emerged as the main consumer of Turkmen gas since 2010, and its share of total gas export reached 98% in 2012.

The gas export from Uzbekistan has been growing from 1999 till 2008 when it reached its peak. However, after 2009 the gas export has been decreasing due to decline in production and increase in domestic consumption. Hence, Uzbekistan's gas CAREX has consequently reduced.

The crude oil and gas exports from Central Asia are equal to 7% and 3% of OPEC's total crude oil and gas exports respectively. The net crude oil export from Kazakhstan is almost equal to Nigerian export, while gas export from Turkmenistan is almost twice lower than Iranian export. In general, the average REED indexes of Central Asian countries are significantly lower for both crude oil and gas as displayed in Figures 2.21 and 2.22.

The main factor of lower crude oil REED index of Kazakhstan than the OPEC indexes is lower monopsony factor. Furthermore, Kazakhstan's crude oil export and economic dependence is lower than the average values for OPEC countries as seen in Table 2.15.

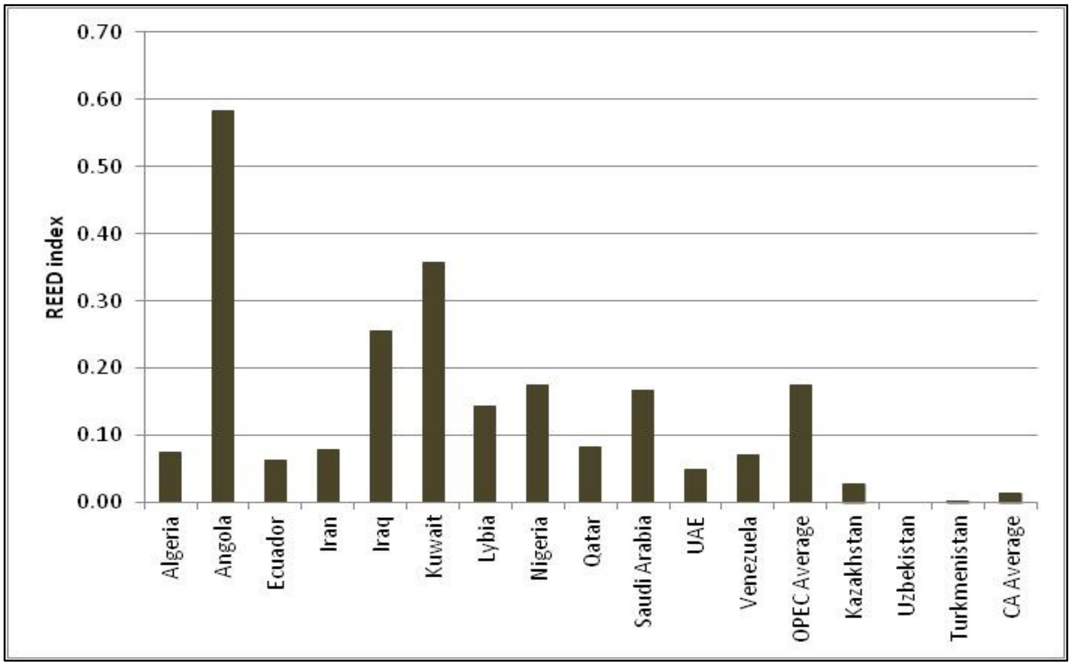


Figure 2.21 Comparison of the crude oil REED indexes for OPEC and Central Asia in 2012

Table 2.15 Crude oil REED indexes of Central Asian republics

	KZ				TM				UZ	
	1995	2000	2005	2012	1995	2000	2005	2012	1995	2000
Export, $B	0.043	5.388	12.325	44.068	0.026	0.031	0.190	0.119	0.000	0.002
D	2	2	2	2	2	2	2	2	2	1
M	0.234	0.117	0.087	0.102	0.616	0.344	0.236	0.445	0.778	1.000
E	0.003	0.295	0.295	0.217	0.011	0.011	0.023	0.003	0.000	0.000
X	0.037	0.510	0.534	0.553	0.064	0.020	0.043	0.013	0.000	0.001
REED	0.000	0.039	0.022	0.025	0.001	0.000	0.001	0.000	0.000	0.000

Notes: No crude oil export Uzbekistan in 2005 and 2012

The gas REED index of Turkmenistan is almost twice lower than the OPEC average. However, only Qatar and Algeria have bigger REED indexes. The monopsony factor of the Turkmen index is significantly higher than the OPEC average as shown in Table 2.16. Generally, it could be said that the security of energy demand in Central Asia is better than in OPEC economies.

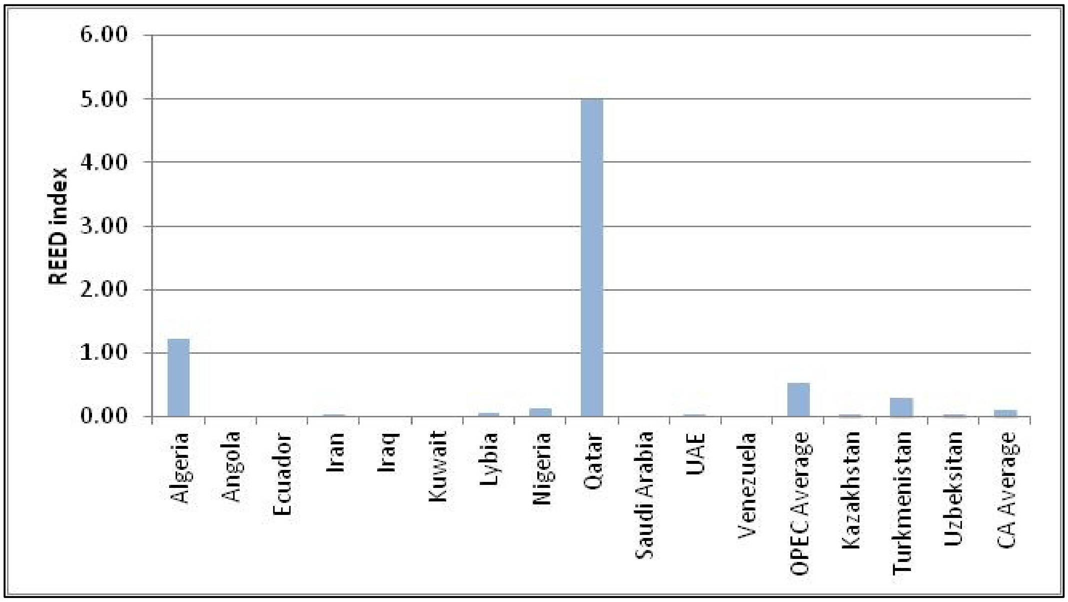


Figure 2.22 Comparison of the gas REED indexes for OPEC and Central Asia in 2012

Table 2.16 Gas REED indexes of Central Asian republics

	KZ			TM			UZ		
	1995	2005	2012	2000	2005	2012	2000	2005	2012
Export, $B	0.001	0.637	3.640	0.414	3.121	7.584	0.172	0.486	0.224
D	2	2	2	1	2	2	1	2	1
M	1.000	0.152	0.170	0.921	0.603	0.959	0.615	0.216	0.587
E	0.000	0.011	0.019	0.292	0.385	0.216	0.012	0.034	0.004
X	0.000	0.040	0.046	0.542	0.712	0.810	0.087	0.134	0.047
REED	0.000	0.000	0.000	0.204	0.290	0.279	0.001	0.002	0.000

Notes: No gas export from Kazakhstan in 2000, Turkmenistan and Uzbekistan in 1995.

The analysis of the time series data allows understanding the development of energy security aspects of Central Asia. The security of energy supply is one of the main political agendas in Kyrgyz Republic and Tajikistan. Meanwhile, Kazakhstan and Turkmenistan, the main oil and gas exporters in the region, have been exploring new markets and export routes to secure the demand for crude oil and gas exports. In the meantime, growing domestic consumption and depleting reserves of hydrocarbons have reduced Uzbekistan's role as regional energy player.

The results of assessment of external energy supply indicate a large variation of risk profiles of energy importing countries. Kyrgyz Republic is the most exposed country to the risk of external energy supply disruption. This may indicate that improvements to energy saving and energy efficiency could significantly boost Kyrgyz Republic's security of external energy supply. Although the energy supply risk profile of Tajikistan is better, development of renewable energy and introduction of energy efficiency measures could also reduce its dependence on external energy supply. Increase in coal import to Uzbekistan could be expected as the government is trying to reduce domestic consumption of gas in order to fulfill its export obligations to China.

The results of analysis of energy export demand security reveal China's rise in

Central Asian energy market. China has increased its presence in the region by launching construction of a gas pipeline passing through Kyrgyz Republic and Tajikistan. The project would have twofold effect in the form of improved gas supply to China and higher political and economic influence in Kyrgyz Republic and Tajikistan as energy supplier. The pipeline would improve the security of energy supply in the republics.

Although overall security of energy export demand in Central Asia is better than in OPEC economies, export diversification is vital. The worsening geopolitical and geo-economic situation in Russia endangers the existing energy export routes to Europe. Hence, alternative supply routes to Europe should be considered. Furthermore, India and Pakistan could be attractive destinations for Central Asian energy exports.

On the regional level, a regional cooperation for effective water-energy management could be beneficial for both energy exporting and importing countries. Development of CASA-1000 project [55] and agreement between Kazakhstan and Kyrgyz Republic to purchase electricity from each other during shortage periods could help to solve the water-energy disputes and improve the regional energy security. However, the existing political situation is competitive rather than oriented towards cooperation.

2.7 Summary

Former Soviet Central Asian republics have chosen a different path towards economic development since the dissolution of the Soviet Union. Apart from difference in economic development, there are significant variations in energy profiles. Countries face different energy security issues due to availability of energy resources.

Six-factor Risky External Energy Supply (REES) index and four-factor Risky Energy Exports Demand (REED) index used to measure external energy supply and energy export demand securities in Central Asia. The results are compared to the EU and OPEC countries respectively.

External supply of oil products imposes the bigger risk to Kyrgyz Republic and Tajikistan than gas and coal. The REES indexes of Kyrgyz Republic and Tajikistan are lower for coal and gas, while the average REES indexes for oil are significantly higher than those of the EU. Although the REED indexes of Central Asian hydrocarbon exporters for crude oil and gas are lower than those of OPEC countries, Kazakhstan and Turkmenistan have transformed as the hydrocarbon export dependent economies. It has consequences on country’s economic growth, energy system and resulting environmental impact. In order to define effective policy to diversify the economy from crude oil dependence, effective energy consumption and reduce environmental impact, analysis of relationship between the variables is an imperative policy issue for Kazakhstan.

Chapter 3

Economy, Energy and the Environment in Kazakhstan

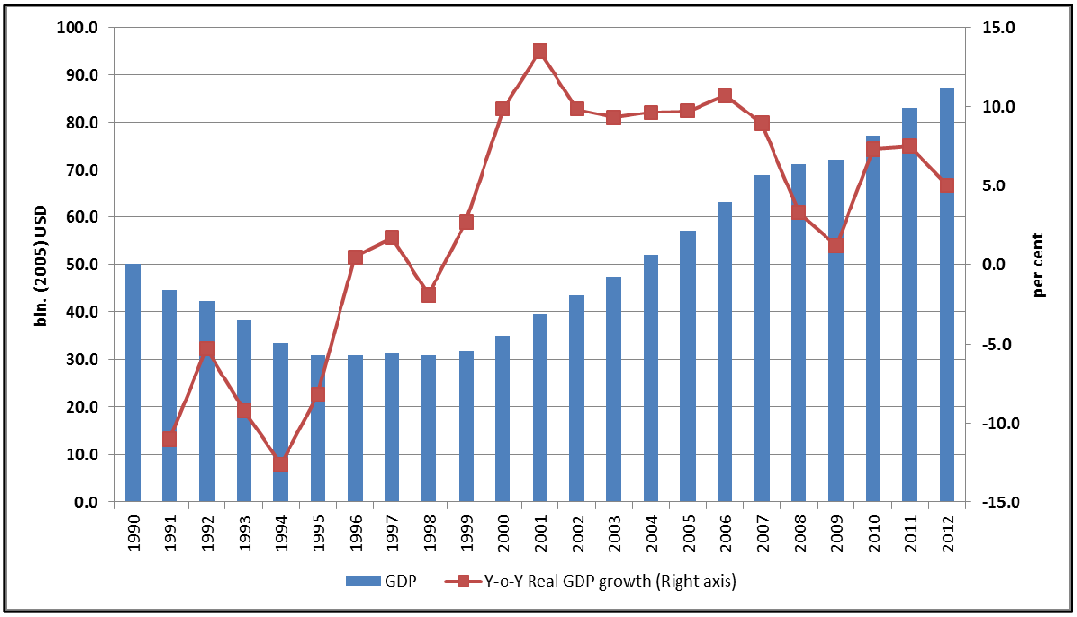
Kazakhstan owns large reserves of energy resources, which affects its economic performance and causes many environmental problems. The reserves are one of the largest among the former Soviet countries. Together with other mineral reserves the energy reserves are the basis of extractive economy of Kazakhstan. Oil-dependence makes Kazakh economy vulnerable to world oil market. This affects both short- and long-term economic growth and development of the country. Economic diversification is a key to overcome resource dependence of Kazakh economy.

While revenue from export of hydrocarbons is a basis of economic growth, coal consumption is a primary domestic fuel. Policies and initiatives in Kazakhstan, aimed at reducing environmental burden and promoting renewable energy technologies, primarily focus on recent commitments to reduce greenhouse gases (GHG) emissions and the upcoming EXPO 2017 [56]. This combination creates an incompatibility between expansions of the coal production and attempts to meet the emissions reduction target. Both reduction of the coal dependency and promotion of green energy are not only necessary to fulfill the GHG commitment, but also vital to health and well-being of the nation. Currently, coal is the cheapest fuel in Kazakhstan, and therefore the most attractive for both industrial and residential users. However, the health costs associated with the use of coal are often unseen, and if these costs are accounted for, coal becomes an expensive fuel. Therefore, Kazakhstan has to define energy strategy that departs from excessive dependence on coal consumption.

In order to develop the effective policy that contributes to diversification of Kazakh economy, while reducing its environmental impact, it is important to study the structure of the economy, energy and related environmental problems. This chapter aims to help to define the policy based on the relationship of the factors.

3.1 Economy of Kazakhstan

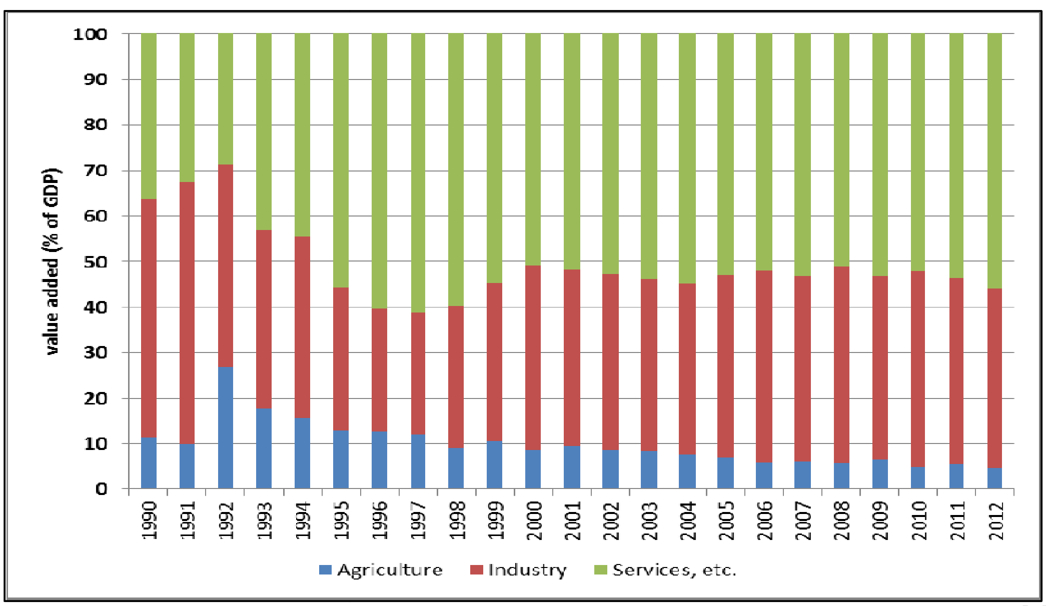
The size of Kazakh economy is the largest in Central Asia. The economic performance of the country was affected by major political change and favorable commodity prices. The dissolution of the Soviet Union led to a massive economic downturn due to massive disruption of production as indicated in Figure 3.1. Almost 40% real GDP decline (4.8% annually) was recorded from 1990 till 1999. Combination of strategies towards a market-based economy, development of major oilfields and the commodity boom led to double-digit GDP growth since 2000. From 2000 till 2007 Kazakh GDP almost doubled in size. However, overreliance on commodity extraction and export made the economy of Kazakhstan vulnerable to commodity price shocks. For example, the global financial crisis of 2008-2009 slowed down economic output of the country. Economic growth of Kazakhstan has been significantly slower than in pre-"Lehman Shock" period, possibly indicating economic stagnation.



Source: World Bank [7]

Figure 3.1 Year-over-year GDP growth in Kazakhstan

The transition process has been accompanied by major disruption of production and significant changes in the structure of Kazakh GDP as seen in Figure 3.2. As shown, it is likely that the economy of Kazakhstan has become more service-oriented. The value added by services and industry have increased by 165% and 21% respectively since 1990, while agricultural value added has declined by slightly more than 25%.



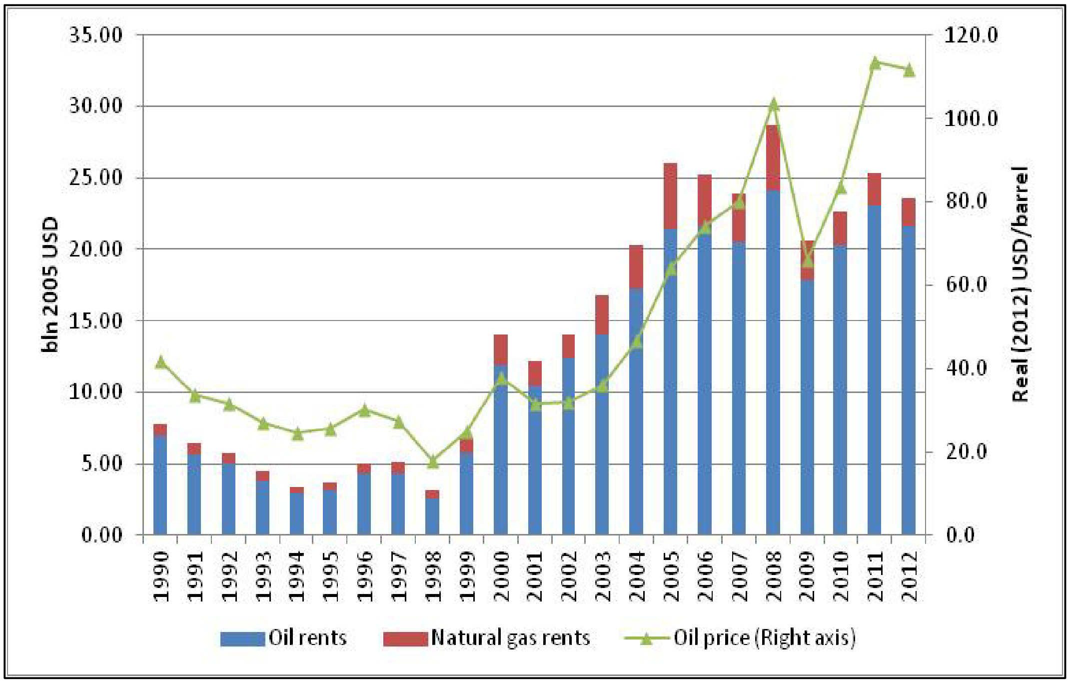
Source: World Bank [7]

Figure 3.2 The structure of GDP

Auty and Warhurst (1993) defined a mineral economy as economy which generates at least 10% of its GDP from mining and at least 40% of its foreign exchange earnings come from mineral exports [57]. Kazakhstan's economy easily qualifies as a mineral economy. Oil production and export allowed Kazakhstan to become the second largest economy in the Commonwealth of Independent States (CIS) after Russia. The republic was the first country among the former Soviet Union states to receive an investment credit rating [8]. The abundant resources of hydrocarbons and favorable laws to access its mineral reserves attracted far greater inflow of Foreign Direct Investment (FDI) than other former Soviet countries. Oil boom in Kazakhstan has helped to significantly decline the poverty and improve the living standards of population [58-59]. Furthermore, the resource income has lowered inequality in the republic [60].

Auty (1997) suggested that Kazakhstan's elite convinced to take oil-dependence path without preparing for negative effects of such strategy [61]. Strauss (2000) suggested that given the institutional setting of Kazakhstan, the republic was destined to suffer from natural resource curse phenomenon [62]. Similarly, Guriev et al. (2009) state that Kazakhstan entered oil boom with weak institutions and they have not significantly improved over time [63]. Moreover, Smith (2008) argues that Kazakh ruling elite has favored short-term economic growth fueled by oil and gas revenues over long-term economic development [64]. Furthermore, the study concludes that the elite are interested in prolonging the resource dependence as it directly benefits them. Esanov et al. (2001) suggest that despite its economic progress and positive changes in the policy, Kazakhstan's performance has been lower than its potential [65]. The resource dependence has negative effects on stability of government revenues based on resource rents and the financial system of the country.

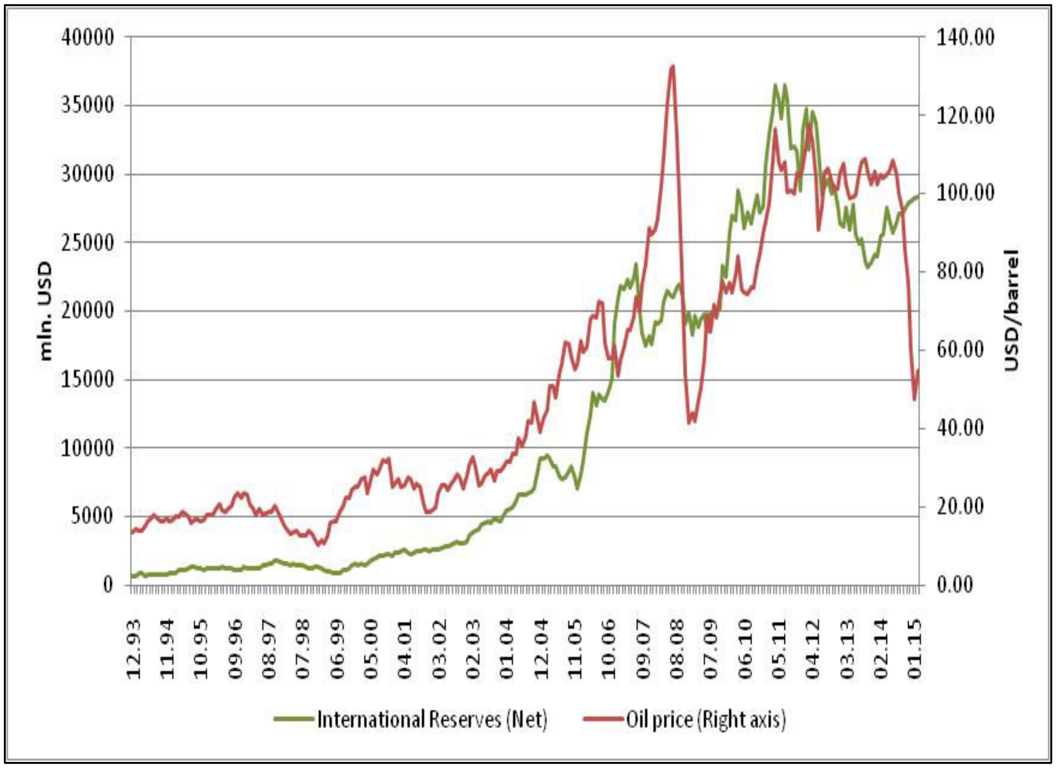
The oil revenues have become the backbone of Kazakhstan's economy. The scale of oil and natural gas revenues in Kazakhstan is the largest in Central Asia. The real volume of oil and natural gas revenues has increased by 205% since 1990, while oil rents consist 92% of total rents. The total volume of the rents in Kazakhstan is highly dependent on world oil price as shown in Figure 3.3.



Sources: World Bank [7] and IMF [66]

Figure 3.3 Volume of oil and natural gas rents in Kazakhstan

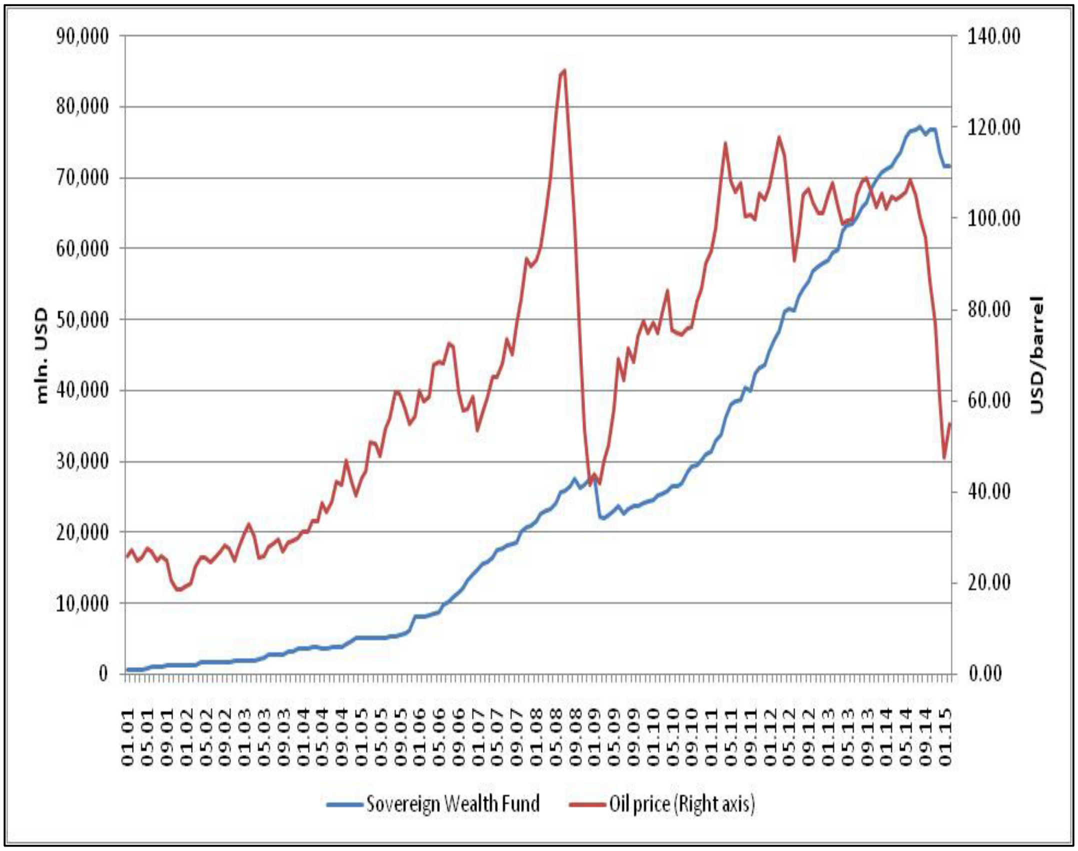
The volatility of world oil prices also produces large fluctuations in Kazakhstan's finances [45]. The net international reserves of Kazakhstan have increased by over 1,800% since 2000, when the world oil prices started climbing. The reserves have reached its maximum value in 2011, when the oil prices had a prolonged high period as presented in Figure 3.4. Until recently, the reserves have often been spent to keep the exchange rate of KZT fixed.



Sources: National Bank of Kazakhstan[67] and IMF [66]

Figure 3.4 International reserves of Kazakhstan (1993-2015)

Sovereign Wealth Fund (SWF) of Kazakhstan was established in 2000 to accumulate revenues from oil, gas and other commodity exports to allow the government of Kazakhstan to deal with revenue fluctuations. It functions as stabilization and a saving fund [68]. The volume of SWF is also susceptible to world oil fluctuations as displayed in Figure 3.5. It is likely that the funds are usually used to finance government budget deficits. However, the reports on accumulation and spending of SWF funds provided by the National Bank of Kazakhstan are general and do not provide details of transactions [68].



Sources: National Bank of Kazakhstan[67] and IMF [66]

Figure 3.5 Sovereign Wealth Fund of Kazakhstan (2001-2015)

It is likely that the lengthy period of low commodity prices will cause quicker depletion of the reserves without introduction of a flexible exchange rate in short-run and structural economic reforms in a long-run. Another important external factor that would affect the economy of Kazakhstan is the membership of the country in the Eurasian Economic Union (EEU). Devaluation of the Russian ruble needs to be matched by a devaluation of KZT in order to keep Kazakh producers to stay price competitive against Russian counterparts.

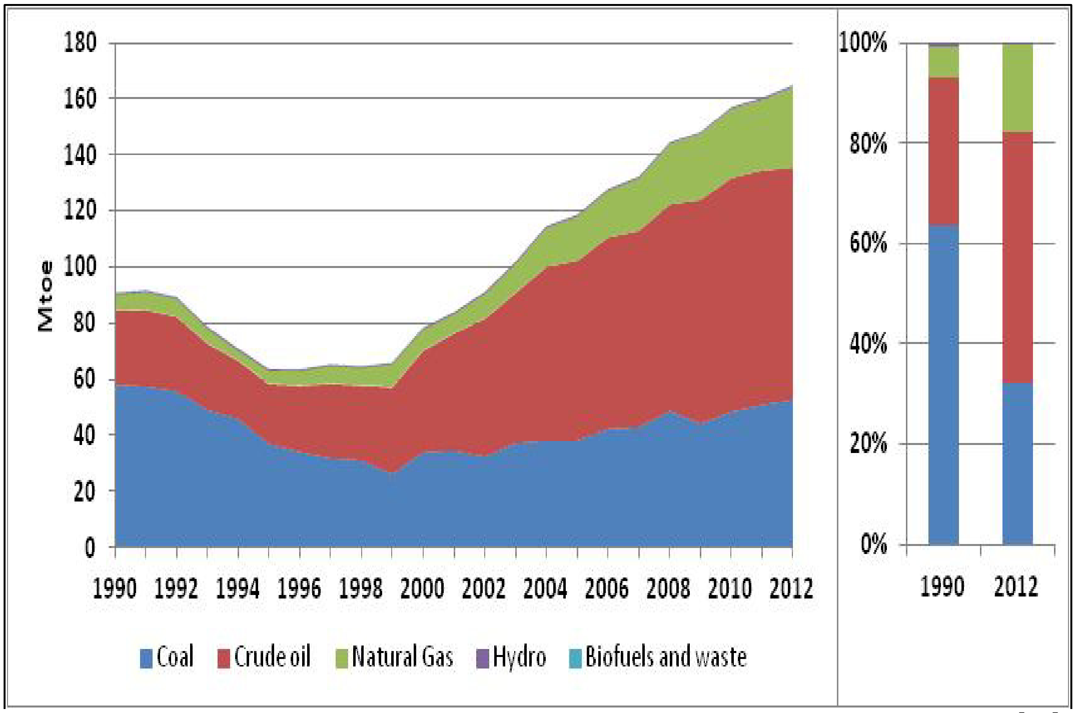
3.2 Energy System

Energy sector is the cornerstone of economic growth of Kazakhstan. Particularly export of hydrocarbons makes a vital contribution to the national income. Kazakhstan possesses large energy reserves. Energy production and export, particularly hydrocarbons, play significant role in economic growth of the country. Hence, energy investments are significantly higher than in other sectors.

It clear that the energy sector overall is a factor of production in the country. Hence, many of environmental problems Kazakhstan are likely to be a result of the fossil fuel dependence. The diverse environmental impacts are created during all stages of fossil fuel life cycle.

3.2.1 Fossil Fuel

Production, consumption and export of fossil fuel play important role in economic growth and energy security of Kazakhstan. Total energy production in Kazakhstan primarily consists of fossil fuel as indicated in Figure 3.6. The productions of crude oil and natural gas have increased by three and five times respectively, while coal production remained relatively unchanged.



Data source: IEA [22]

Figure 3.6 Total energy production in Kazakhstan

Enormous reserves of fossil fuel in combination with relatively stable political and investment climate allowed Kazakhstan to become one of the important players in the global energy market.

The dynamics of fossil fuel production and consumption could be divided into two major time periods:

- From 1990 to 1999 the setback period after the breakdown of the Soviet Union;
- From 2000 to 2014 the period of economic recovery based on boost in the natural resources export due to high prices on commodities, particularly energy sources.

The most significant growths are achieved in oil and natural gas production, while production of coal decreased for the period from 1990 to 2014 as presented in Table 3.1. Fossil fuel production and consumption have been on rise in the period 2000-2014.

Table 3.1 Fossil fuel production and consumption dynamics in Kazakhstan

Activity	Change 1990-2014, %	Change 1990-1999, %	Change 2000-2014, %
Oil production	213.4	16.8	128.9
Oil consumption	-39.7	-67.5	84.0
Oil export	1,497.8	444.4	140.1
Natural gas production	199.6	-4.1	149.6
Natural gas consumption	-53.5	-61.6	12.4
Natural gas export	137.5	73.8	406.3
Coal production	-18.4	-55.6	43.7
Coal consumption	-14.0	-50.6	48.9

Data Source: BP Statistical Review of World Energy 2015 [30]

3.2.2 Coal

Coal is the most exploited energy source in Kazakhstan and the key segment of national economy. Energy mix of Kazakhstan is dominated by coal, which mainly used in power generation and accounts for 39% of total primary energy demand [22]. Approximately 60% of the coal in Kazakhstan is used as the steam coal at the power plants, almost 15% of coal is used to heat space and water by residential sector and more than 20% of coal mined in Kazakhstan is exported to other countries, primarily to Russia and Kyrgyz Republic [69].

Kazakhstan possesses abundant resources of coal. Proved reserves of coal in Kazakhstan are 33.6 billion tons, which consist 3.8% of total world reserves. The reserves are sufficient for 309 years. The reserves of hard coal are 21.3 billion tons and the reserves of lignite are 12.3 billion tons [69]. The regional distribution of coal reserves is shown in Table 2.11. The main coal producing regions are Pavlodar and Karagandy.

Table 3.2 Regional distribution of recoverable and unrecoverable coal reserves in million tons

Region	Recoverable reserves	Share of total (%)	Non-recoverable reserves
Akmola	278.3	0.8	14.7
Aktobe	1,427.3	4.3	151.1
Almaty	936.9	2.8	9,975.3
Atyrau	-	-	-
East Kazakhstan	1,052.8	3.1	34.7
Zhambyl	6.6	0.0	0.9
West Kazakhstan	-	-	-
Karagandy	10,065.0	30.0	4,446.8
Kostanay	7,535.9	22.4	12,081.6
Kyzylorda	-	-	
Mangystau	-	-	42.6
Pavlodar	11,920.0	35.5	1,798.4
North Kazakhstan	-	-	-
South Kazakhstan	359.9	1.1	33.8
Total	**33,582.6**		**28,579.9**

Source: Concept of coal industry development in Kazakhstan until 2020 [69]

Better quality coal with higher calorific value from Kargandy and Shubarkol basins is utilized in metallurgy, while coal with low calorific value from Ekibastuz basin mostly used at power plants. Coal is primarily consumed for co-generation of electricity and heat at large scale State District Power Stations (SDPS), thermal power plants and boiler stations for district heating. Currently, around 80% of electricity is produced by combustion of coal [70]. Most of the SDPS plants are located in the close vicinity from the coal mines, mainly in the northern and central part of the country. Table 3.3 enlists major coal-fired power plants and type of coal used. The largest coal producers as well as the power plants are the structural units of large power and metallurgical companies.

Table 3.3 Type of coal consumed at major coal-fired power plants

Type of coal	Major power plants	Capacity, MW	Total capacity, MW	Share of total
Ekibastuz	Ekibastuz SDPS-1	4,000	9,975	85%
	Aksu Thermal Power Plant-1	2,100		
	Ekibastuz SDPS-2	1,000		
	Almaty thermal plant-2	510		
	Almaty thermal plant-3	360		
	Astana thermal plant-2	350		
	Karagandy thermal plant-3	395		
	Pavlodar thermal plant-1	350		
	Pavlodar thermal plant-3	440		
	Petropavl thermal plant-2	470		
Borly	Karagandy SDPS-2	660	957	8%
	Zhezkazgan thermal plant	177		
	Balkhash thermal plant	120		
Karagandy	Karagandy thermal plant 2	435	784	7%
	Ispat Karmet	204		
	Almaty thermal plant-1	145		

Source: Bukhman, 2003 [71]

Main problem of coal in Kazakhstan is its high ash content. This issue contributes to the coal-fired power plants' growing problem of stability of coal combustion and reliability of furnace as well as environmental impact [72]. The Table 3.4 shows that coal produced in Kazakhstan does not meet requirements for coal in the world market. The average ash content of coke sold on world market is 7-8% and coal is 10-14% [70]. Due to its inferior quality the Kazakh coal makes is mainly consumed at domestic power plants.

Table 3.4 Characteristics of coal produced in Kazakhstan

Basins	Average ash content, %	Average calorific value, kcal/kg of coal equivalent
Karagandy	29.5	5,200
Karagandy coke	24.0	5,700
Shubarkol	21,7	4,693
Kuu-chekin	41.0	4,260
Borly	46,0	3,472
Ekibastuz	42.0-44.0	3,830-4,060
Maikobe	22.4	4,057
Kazhyra	20.4	4,438

Source: Yesentugelova et al., 2003 [73]

Due to geology of the deposits, surface (open cast) mining is a main method of extraction in Kazakhstan [74]. Therefore, coal remains the cheapest energy source. The cost of 1 ton of coal consumed for the power production consists 5-15 US dollars (USD) [75]. Due to high cost of natural gas (2-2.5 times than coal), the energy industry will be oriented towards the use of domestic coal.

The biggest emissions in Kazakhstan are due to energy activities, and coal combustion is the main contributing factor. Apart from combustion process, fugitive leakage of methane from coal mining (underground and surface) is another environmental impact of coal industry. Furthermore, coal-fired power plants generate non-combustible waste which causes water and soil contamination. The environmental effects of coal consumption and production could have long-term negative effect on the human health in Kazakhstan.

Coal mines are usually the part of integration organizations that also operate power plants and produces metals [76]. Hence, often the environmental impacts and costs of production are not transparent. It also affects the tariff calculation for coal-fired thermal power plants.

3.2.3 Crude Oil and Natural Gas

The hydrocarbons sector is the driving force of Kazakh economic growth. The reserves of hydrocarbons in Kazakhstan are among the biggest in the world. The state balance of hydrocarbon reserves consists of 256 deposits, including 236 oilfields, 64 gas condensate deposits and 213 natural gas deposits [31]. However, the reserves are unevenly distributed. The main production areas of hydrocarbons are in the west and northwest of the country, geographically distant from the major demand centers in the south.

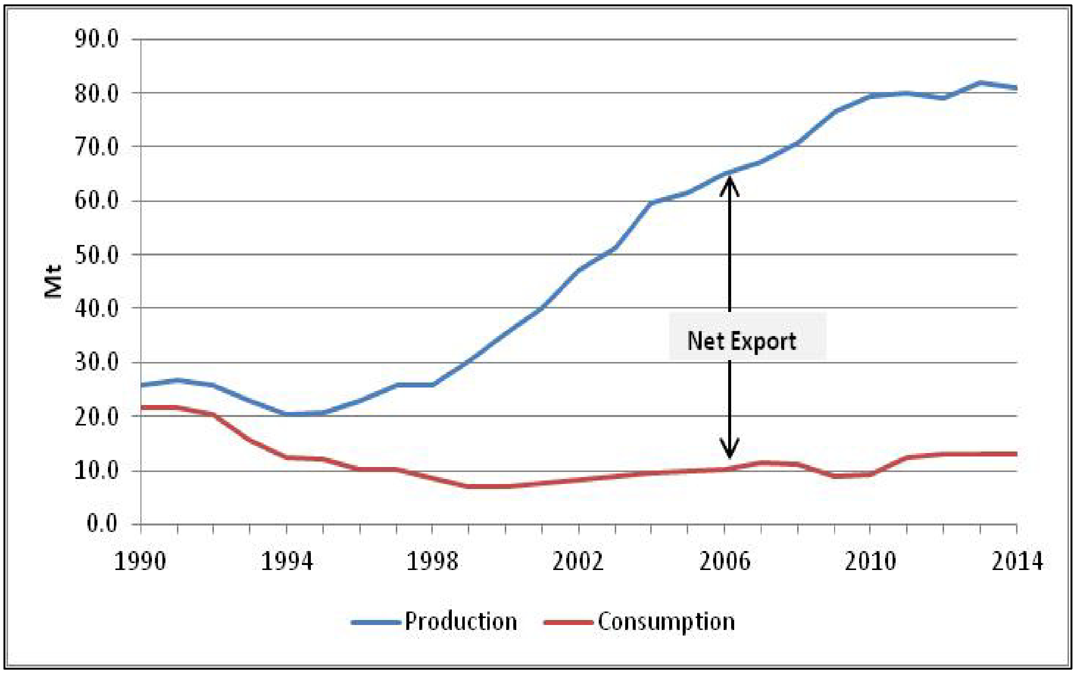
Table 3.5 indicates production of hydrocarbons in Kazakhstan in 2014. The leading crude oil producing regions are Atyrau, Mangystau, Kyzylorda and Aktobe. Majority of natural gas reserves are associated with oil. Additionally, gas in Kazakhstan is sour and, therefore, requires expensive processing. Hence, the priority is given to production of liquid hydrocarbons over gas. The main volume of natural gas, including condensate, is produced in West Kazakhstan, Atyrau and Aktobe.

Table 3.5 Production of oil, natural gas and condensate in 2014

Region	Oil			Natural Gas			Condensate		
	Number of Fields	kilotons	Share of total (%)	Number of Fields	billion m^3	Share of total (%)	Number of Fields	thousand tons	Share of total (%)
Akmola	-	-	-	-	-	-	-	-	-
Aktobe	35	7,266.4	10.7	29	4,495.2	10.3	7	86.5	0.7
Almaty	-	-	-	-	-	-	-	-	-
Atyrau	98	31,943.2	47.0	59	14,786.7	34.0	6	-	-
East Kazakhstan	1	0.8	0.0	1	419.6	1.0	-	-	-
Zhambyl	-	-	-	4	327.8	0.8	2	20.7	0.2
West Kazakhstan	10	283.8	0.4	13	19,906.4	45.8	12	12,777.2	98.9
Karagandy	10	0.0	0.0	12	0.0	0.0	3	-	-
Kostanay	-	-	-	-	-	-	-	-	-
Kyzylorda	23	9,919.8	14.6	25	1,476.0	3.4	8	0.0	0.0
Mangystau	59	18,493.7	27.2	68	2,026.1	4.7	26	33.5	0.3
Pavlodar	-	-	-	-	-	-	-	-	-
North Kazakhstan	-	-	-	-	-	-	-	-	-
South Kazakhstan	-	-	-	2	-	-	-	-	-
Total	**236**	**67,907.7**		**213**	**43,437.8**		**64**	**12,917.9**	

Source: Djanturaeva [78] and the Committee on Statistics [6]

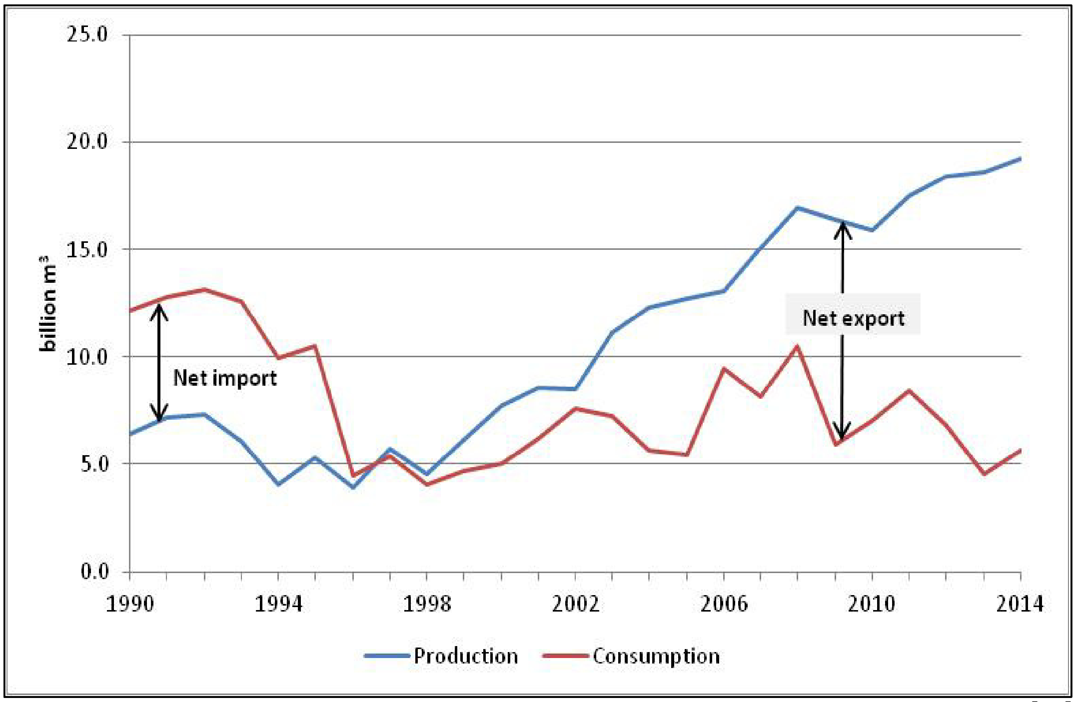
Production and export of crude oil is the main source of economic growth in the country. Figure 3.7 shows the growth of crude oil export in Kazakhstan. The faster growth of net export is observed from year 2000 due to high oil price in the world market. However, the limited access to international markets is the main restraining factor to rapid export growth. Almost 80% of produced crude oil is exported, while the rest is used for energy transformation domestically [22]



Data Source: BP Statistical Review of World Energy 2015 [30]

Figure 3.7 Production, consumption and net export of crude oil

Kazakhstan has transformed from net importer to net exporter of natural gas as seen in Figure 3.8. Due to growing domestic demand for natural gas, Kazakh government's aspiration is to reduce its dependence on gas imports by development of domestic gas fields and prohibiting associate gas flaring. Almost 20% of total natural gas production is exported, while the rest used domestically. According to World Energy Outlook 2010 [79], Kazakhstan will outplace domestic consumption and emerge as a major gas producer with output reaching almost 70 billion m^3 by 2035. Additionally, the use of natural gas to replace coal in power generation is seen as a way to meet Kazakhstan's emissions reduction goals.



Source: BP Statistical Review of World Energy 2015 [30]

Figure 3.8 Production, consumption, net import and net export of natural gas

The hydrocarbons production has enormous environmental impact, including problems of sulfur disposal, flaring of associated petroleum gas and oil spills, especially during offshore operations. In addition to environmental issues, the rising share of foreign investments in the oil and gas sector of Kazakhstan has created the growth of capital outflow from the country. The cost of oil production is about 20% of the world market price, taxes are 15-20% of gross income, and the administrative costs are 15%. After taking into account these expenses the foreign companies enjoy staggering annual net profit of over 100 billion USD – the capital that easily flows out of the country. Furthermore, under the product sharing agreement the profit share of Kazakhstan has decreased from 35% to 20%, and the share of the foreign contractors has increased from 65% to 80% [78]. This situation clearly calls for a new development of oil and gas sector that will promote competiveness and assure national security.

The oil and gas industry has emerged as the locomotive of Kazakh economy. Hence, ensuring the security of oil revenue, the bloodline for economic growth, has become the main task for the government of Kazakhstan. Therefore, there is a need to understand the relationship between energy use, economic growth and resulting environmental degradation in order to develop the effective policies.

3.3 Environmental Problems in Kazakhstan

Kazakhstan has a long history of environmental problems. The long-term environmental issues include radiation effects of Semipalatinsk nuclear test site, where the Soviet Union conducted 456 nuclear tests from 1949 till 1989 and the shrinking Aral Sea. Both turned into the environmental health disasters and drew attention of the researchers around the world [80-88]

The changes in air temperature accompanied with decrease in precipitation indicate Kazakhstan's vulnerability to climate change [89]. Furthermore, the evidence of climate change seems to be higher in urban areas [90]. Kazakhstan has been taking active role in combating climate change by working towards becoming Annex I country in the Kyoto and post-Kyoto Protocol regime [91]. Currently Kazakhstan is the non-Annex I party to the United Nations Framework Convention on Climate Change (UNFCCC). Quantified Emission Limitation or Reduction Objectives (QELROs) committed by Kazakhstan is 93% of 1990 base level by 2020 in Annex B of the Kyoto Protocol for the second commitment period [24].

About 5 million people in Kazakhstan live in an area with polluted air, and the cost of health damage from the air pollution reaches 70.8 USD per person, or 76.2 USD per ton of air pollutant [92]. The major source of the air pollution in Kazakhstan is the energy sector, which is primarily fuelled by coal. Coal is the most abundant fossil fuel on Earth, and Kazakhstan's reserves make up almost 4% of the world`s total coal reserves [30].

Like other fossil fuel rich countries, Kazakhstan is vulnerable to the phenomenon of "carbon curse". The curse states that fossil fuel rich countries tend to be more carbon-intense [93]. In order to overcome to make Kazakh economy less carbon-intense, there is a need to understand the relationship between economic growth, energy use and resulting CO_2 emissions.

3.4 Modeling CO_2 Emissions, Energy Use, and Economic Growth

In the light of Kazakhstan's commitment to reduce its CO_2 emissions as wells as develop the green economy, the country has to reconsider policies and strategies in order to meet the desirable target. An effective policy addressing economic growth, energy use and resulting environmental issues is not possible without analysis of relationship between the aforementioned factors.

Main research strand on the relationship between economic growth and environmental pollutants is focused on testing the validity of environmental Kuznets curve (EKC) hypothesis, which proposes an inverted U-shape relationship between the level of environmental degradation and economic growth [94]. EKC hypothesis states that during the early stages of economic growth, environmental degradation increases, but beyond some level of income the trend reverses, so that at high income levels economic growth leads to environmental improvement in developed countries [95].

Emerging economies often specialize in the production of goods that are labor and natural resources intensive. Therefore, the EKC hypothesis is problematic for developing countries where income level is generally below the turning point supposed by the hypothesis. The method aims to examine if the higher economic growth converts into greater efforts to reduce emissions [96].

3.4.1 Methodology

Following the empirical literature in energy econometrics, the long-term relationship between CO_2 emissions, energy consumption and real GDP, with a view to testing of the EKC hypothesis, is specified as follows:

$$LCO_t = \beta_0 + \beta_1 LE_t + \beta_2 LGDP_t + \beta_3 LGDP_t^2 + u_t \quad (3.1)$$

where LCO_t, LE_t and $LGDP_t$ represent natural logarithms of CO_2 emissions, energy use and real GDP for year t, respectively. Given the variables are in natural logarithms, the parameters β_1, β_2 and β_3 represent the long-run elasticity estimates and u_t is an error term. Under the EKC hypothesis, the signs of β_1 and β_2 are expected to be positive, while β_3 is negative to reflect the inverted U-shape pattern. Pao et al. (2011) [96] suggested using the nested linear models with variance inflation factor (VIF) [97], adjusted R^2 and Jarque and Bera (JB) statistics [98] to avoid overestimating the importance of the independent variables and multicollinearity as following:

$$LCO_t = \begin{cases} a_1 + b_1 LE_t + u_t & \text{(I)} \\ a_2 + b_2 LGDP_t + u_t & \text{(II)} \\ a_3 + b_3 LGDP_t + c_3 LGDP_t^2 + u_t & \text{(III)} \\ a_4 + b_4 LE_t + c_4 LGDP_t + d_4 LGDP_t^2 + u_t & \text{(IV)} \\ a_5 + b_5 LE_t + c_5 LGDP_t + u_t & \text{(V)} \end{cases} \tag{3.2}$$

If $LGDP_t^2$ is not included, it indicates a monotonic relationship between CO_2 emissions and GDP growth, when energy use does not change.

Once the appropriate models are selected, the presence of Granger causality among the variables is tested using the Vector Error Correction Model (VECM) and Vector Autoregressive (VAR) models. The analysis includes the following steps:

a) The order of the integration of the variables is viable if the variables under investigation are of the same order of co-integration. The Augmented-Dickey-Fuller (ADF) test is used for a presence of unit root of the variables [99]:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \delta_{o-1} \Delta y_{t-p+1} + \varepsilon_t \tag{3.3}$$

where α is a constant, β is a time trend coefficient and p is the lag order of the autoregressive process defined by the Akaike's Information Criterion (AIC). The unit root is tested under the null hypothesis $\gamma = 0$ based on the Dickey-Fuller test statistic:

$$DF_\tau = \frac{\hat{\gamma}}{SE(\hat{\gamma})} \tag{3.4}$$

b) If all of the variables are integrated at the same order, the Johansen maximum likelihood method [100] is utilized to test the presence of the co-integration between the variables. The presence of co-integration indicates the Granger causality at least in one direction [101]

c) If the co-integration of the variables exists, the VECM is used to test for presence and directions of long- and short-run causality among co-integrated variables [96]:

$$\Delta LCO_t = \gamma_{10} + \sum_{i=1}^{m_1} \gamma_{11i} \Delta LCO_{t-i} + \sum_{i=1}^{n_1} \gamma_{12i} \Delta LGDP_{t-i} + \sum_{i=1}^{k_1} \gamma_{13i} \Delta LE_{t-i} + \delta_1 ECT_{t-1} + \mu_{1t} \tag{3.5}$$

$$\Delta LE_t = \gamma_{20} + \sum_{i=1}^{m_2} \gamma_{21i} \Delta LCO_{t-i} + \sum_{i=1}^{n_2} \gamma_{22i} \Delta LGDP_{t-i} + \sum_{i=1}^{k_3} \gamma_{23i} \Delta LE_{t-i} + \delta_2 ECT_{t-1} + \mu_{2t} \tag{3.6}$$

$$\Delta LGDP = \gamma_{30} + \sum_{i=1}^{m_3} \gamma_{31i} \Delta LCO_{t-i} + \sum_{i=1}^{n_3} \gamma_{32i} \Delta LGDP_{t-i} + \sum_{i=1}^{k_3} \gamma_{33i} \Delta LE_{t-i} +$$

$$\delta_3 ECT_{t-1} + \mu_{3t} \quad (3.7)$$

where:

$$ECT_{t-1} = LCO_{t-1} - \alpha_0 - \alpha_1 LE_{t-1} - \alpha_2 LGDP_{t-1} \quad (3.8)$$

The sign Δ is the first-difference operator; m_i, n_i and k_i are the optimum lag lengths determined by the AIC process [102]; μ_{it} are the serially uncorrelated error terms; δ_1, δ_2 and δ_3 are the speeds of return to equilibrium of the variables *LCO*, *LE* and *LGDP* respectively when the long-run equilibrium is violated. The short-run causality from *LGDP to LCO* exists if the results of a Wald test reject the joint null hypothesis H_0:γ_{12i}=0; the causality runs in other direction (from *LCO* to *LGDP*) if the H_0:γ_{31i}=0 is rejected. *LCO* responds to the long-run disequilibrium if H_0:δ_1 is rejected, indicating the long-run causality. The strong long-run Granger causality from *LGDP to LCO* exists if H_0:γ_{12i}=δ_1 =0 is rejected. Similar logic applies to other variables of the model.

If the variables have no common stochastic trend, the VAR model is the most convenient model to identify the presence and directions of Granger causality. Unlike the VECM, the VAR model does not provide the long- and short-run causality. A bivariate VAR model is defined as follows [103]:

$$\Delta LCO_t = \varepsilon_{10} + \sum_{i=1}^{m_1} \vartheta_{11i} \Delta LCO_{t-i} + \sum_{i=1}^{n_1} \vartheta_{12i} \Delta LE_{t-i} + \tau_{1t} \quad (3.9)$$
$$\Delta LE_t = \varepsilon_{20} + \sum_{i=1}^{m_2} \vartheta_{21i} \Delta LCO_{t-i} + \sum_{i=1}^{n_2} \vartheta_{22i} \Delta LE_{t-i} + \tau_{2t} \quad (3.10)$$

Where ε and ϑ are estimation parameters and τ is an error term. The null hypothesis to test Granger causality running from the variable LE to LCO is H_0: ϑ_{12i} = 0. If H_0 rejected, meaning that at least one of ϑ_{12i} is not equal to zero, it means that LE Granger causes LCO. Equation (3.10) is used to define if LCO Granger causes LE.

d) Lastly, the qualities of the VECM and VAR models are tested. The VECM model is inspected for the presence of serial correlation, heteroskedasticity, normality and overall diagnostics of the model. Furthermore, the consistency of the parameters of the VECM model by using the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests [104]. The VAR model is diagnosed for the presence of autocorrelation, residual normality and the impulse response.

3.4.2 Data

Annual data of CO_2 emissions, energy use and real GDP from 1990 to 2012 is collected. The data source of energy use (kilotons of oil equivalent) and real GDP (billion 2005 US dollars) is World Development Indicator (WDI) [7]. CO_2 emissions in kilotons (kt) from GHG inventory submitted to United Nations Framework Convention on Climate Change (UNFCCC) [105]. Friedl and Getzer (2003) [106] argue that the Kyoto Protocol calls for a reduction in the percentage of emissions and suggest the use of total, rather than per capita, emissions. For modeling purposes, all data was converted into natural logarithms and the results can be interpreted in growth terms. The descriptive statistics of the variables are provided in Table 3.6.

Table 3.6 Descriptive statistics of the variables

Statistics	GDP, bln (2005) USD	Energy use, ktoe	CO_2, Mt
Mean	50.6	56.5	168.5
Standard Deviation (SD)	18.3	15.2	44.7
Median	44.7	58.1	164.1
Max	87.2	78.8	260.2
Min	30.8	34.5	91.4

Figure 3.9 indicates that the trends of the series decline from 1992 and begin to rise from 2000. Table 3.7 shows growth rates in percentage for different time periods.

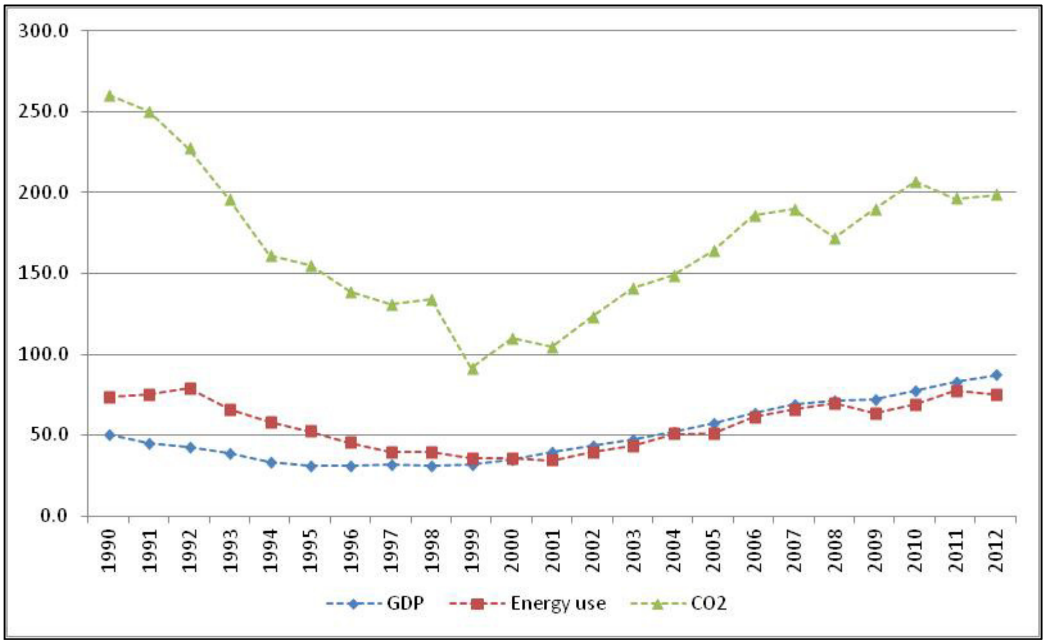


Figure 3.9 Time series plot of CO_2 emissions, energy use and real GDP

Table 3.7 Growth rates in percentage for each variable

Period	CO_2 Emissions	Energy Use	GDP
1990-2012	-23.67	1.91	73.54
1990-1999	-64.88	-51.09	-36.77
2000-2012	80.41	109.80	149.97

After the breakup of the Soviet Union in 1991, the demand for industrial products sharply dropped causing decline in GDP, energy use and GHG emissions. Economy of Kazakhstan has been experiencing significant growth since the beginning of 21st century due to combination of natural resources export, high prices on commodities and attractive foreign investment climate in the country. As a result of booming economy, energy use and thusly environmental degradation have grown consequently.

Table 3.8 Coefficients of Equation (3.2)

	Independent variables							
Model	LE	LGDP	$LGDP^2$	Intercept	R^2	Adj. R^2	JB	p-value
(3.2-I)	1.438*** (12.851)			1.438*** (5.044)	0.887	0.882	0.193	0.908
(3.2-II)		0.427*** (3.006)		3.441 (6.240)	0.301	0.268	0.794	0.672
(3.2-III)		4.235 (1.050)	-0.487 (-0.945)	-3.944 (-0.503)	0.331	0.264	0.443	0.801
(3.2-IV)	0.981*** (11.579) [1.745]	3.181** (2.179) [803.094]	-0.418** (-2.243) [800.793]	-4.835* (-1.707)	0.917	0.904	0.431	0.806
(3.2-V)	0.988*** (10.634) [1.744]	-0.090 (-1.214) [1.744]		1.493*** (5.229)	0.895	0.884	0.402	0.818

Note: Figures in parenthesis indicate *t*-statistics. Figures in brackets are VIF.
*, ** and *** indicate the rejection of a null hypothesis at 10%, 5% and 1% level of significance.

3.4.3 Empirical Findings

The results of the empirical analysis are presented in Table 3.8. The main findings are:

1) The values of VIF and JB statistics indicate that including $LGDP^2$ is not desirable;
2) The results do not support EKC hypothesis and indicate a monotonic decrease relationship between LCO emissions and economic output (LGDP), when energy use (LE) does not change;
3) Energy use has greater impact on CO_2 emissions than economic output. Energy use effect on CO_2 emissions reaches 88.7% (R^2), while economic output affect emissions reaching only 30.1%;
4) The results of analysis indicate that 1% increase in energy use increases CO_2 emissions by 0.988% when GDP does not change;
5) 1% increase in real economic output decreases CO_2 emissions by 0.09% when energy use does not change;
6) Based on the results of the analysis it is concluded that CO_2 emissions appear to be energy use elastic and GDP inelastic in Kazakhstan.

The results of unit root test indicate that the series appear to contain a unit root at levels, but stationary in their first difference, indicating that they are integrated at order one i.e. *I(1)* as displayed in Table 3.9.

Table 3.9 Results of ADF unit root test

Variable	Level	1st difference
LCO	-0.522	-4.379***
LE	-0.216	-1.967**
LGDP	-2.304	-2.724*

Note: *, ** and *** indicate that the null hypothesis is rejected at 10%, 5% and 1% level respectively. The optimal lag lengths are selected using AIC.

The results of Johansen's co-integration test of model (3.2-V) indicate that the variables are co-integrated as shown in Table 3.10. The presence of co-integration among the variables indicates that Granger causality exists at least in one direction.

Table 3.10 Results of Johansen's co-integration test of model (3.2-V)

Variables: LCO, LE and LGDP					
Eigenvalue	Trace Statistic	5% critical value	Max. Eigen Statistic	5% critical value	Number of co-integration
0.946	44.562**	29.797	29.506**	21.131	None
0.464	15.056	15.495	13.104	14.265	At most 1
0.089	1.952	3.841	1.952	3.841	At most 2

Note: The optimal lag lengths are selected using AIC. ** indicates the rejection of a null hypothesis at 5% level of significance.

However, the results of Johansen's co-integration test of model (3.2-V) do not indicate the presence of co-integration among the variables as displayed in Appendix II. Hence, the VECM model is not suitable for testing Granger causality in the model (3.2-V). The VAR model is applicable for the purpose instead.

The short-run and joint short- and long run F-statistics and long-run t-statistics are for equations (3.5-3.8) are reported in Table 3.11. The estimated coefficients for one period of lagged ECT are not negative for ΔLCO and ΔLE and statistically insignificant. This indicates that the ECT is not important in adjustment to equilibrium. There are signs of unidirectional short-run causality running from economic output to CO_2 emissions and from CO_2 emissions to energy use. However, low R^2 (41%) of the model, the fact that the residuals are not normally distributed and CUSUM and CUSUMSQ statistics of *LGDP* and *LCO* are off the critical bounds may indicate that the results of the VECM model may not be suitable to define the Granger causality among the variables. The results of the diagnostics of the VECM model are presented in Appendix II.

Table 3.11 Results of the VECM model

Dependent variables	Source of causation						
	Short-run *F*-statistics			Long-run *t*-statistics	Joint short-run and long-run *F*-statistics		
	ΔLCO	ΔLE	ΔLGDP	ECT	ΔLCO/ ECT	ΔLE/ ECT	ΔLGDP/ ECT
ΔLCO		0.842	7.187*	0.072		0.028	4.850*
ΔLE	6.036*		0.639	4.857	27.310**		18.415**
ΔLGDP	0.249	0.399		-0.026	0.275	0.206	

Note. The optimal lag length is one. ** and * indicate 1% and 5% level of significance respectively.

The results of Granger causality test using the VAR model for the model (3.2-I) are presented in Table 3.12. The outcome indicates the presence of the bidirectional causality between energy use and CO_2 emissions in Kazakhstan. The diagnostic tests of the VAR model indicate that residuals are multivariate normal, the absence of autocorrelation and the impulse responses to Cholesky 1% shock are well within the critical boundaries as presented in Appendix II.

Table 3.12 Results of the VAR model

Null hypothesis	Wald test statistics	
	χ^2	p-value
LE≠>LCO	19.824	0.000***
LCO≠>LE	11.301	0.046**

Note. *** and ** indicates the rejection of a null hypothesis at 1% and 5% level of significance respectively.

The dynamic relationship between CO_2 emissions, energy use and real GDP is described by equation (3.2) declining EKC hypothesis. This contradicts the results of Apergis and Payne study (2009) [107], which report an inverted U-shaped relationship between per capita emissions and per capita real GDP for the Commonwealth of Independent States (CIS) as a whole. However, it agrees with results of Pao et al. (2011) [96] for Russian Federation, the country which in overall faces similar economic and environmental issues. Furthermore, the results of the empirical analysis suggest that the model (3.2-I) could be a suitable model to test the presence of Granger causality between CO_2 emissions and energy use.

Clearly, existing strategies and the absence of adequate mitigation measures will lead to further direct and indirect environmental degradation. Furthermore, existing efforts directed towards energy efficiency and development of renewable energy will have a limited effect on overall situation [108]. Therefore, stricter GHG mitigation measures have to be adopted and existing policies addressing improvement of energy efficiency and development of renewable energy have to be actively expanded. A coordination framework between the state agencies responsible for designing and implementing development plans and national climate change commitments has to be developed.

The absence of the Granger causality between GDP and CO_2 emissions could be explained by the fact that the main source of the national income in Kazakhstan is the oil revenue. The presence of bidirectional causality between energy use and CO_2 emissions indicates that the policies energy efficiency and energy saving would cause reduction of CO_2 emissions and vice-versa. Furthermore, it is likely that such measures will not hinder economic growth of Kazakhstan.

The economy of Kazakhstan is most likely to be affected by resource curse, when the economies with abundant natural resources tend to develop worse than countries with fewer natural resources. Among the negative effects of resource dependence, the effects of the Dutch disease have the biggest impact on Kazakh economy. The phenomenon causes decline in manufacturing and agricultural sectors due to a boom in a natural resource sector of the country [45]. It is likely that the Dutch disease also contributes to environmental degradation. Hence, it is important to study the mechanisms of the Dutch disease in Kazakhstan.

3.5 The Dutch Disease in Kazakhstan

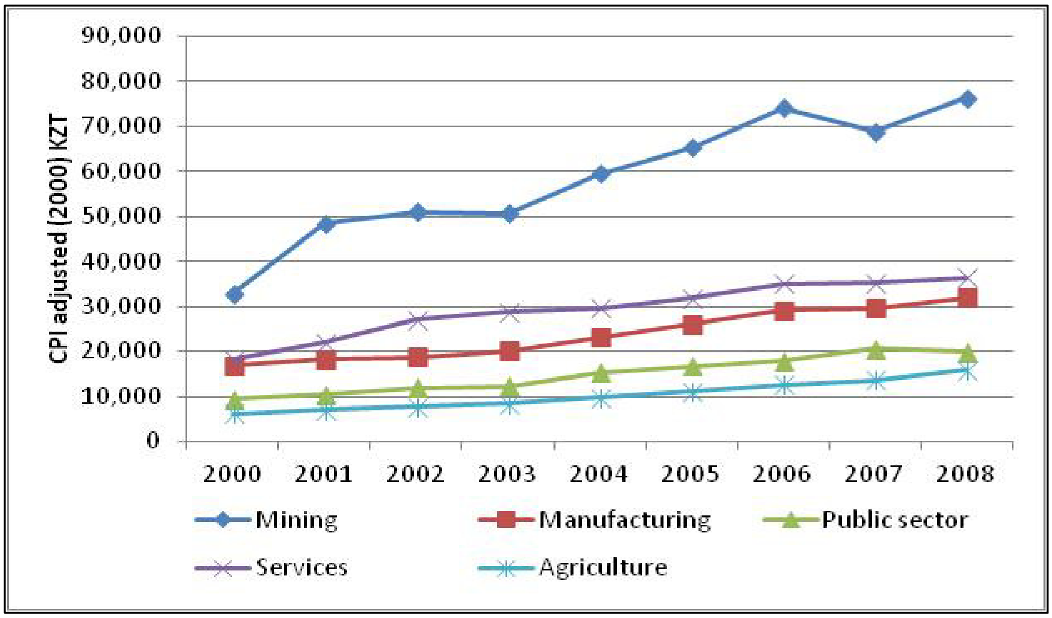
An abundance of natural resources offers vast opportunities for development of the country. Nonetheless, a number of studies suggested that commodity-rich countries tend to perform worse economically in the long-run than countries with limited natural resources [16, 57-62]. This is because the rise in international commodity prices leads to structural changes in country`s trade profile towards dominance of natural resources export. Consequently, the economy becomes less diverse due to structural industrial changes triggered by natural resources boom and more volatile to commodity price fluctuations [112].

In 1977, the Economist coined the term “Dutch disease” to describe the decline of the manufacturing sector in the Netherland after the discovery of a large natural gas field [113]. The Dutch disease implies a causal relationship between the increase in the natural resources sector and a decline in non-commodity sectors (manufacturing and agriculture). There are two major effects that cause a decline in non-commodity sectors [45, 114-115]:

- Capital and labor sources tend to shift from these sectors to the booming sector;
- The foreign currency inflow from commodity exports leads to appreciation of domestic currency, making the non-commodity sectors less price competitive on the export market.

This process leads to higher levels of cheap imports, triggering deindustrialization as the non-commodity industries decline due to capital and labor outflow from manufacturing industries and agriculture to the mineral sectors. Furthermore, it is likely that effects of the phenomenon are more severe in developing countries than in advanced economies due to the technological gap [116]. The Dutch disease remains an important problem for commodity-based economies, like Kazakhstan, and it is crucial to minimize its negative effects.

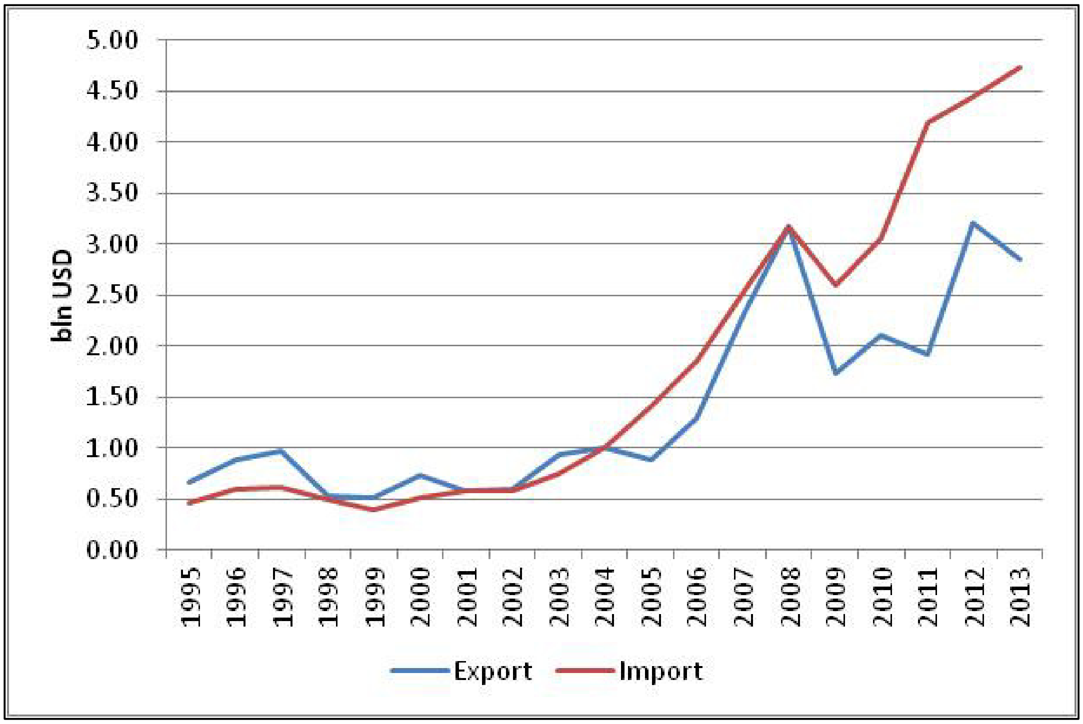
Oil boom caused a significant gap between salaries in different industries in Kazakhstan. The salaries in mining industries are significantly higher than in other sectors, while the salaries in agriculture are the lowest as seen in Figure 3.10. Hence, the mining sectors attract the best talents from other industries.



Source: the Committee on Statistics [6]

Figure 3.10 Average salaries in different industries

While the decline of the manufacturing sector of Kazakhstan was inevitable straight after the collapse of the USSR due to its obsolete technological level, poor product line-up and the low quality of good offered, decline in agricultural and food processing sectors was caused by bad policies, lack of support of producers and possibly the effects of the Dutch disease. As a result, the real agricultural output has slumped more than four times since 1990. Subsequently, Kazakhstan has transformed from exporting country to agricultural import country, raising the issue of food security as seen below:



Source: WTO [117]

Figure 3.11 Balance of trade of agricultural products in Kazakhstan

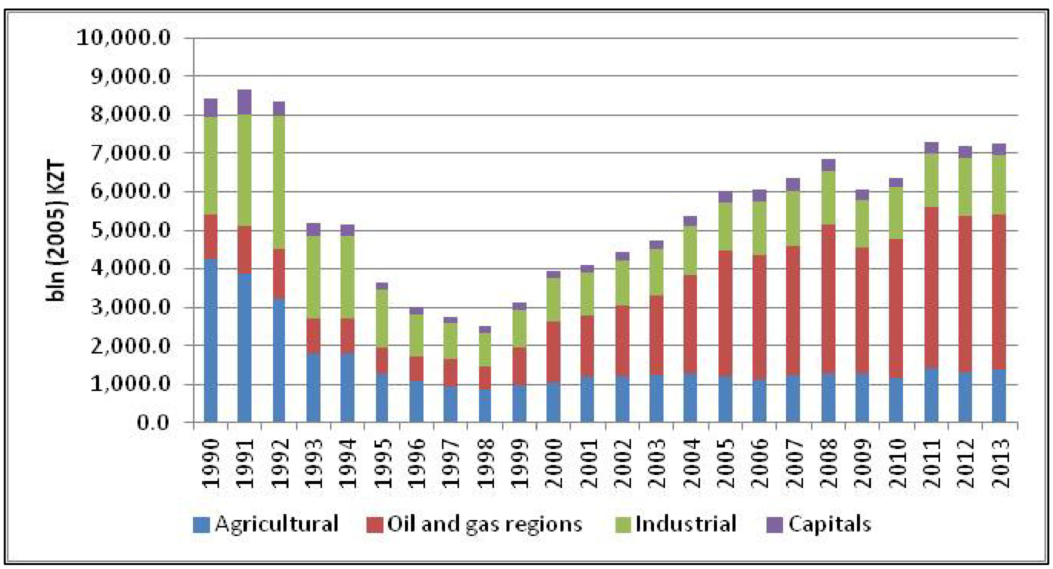
The transformation of Kazakhstan towards oil-based economy had effects on regional development. Based on the structure of the regional output the regions of Kazakhstan could be divided into four groups: agricultural, oil and gas, industrial and capitals. In the early 1990s the output of industrial regions was the largest in the country, followed by agricultural regions. Whilst oil and gas regions located near the bottom of the rating. However, the transformation process has lifted oil and gas regions to the top, while agricultural regions have slumped to the bottom of the rating presented in Table 3.13.

Table 3.13 Rating of the regions based on industrial and agriculture output

Region	1990	1995	2000	2005	2010	2011	2012	2013
Agricultural								
Akmola	4	5	12	13	13	13	13	13
Almaty	7	10	7	10	10	10	9	9
Zhambyl	9	13	15	15	15	15	15	15
Kostanay	3	4	8	9	9	9	11	11
South Kazakhstan	5	6	5	11	11	11	10	10
North Kazakhstan	6	9	14	14	14	14	14	14
Oil and Gas								
Aktobe	10	7	9	5	4	5	5	6
Atyrau	15	8	1	1	1	1	1	1
West Kazakhstan	12	14	10	4	5	3	3	3
Kyzylorda	14	16	13	6	7	6	8	8
Mangystau	13	11	3	2	2	2	2	2
Industrial								
Karagandy	1	1	2	3	3	4	4	4
Pavlodar	8	2	6	7	6	7	6	5
East Kazakhstan	2	3	4	8	8	8	7	7
Capitals								
Astana	16	15	16	16	16	16	16	16
Almaty	11	12	11	12	12	12	12	12

Source: Author's calculations based on data from the Committee on Statistics [6]

The share of output of oil and gas regions has increased from 13.8% till 55.5%, while the shares of industrial and agricultural regions in the total output have decline from 30% and 50.4% till 20.8% and 19.2% respectively as seen in Figure 3.12.



Source: Author's calculations based on data from the Committee on Statistics [6]

Figure 3.12 Industrial and agricultural production by type of the regions

Transformation of trade profile of Kazakhstan in 1995-2012 is provided in Appendix III. The resource dependence inevitably leads to the transformation of the trade profile of the country towards reliance on commodity export. The share of crude oil and gas in the total export of Kazakhstan has reached over half of all export by 2000, when the increasing prices of oil and gas caused a boom in the sector. By year 2012, the combined share of oil and gas reached 60% of the total export from Kazakhstan. The main exporting commodities from Kazakhstan included crude oil and gas, wheat, metals and radioactive chemicals. The main importing commodities included animal and vegetable products, foodstuffs, chemicals, clothing, stones, machinery and transportation. The commodities that went from net exporting to net importing include chemicals, textiles and raw leather and furs. The commodities that went from net importing to exporting include gold and gas.

The dominance of one commodity in the trade profile leads to the less export diversity, causing the risk of the commodity price volatility. The export diversity in Kazakhstan is measured by the Herfindahl-Hirschman Index (HHI) for the period 1995-2012 based on data from Hausman et al (2011) and Simoes and Hidalgo (2011) [53-54]. The HHI is the preferable measure of export concentration and it is defined as follow [118]:

$$HHI = \sum_{i=1}^{N} s_i^2 \quad (3.11)$$

where s_i is share of commodity i in total export and N is the number of commodities in the export profile. The higher values of HHI indicate less diversity of export.

The results indicate that the export the Kazakh export diversity has become less diverse due to increase in crude oil export as seen in Figure 3.13. Export diversification in Kazakhstan would have a positive effect on income growth [118]. Export diversification would require diversification of industrial and agricultural outputs.

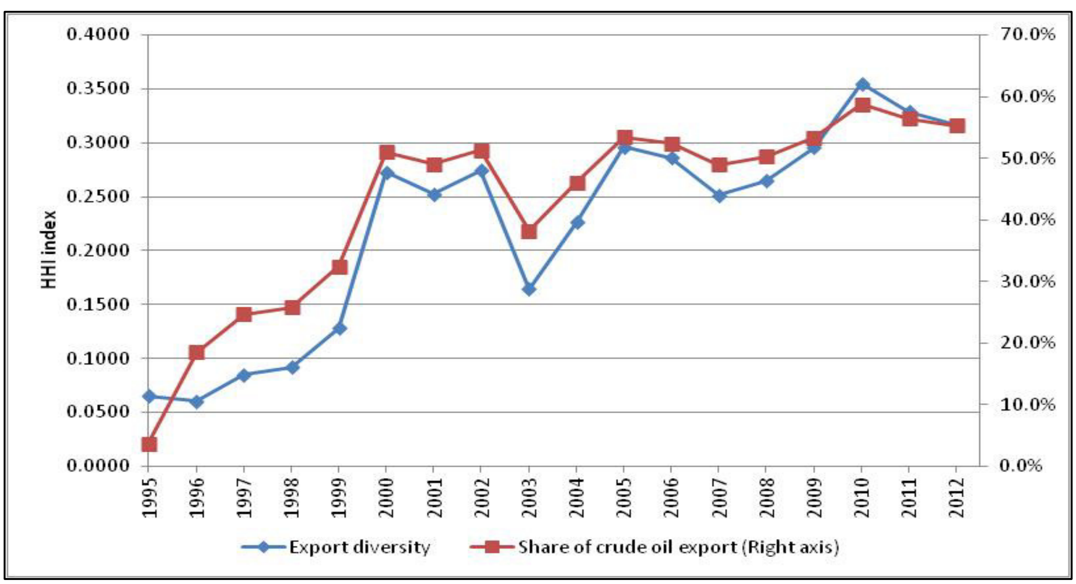


Figure 3.13 Export diversity and share of crude oil volume in total export

There are number of research papers that studied the effects of oil-dependence and the presence of the Dutch disease in Kazakhstan. Auty (1999) suggested that it is unlikely that the Kazakh economy would be become over-dependent on oil and gas production and expert in the presence of substantial hard minerals endowment. However, the author cautioned the government to introduce prudent economic policies in order to avoid the Dutch disease [119].

The study conducted by Egert (2012) empirically tested the mechanisms of the Dutch disease in Central and South-West Asia in two ways: testing the link between nominal and real exchange rates and commodity prices and the growth effects of resource abundance and oil price [112]. Although, the study failed to establish the presence of resource and spending effects in the countries under investigation, the results indicated the presence of the Dutch disease in the form of oil price effect on nominal and real appreciation of the currency, causing the decline of manufacturing.

Egert and Leonard (2007) tested the presence of the Dutch disease effects on the Kazakh economy using the disaggregated sectoral data [120]. The Dutch disease was tested by testing the presence of negative effect of oil price increase on non-oil manufacturing output. The study established that the appreciation of the nominal and real exchange rates did not cause the decline in the manufacturing sector.

Kutan and Wyzan (2005) examined the presence of the Dutch disease in Kazakhstan by using the extended Balassa-Samuelson model. The study established that the increase in world oil price causes real exchange rate appreciation. Hence, it was concluded that the Kazakh economy is vulnerable to the Dutch disease [121].

The regional panel data analysis by Oskenbayev and Karimov (2013) documented the presence of the labor force migration from traded sectors to non-traded sectors [122]. Howie and Atakhanova (2014) identified that the resource boom in Kazakhstan lowers inequality when the labor income, institutional quality, education and healthcare spending are controlled [60].

This study suggests testing the effects of world oil price and tradable industries output on currency appreciation. Consequently, currency appreciation affects the non-tradable industries and agricultural output. The presence and directions of Granger causality is examined among the variable by utilization of a bivariate VAR models. The type of relationship among the variables is estimated by correlation coefficients.

3.5.1 Methodology

The industries are grouped based on the trade profile of Kazakhstan into tradable and non-tradable industries. Tradable industries consist of iron and steel, non-ferrous metals, oil and gas industries. Non-tradable industries include power, chemical, food, light, pulp and paper, machinery, coal and other non-specified industries.

Kazakh Tenge is a typical petrocurrency, the value of which appreciates when world oil price rises [123]. KZT was pegged to the US dollar, and its nominal exchange was regulated by the National Bank in the period under investigation. Furthermore, the state control of prices of goods in the consumer basket could affect the real effective exchange rate in Kazakhstan. Hence, the better measure of currency appreciation/depreciation is required. Dolan (2014) suggests using the ratio of GDP per capita at market exchange rates over GDP per capita adjusted to purchasing power parity (PPP) [124].

For modeling purposes, data on outputs and oil price were converted into natural logarithms. The variables under investigation are: CA is a currency appreciation; LT is an output of tradable industries; LNT is an output of non-tradable industries; LA is an agricultural production; LO is a world oil price.

The logic behind VAR model is based on the assumption that the future value of the variable depends on the past values of itself and other variables of the model. A bivariate VAR model with two time series Y and X could be presented as follows [103]:

$$\Delta Y_t = \alpha_{10} + \sum_{i=1}^{T_{11}} \beta_{11i} \Delta Y_{t-i} + \sum_{i=1}^{T_{12}} \beta_{12i} \Delta X_{t-i} + \mu_{1t} \quad (3.12)$$

$$\Delta X_t = \alpha_{20} + \sum_{i=1}^{T_{12}} \beta_{21i} \Delta X_{t-i} + \sum_{i=1}^{T_{22}} \beta_{22i} \Delta Y_{t-i} + \mu_{2t} \quad (3.13)$$

Where Δ is the difference operator, T is the lag order, α and β are the estimation parameters, μ is an error term. The presence and directions of Granger causality is based on the results of Wald test with null hypothesis as follows [103]:

$$\boldsymbol{H_0} : X \neq> Y: \beta_{12i} = 0, i = 1,2, \dots q \quad (3.14)$$

$$\boldsymbol{H_0}: Y \neq> X: \beta_{22i} = 0, i = 1,2, \dots q \quad (3.15)$$

If $\boldsymbol{H_0}$ is rejected, then it suggests that past values of X/Y has a significant linear predicative power on the current values of Y/X and the Granger causality exists.

Prior to testing VAR models, a presence of unit root of the variables needs to be tested The ADF test is utilized for the purpose. Correlation coefficients are used to explain the predictive relationships between the variables.

3.5.2 Data

The study uses annual data for the period between 1993 and 2013. The data source for industrial and agricultural output is the Committee on Statistics of the Republic of Kazakhstan [6] and adjusted to the constant prices of FY2005 using price deflator from the United Nations Statistics Division [125]. The data on GDP per capita acquired from the World Development Indicators [7], while the information on world oil price obtained from BP Statistical Review of World Energy [30]. The descriptive statistics of the variables under investigation are below:

Table 3.14 Descriptive statistics of the variables

Statistics	CA	Oil price, USD (2013)/bbl	Tradable	Non-tradable	Agriculture
			trillion (2005) KZT		
Mean	0.31	56.32	2.75	1.54	0.82
SD	0.14	33.50	1.37	0.45	0.13
Median	0.23	38.55	2.50	1.54	0.82
Max	0.59	115.22	4.72	2.70	1.20
Min	0.16	18.17	0.84	0.91	0.59

Figure 3.14 and Table 3.15 display the time series plot of the variables and growth rates for different periods. As shown, the world oil price and tradable

industries experienced a fast growth from 1999, while the currency appreciation started from 2003. The "Lehman shock" caused a steep decline in both tradable and non-tradable industries by 16.9% and 8.4% respectively, whilst agricultural output increased by 11.6%.

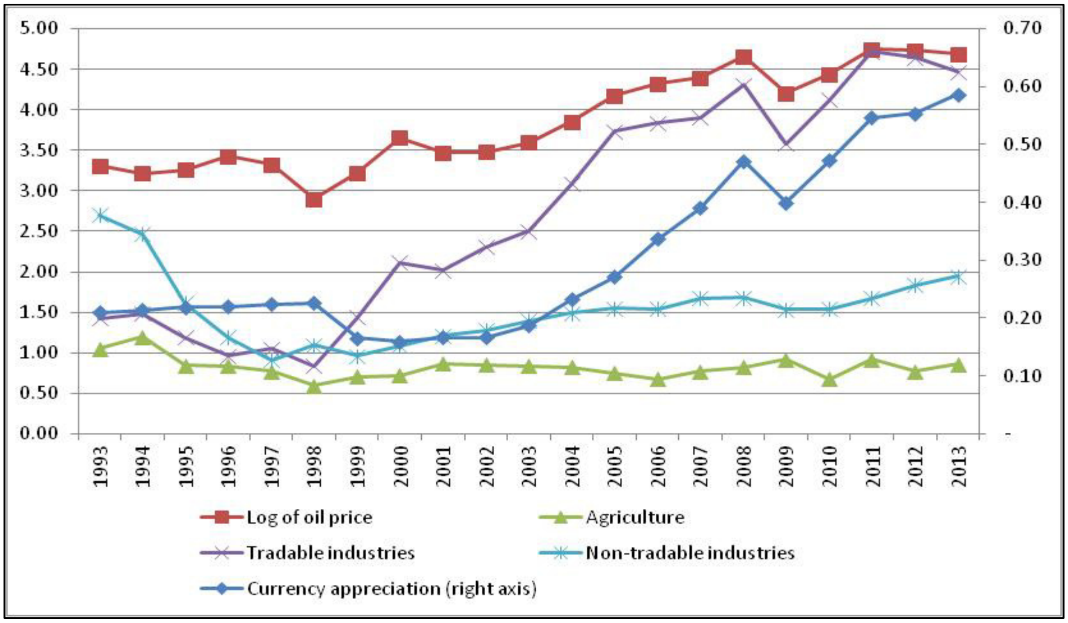


Figure 3.14 Time series plot of currency appreciation rate, agricultural output, log of oil price and output of tradable energy and non-tradable industries

Table 3.15 Average annual growth rates of variables for different periods

	1993-1998	1999-2008	2009	2010-2013
Agriculture	-16.3%	3.8%	11.6%	1.2%
Tradable industries	-15.1%	19.6%	-16.9%	6.1%
Non-tradable industries	-16.5%	4.6%	-8.4%	6.2%
Total	-17.0%	10.7%	-11.4%	5.0%

3.5.3 Empirical Findings

The correlation coefficients indicate the positive relationship between currency appreciation rate, world oil price, the outputs of tradable and non-tradable sectors, and agricultural output has negative relationship with all variables, apart from non-tradable industries as seen in Table 3.16. It possibly suggests that increase in agricultural output may have positive effects on industrial output of non-tradable industries.

Table 3.16 Correlation matrix of the variables

	CA	LT	LNT	LO	LA
CA	1.000				
LT	0.745	1.000			
LNT	0.416	0.376	1.000		
LO	0.895	0.936	0.356	1.000	
LA	-0.030	-0.020	0.637	-0.066	1.000

The results of unit root test indicate that the variables contain unit root in their levels, but stationary in their levels. This indicates that the variables are integrated at order one i.e. *I*(1) as displayed in Table 3.17.

Table 3.17 Results of ADF unit root test

Variable	Level	1st difference
CA	0.872	-3.914***
LA	-0.746	-6.968***
LNT	-0.186	-2.712***
LO	-0.551	-4.870***
LT	-0.581	-3.031*

Note: * and *** indicate that the null hypothesis is rejected at 10% and 1% level respectively. The optimal lag lengths are selected using AIC.

Table 3.18 contains the outcomes of Granger causality tests. The tests established the following:

- Unidirectional causality running from world oil price to currency appreciation rate;
- Unidirectional causality running from tradable industries output to currency appreciation rate;
- Unidirectional causality running from currency appreciation rate to non-tradable industries output;
- Unidirectional causality running from currency appreciation to agricultural output.

Table 3.18 Results of Granger causality tests using the VAR models

Null hypothesis	Lag length	Wald test statistics	
		χ^2	p-value
LO≠>CA	1	5.465	0.019**
CA≠>LO	1	0.010	0.922
LT≠>CA	1	7.151	0.008***
CA≠>LT	1	0.379	0.538
CA≠>LNT	5	9.719	0.084*
LNT≠>CA	5	8.019	0.155
CA≠>LA	5	35.393	0.000***
LA≠>CA	5	3.725	0.590

Note. ***, ** and * indicates the rejection of a null hypothesis at 1%, 5% and 10% level of significance respectively.

The results indicate that increase in world oil price and the output of the tradable industries result in currency appreciation. Consequently, currency appreciation increases output in non-tradable industries and decreases agricultural output. Based on the lag length, it could be said that the changes in world oil price and tradable industries output have immediate effect on currency appreciation, while the impact of currency appreciation on non-tradable industries and agricultural output has delayed effect. The lagged effects of the currency appreciation on non-tradable industries (5 years) and agriculture (5 years) could be the consequence of the regional differences. Moreover, it could be suggested that the tradable industries have a trickledown effect on non-tradable industries.

3.6 Summary

This chapter has two distinct research questions. First, analysis of the main CO_2 emissions determinants carried out by testing the EKC hypothesis. The results do not support EKC hypothesis and energy use exhibits a positive significant impact on CO_2 emissions, while there is no Granger causality between emissions and economic output. The presence and directions of Granger causality between energy use and CO_2 emissions are tested using the VAR model. The results of the analysis indicate the presence of the bidirectional causality between the variables.

The presence of bidirectional causality between energy use and CO_2 emissions indicates that the policies addressing energy efficiency and energy saving would cause reduction of CO_2 emissions and vice-versa. It is likely that such measures will not hinder economic growth of Kazakhstan. The absence of the Granger causality between GDP and CO_2 emissions may indicate that the economic growth of Kazakhstan is based on the oil revenue.

Second, the presence of the Dutch disease is tested by utilizing bivariate VAR models with time series data of currency appreciation, output of tradable industries, output of non-tradable industries, agricultural production and world oil price. The theoretical framework of the Dutch disease states that the economic development of natural resources leads to a decline in manufacturing sector and agriculture. The results of correlation analysis indicate that currency appreciation rate is positively correlated with world oil price and the outputs of tradable sectors, currency appreciation positively correlated with non-tradable industries output, while it negatively affects agricultural production.

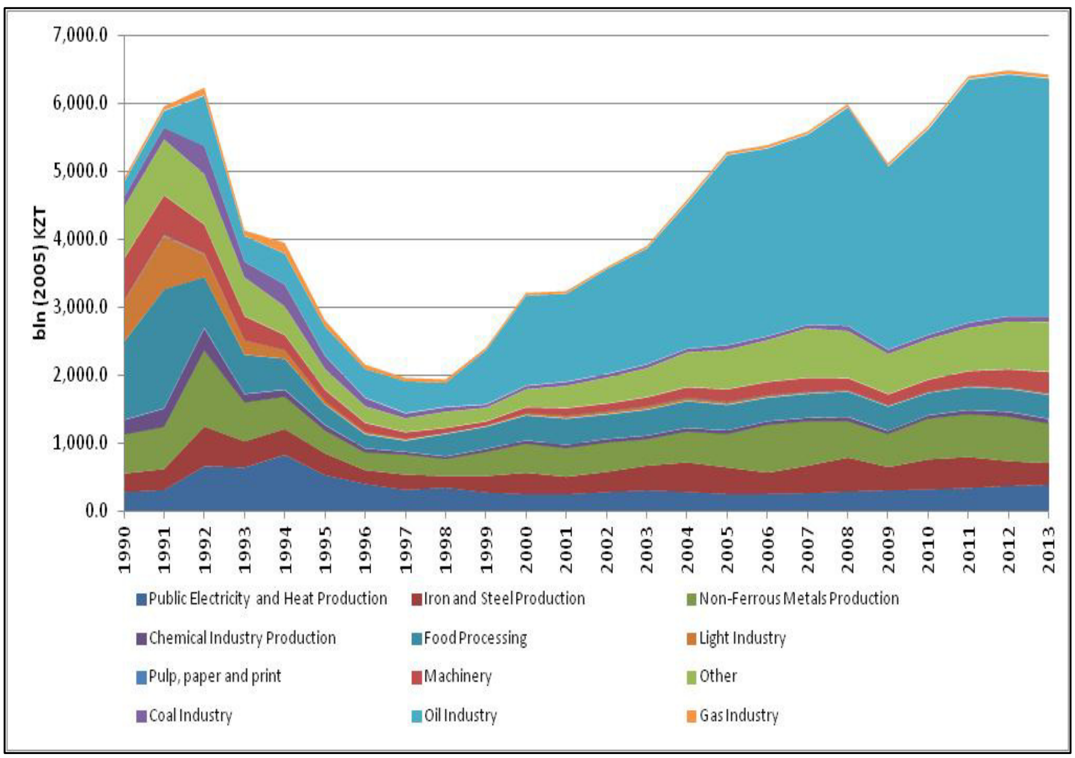
The outcomes of Granger causality tests using VAR models indicate the presence of unidirectional causalities running from world oil price and tradable industries production to currency appreciation, while there are unidirectional causalities running from currency appreciation rate to non-tradable industries output and agricultural output. The lag length of VAR models defined by the AIC process indicate that world oil price and output of tradable industries have immediate effect (1 year) on currency appreciation, while the currency appreciation has delayed effect (5 years) on non-tradable industries and agriculture.

Chapter 4

Decomposition Analysis of Industry Sector CO_2 Emissions from Fossil Fuel Combustion in Kazakhstan

Kazakhstan's industry is primarily based on the extraction and export of the natural resources, primarily crude oil that country possesses in enormous amounts. Share of industrial output in GDP has increased from 20.5% in 1990 till 30.8% in 2012 [6]. In 2014, over one million people (almost 12% of economically active population) were employed in the sector [6].

The industry of Kazakhstan has undergone a significant structural transformation since the Soviet period. Kazakhstan has transformed from diverse economy with a dominant share of processing industries into mostly oil export-dependent economy as displayed in Figure 4.1. Hence, the economy of Kazakhstan could be vulnerable to commodity price volatility.

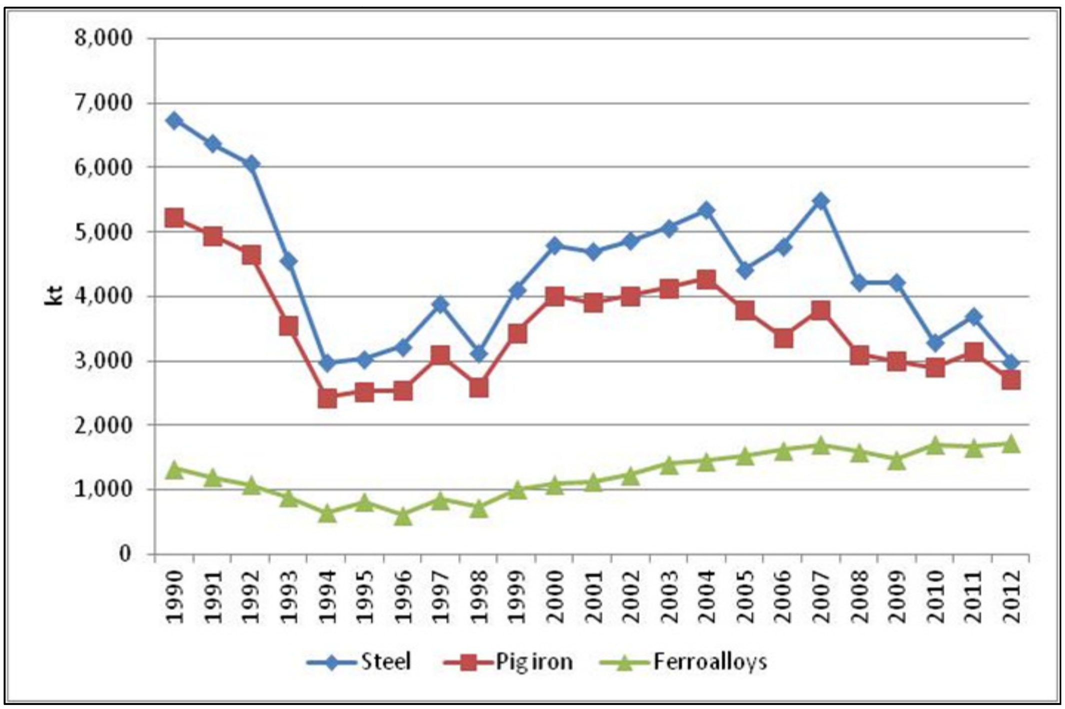


Source: Author's calculations using data from the Committee on Statistics [6] and price deflator from the United Nations Statistics Division [125]

Figure 4.1 Structure of industrial output in Kazakhstan

Power production in Kazakhstan mainly relies on thermal power plant. Traditionally, most of electricity generation comes from coal-fired power plants mainly built in the Soviet time. Due to harsh climatic conditions in winter, a significant amount of energy is utilized for district heating purposes. The heat is provided by cogeneration plants and boiler stations. Existing power plants and distribution infrastructure are often highly deteriorated and ineffective, what results in significant energy losses. The power generation sector is responsible for a majority of CO_2 emissions from industrial production and it is the most energy intense among the sectors.

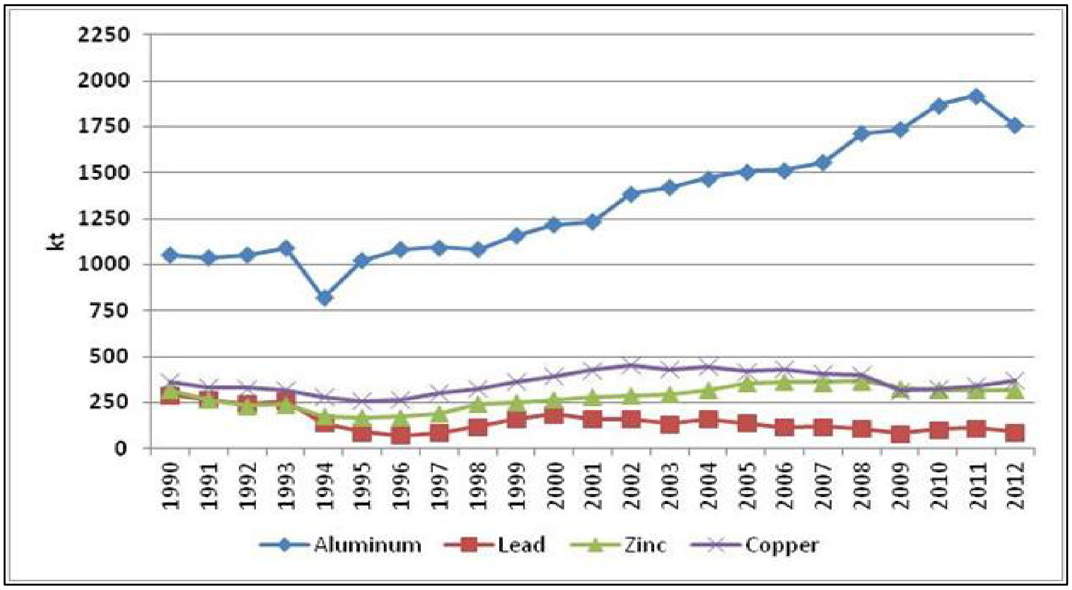
Although productions of steel and pig iron have decreased by 1.8 and 1.7 times respectively since 1990, the industry remains one of the most developed in the country as seen in Figure 4.2. The industrial output has been on rise since 2000 following the decline caused by demand disruption after the collapse of the USSR in 1990s. The peak of industrial production was in 1992, and the output has not reached that value yet. Historically, coal has been the fuel of choice for the industry due to its abundance and cheap mining and transportation costs as the iron and steel production plants are located near the major coal mines. A blast furnace is primarily used to produce iron, while basic oxygen furnace is the main method of steelmaking in Kazakhstan.



Source: GHG Inventory [105]

Figure 4.2 Main products of iron and steel industry

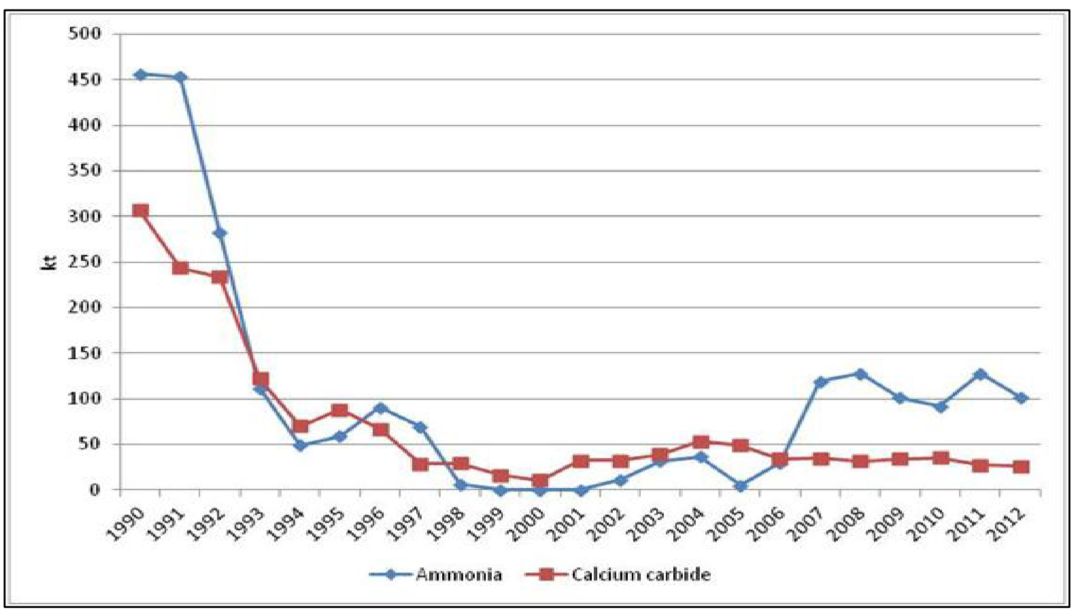
The non-ferrous metals like copper, lead and zinc has long been produced in the country. However, more recently production of aluminum, titanium, magnesium and other metals have become the focus. The industrial output has already surpassed 1990 level and the further growth is expected as seen in Figure 4.3. The metals are primarily exported and a very small share of products used domestically. The industry has increased its coal consumption by almost eight times since 1990.



Source: the Committee on Statistics [6]

Figure 4.3 Production of main non-ferrous metals in Kazakhstan

The chemical industry is based on the utilization of phosphate and various salt reserves and petrochemical industry. The industrial output has reduced 3.6 times since 1990 and the share of the industry in the total industrial output has shrunk from 4% till just 1% in 2012. However, the industry has been on the recovery path with the average annual growth of 5% since 2000, when the size of the industry has reduced almost six times. Productions of ammonia and calcium carbide have declined by 78% and 91% respectively since 1990 as shown below:

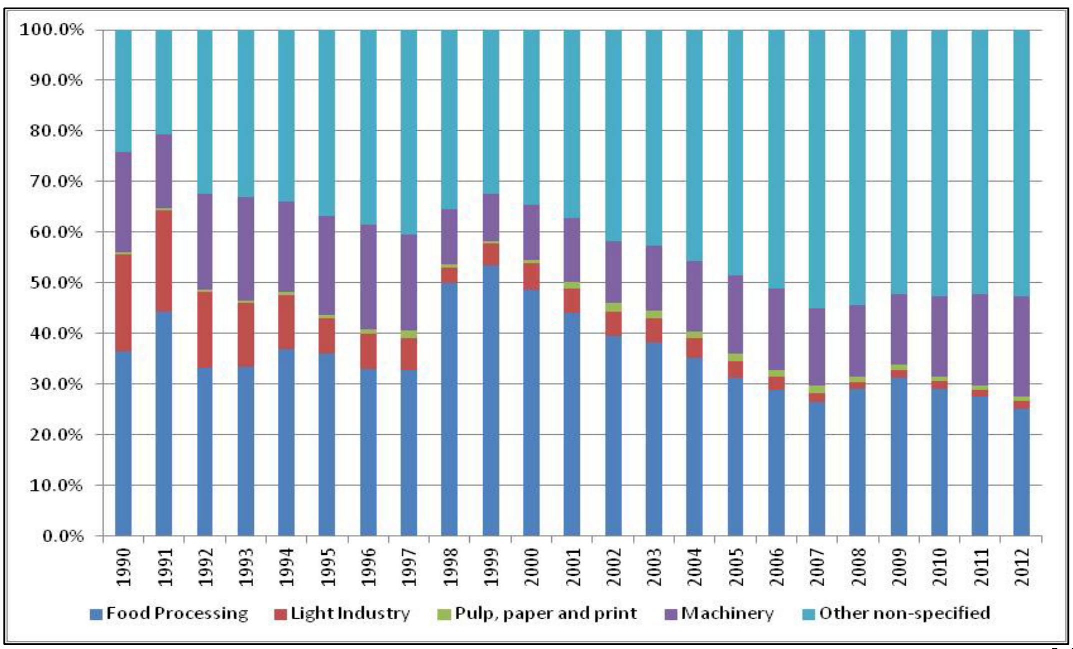


Source: GHG Inventory [105]

Figure 4.4 Production of main non-ferrous metals in Kazakhstan

Coal, oil and gas industry is significantly important for the economy of Kazakhstan due to large reserves of hydrocarbons. Kazakhstan has strategic plans to increase production of coal, oil and gas. While oil and gas present a valuable export commodity, domestic consumption of coal is expected to increase by 12% by 2020 [126]. The share of coal, oil and gas industries in total industrial output has increased from just fewer than 10% in 1990 till almost 57% in 2012, while the shares of all other industries have reduced almost twice for the same period. This may indicate that the economy of Kazakhstan maybe vulnerable to the oil curse [45]. This study includes CO_2 emissions related to production and refining activities and does not include emissions caused by flaring associated petroleum gas.

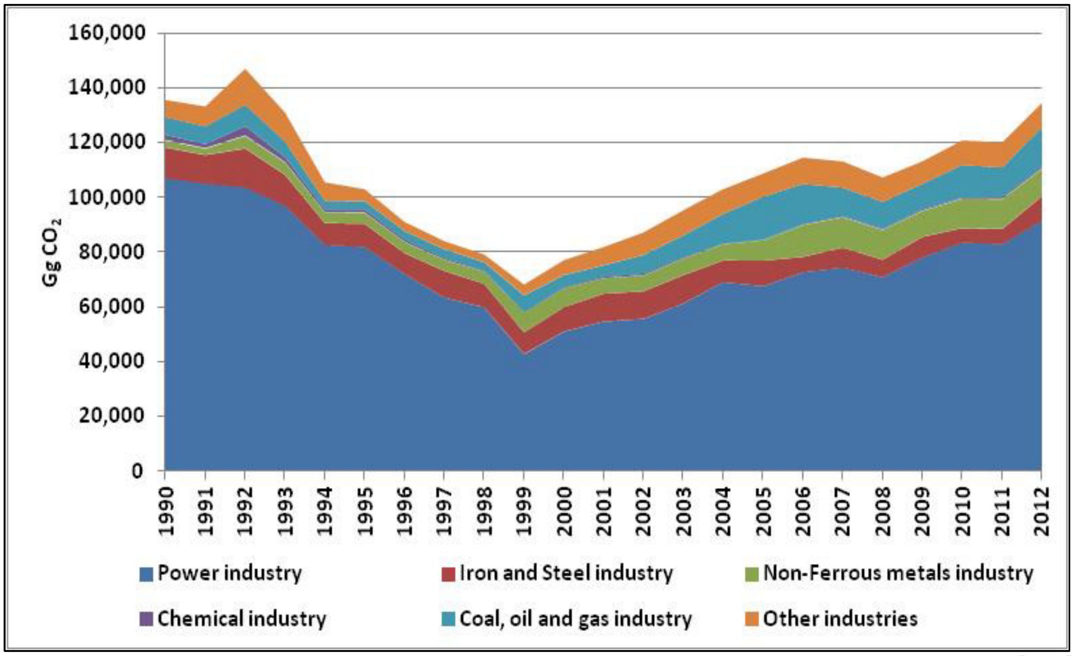
The other industries include machinery, food processing, pulp and paper industry, light industry and other non-specified industries. In other words, mostly processing and manufacturing industries. The share of the industries in the total national industrial output has dropped from 64% in 1990 till 20% in 2012. The structure of the other industries has changed significantly since 1990 as shown in Figure 4.5. As shown, the shares of food processing and light industries have significantly declined. The other non-specified industries have increased from slightly more than 24% in 1990 till almost 53% in 2012, while pulp, paper and print and machinery shares have remained unchanged since 1990.



Data source: the Committee on Statistics [6]

Figure 4.5 Structure of other industries

Due to heavy dependence on cheap domestic coal, the environmental impact of the industry is significant in Kazakhstan. The industry causes almost 70% of the total national CO_2 emissions [105]. The power industry has had the biggest contribution to CO_2 emissions due to industrial activities as seen in Figure 4.6. Total CO_2 emissions caused by coal, oil and gas industry, non-ferrous metals industry and other industries increased comparing to 1990 level, while CO_2 emissions from iron and steel, power and chemical industries have reduced. The main driving factor for CO_2 emissions increase is rise in coal consumption.



Source: GHG Inventory [105]

Figure 4.6 Industry sector CO_2 emissions related to fossil fuel combustion

Hence, it is important to determine the factors affecting the growth of industry sector CO_2 emissions related to fossil fuel combustion. In 2005, Karakaya and Ozcag used decomposition analysis to define the driving forces of CO_2 emissions in Central Asia from fossil fuel combustion [127]. The study distinguished between total primary energy supply and total final energy consumption. The factors investigated were emission factor, energy intensity, fossil fuel intensity, conversion efficiency, economic output per capita and population for the period 1992-2001. The study revealed that the main driving force for CO_2 emissions reduction in Kazakhstan due to reduction of economic activities following the collapse of the Soviet Union. Kojima and Bacon (2009) performed a multi-country decomposition analysis of CO_2 emissions from energy use for several time periods from 1994 till 2006 [128]. The methodologies used are five-factor decomposition (carbon intensity, fossil fuel share, energy intensity, GDP per capita and population effect) and six-factor decomposition that used methodology similar to Karakaya and Ozcag (2005) study. The study indicated that primarily economic activity was the main driving force for CO_2 emissions change in Kazakhstan.

4.1 Methodology

Index Decomposition Analysis (IDA) has been identified as the preferred methodology in energy and environmental studies to investigate the factors influencing energy consumption and its environmental impact [129]. Among the existing IDA methodologies the Logarithmic Mean Divisia Index (LMDI) method has become popular due to its theoretical robustness, adaptability, and ability to provide perfect decomposition [130].

This study aims to conduct a year-to-year decomposition analysis of the factors affecting industrial CO_2 emissions from 1990 to 2012 in Kazakhstan. The existing studies suggest decomposition of CO_2 emissions into five explanatory effects as follows [129-130]:

$$C = \sum_{i,j} C_{ij} = \sum_{i,j} Q \frac{Q_i}{Q} \frac{E_i}{Q_i} \frac{E_{ij}}{E_i} \frac{C_{ij}}{E_{ij}} = \sum_{i,j} QS_i I_i M_{ij} U_{ij} \quad (4.1)$$

where C is the total CO_2 emissions (kt), Cij are CO_2 emissions caused by consumption of fuel j by i industry, Q is total industrial output (billion KZT), Q_i is the output of i industry (bln KZT), E_i is the use of fossil fuel by i industry (PJ), E_{ij} is the fossil fuel consumption of j type by i industry (PJ), S_i is the share of i industry in total industrial output, I_i is the energy intensity of i industry, M_{ij} is the energy mix of i industry, U_{ij} is the CO_2 emission factor of j fuel consumed by i industry.

Total changes in CO_2 emissions between target year T and base year (1990) could be expressed as follows:

$$\Delta C_{tot} = C^T - C^{1990} = \Delta C_{act} + \Delta C_{str} + \Delta C_{int} + \Delta C_{mix} + \Delta C_{emf} \quad (4.2)$$

where ΔC_{act} is the changed in CO_2 emissions caused by changes in activity, ΔC_{str} is the changes in CO_2 emissions caused by industrial output structure, ΔC_{int} is the changes in CO_2 emissions caused by energy intensity, ΔC_{mix} is the changes in CO_2 emissions caused by fuel mix, ΔC_{str} is the changes in CO_2 emissions caused by emission factor. Where:

$$\Delta C_{act} = \sum_{ij} w_{ij} \ln\left(\frac{Q^T}{Q^{1990}}\right) \quad (4.3)$$

$$\Delta C_{str} = \sum_{ij} w_{ij} \ln\left(\frac{S_i^T}{S_i^{1990}}\right) \quad (4.4)$$

$$\Delta C_{int} = \sum_{ij} w_{ij} \ln\left(\frac{I_i^T}{I_i^{1990}}\right) \quad (4.5)$$

$$\Delta C_{mix} = \sum_{ij} w_{ij} \ln\left(\frac{M_{ij}^T}{M_{ij}^{1990}}\right) \quad (4.6)$$

$$\Delta C_{emf} = \sum_{ij} w_{ij} \ln\left(\frac{U_{ij}^T}{U_{ij}^{1990}}\right) \quad (4.7)$$

where w_{ij} is the logarithmic mean of industrial CO_2 emissions in year T and base year (1990) and expressed as follows:

$$w_{ij} = \frac{C_{ij}^T - C_{ij}^{1990}}{\ln C_{ij}^T - \ln C_{ij}^{1990}} \quad (4.8)$$

4.2 Data

The time interval under investigation ranged from 1990 till 2012. The industrial outputs in current prices for each sector were obtained from the Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan [6], and adjusted to the constant prices of FY2005 using price deflator from the United Nations Statistics Division [125].

Data on fossil fuel consumption, CO_2 emissions and implied CO_2 emission factors were acquired from Kazakhstan's national GHG inventory submitted to

United Nations Framework Convention on Climate Change [105]. Biomass combustion and related CO_2 emissions are excluded from analysis as they are carbon-neutral. Energy consumption by fuel is given below:

Table 4.1 Fuel mix by industries in Petajoule (PJ)

Industry	1990					2012				
	Oil	Coal	Gas	Other	**Total**	Oil	Coal	Gas	Other	**Total**
Power	190.4	871.6	193.7	2.5	**1,258.3**	22.8	861.5	181.4	0.0	**1,065.6**
Iron and steel	27.2	59.5	14.5	0.0	**101.1**	16.5	85.4	8.6	0.0	**110.5**
Non-ferrous metals	13.6	13.9	1.9	0.1	**29.5**	9.6	99.4	0.1	0.0	**109.0**
Chemical	2.0	1.9	23.9	2.7	**30.6**	0.1	1.3	10.5	0.0	**11.9**
Coal, oil and gas	47.4	4.3	42.1	5.9	**99.7**	79.6	7.8	143.2	0.0	**230.7**
Other	25.1	36.1	22.3	0.2	**83.7**	10.5	68.9	31.5	0.0	**111.0**
Total	**305.7**	**987.3**	**298.4**	**11.4**	**1,602.9**	**139.0**	**1,124.4**	**375.3**	**0.0**	**1,638.7**

4.3 Empirical Findings

Table 4.2 presents the results of decomposition analysis of CO_2 emissions in Gg. The results indicate that total CO_2 emissions from industrial activities in Kazakhstan have reduced by 1,024.2 Gg or 0.8% from 1990, while the total fossil fuel consumption have increased by 2% for the same period. Coal and gas combustion have increased by 14% and 26% respectively, while oil consumption have dropped by 55% for the period 1990-2012. The activity effect indicates that CO_2 emissions would have grown by 27% if other effects had stayed constant. Improved energy intensity was the main factor for total CO_2 emissions reduction.

Table 4.2 Results of decomposition analysis 1990-2012 (Gg of CO_2)

Industries	ΔC_{tot}	ΔC_{act}	ΔC_{str}	ΔC_{int}	ΔC_{mix}	ΔC_{emf}
Power industry	-15,490.4	27,351.4	-394.8	-43,105.0	1,782.1	-1,124.1
Iron and steel industry	-2,374.0	2,829.7	66.4	-2,007.6	832.1	-4,094.6
Non-ferrous metals industry	7,515.7	1,387.9	-733.5	5,796.7	1,069.8	-5.2
Chemical industry	-1,134.1	307.6	-1,534.5	198.9	43.7	-149.8
Coal, oil and gas industry	7,849.8	2,664.7	17,799.5	-12,522.9	-80.5	-11.1
Other industries	2,608.8	2,071.3	-8,374.5	8,373.8	359.7	178.5
Total	**-1,024.2**	**36,612.6**	**6,828.7**	**-43,266.1**	**4,006.8**	**-5,206.3**

The results of the analysis are presented in the form of indexed time-series charts. The results indicate that coal, oil and gas industry, non-ferrous metals industry and other industries surpassed CO_2 emissions level of 1990, while power industry, iron and steel industry and chemical industry are still below that level.

The total CO_2 emissions from the power industry have reduced by 14% since 1990. However, the industry remains the biggest cause of CO_2 emissions in Kazakhstan. The main driving factor affecting CO_2 emissions changes caused by power industry is the industrial activity of the sector as seen in Figure 4.7. Energy intensity had the biggest contribution to the emissions reduction. The share of oil consumption in the fuel mix of the industry has dropped by 88% from 1990. Despite being the main cause of CO_2 emissions from total industry in Kazakhstan, the share of the power industry never exceeded 25% of the total industrial output.

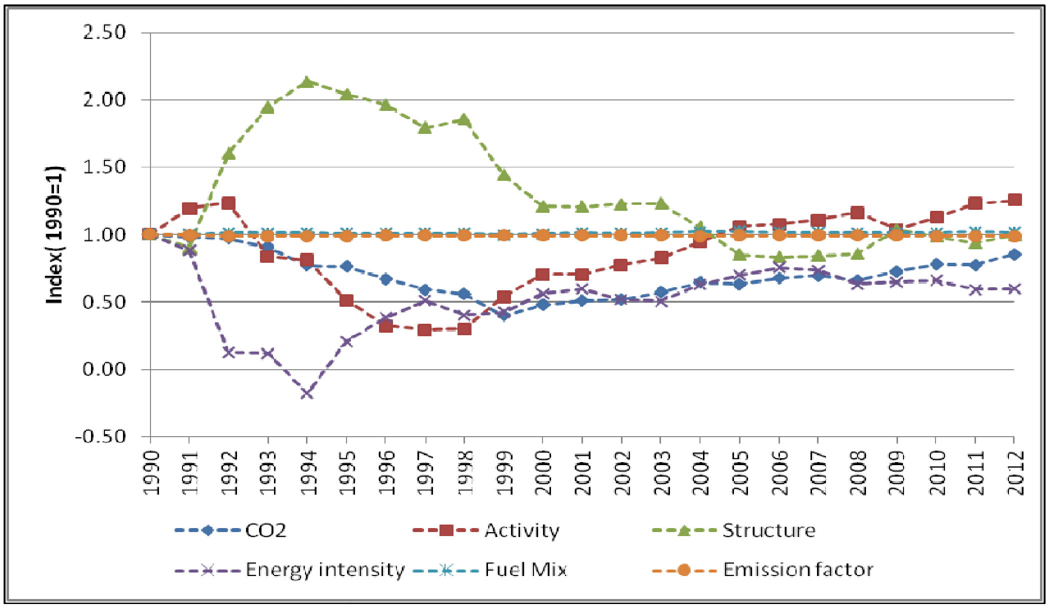


Figure 4.7 Results of decomposition analysis for power industry

CO_2 emissions related to the iron and steel industry have reduced by 21% since 1990. The decline in CO_2 emissions in 1990s was caused by output contraction, while improvements in energy intensity and emission factor due to fuel switching were the main causes of CO_2 emissions reduction in 2000s as in Figure 4.8. For the whole period from 1990 to 2000, the main factors affecting emissions increase were the industrial activity and the output structure, while the energy intensity drove down the emissions by 18%.

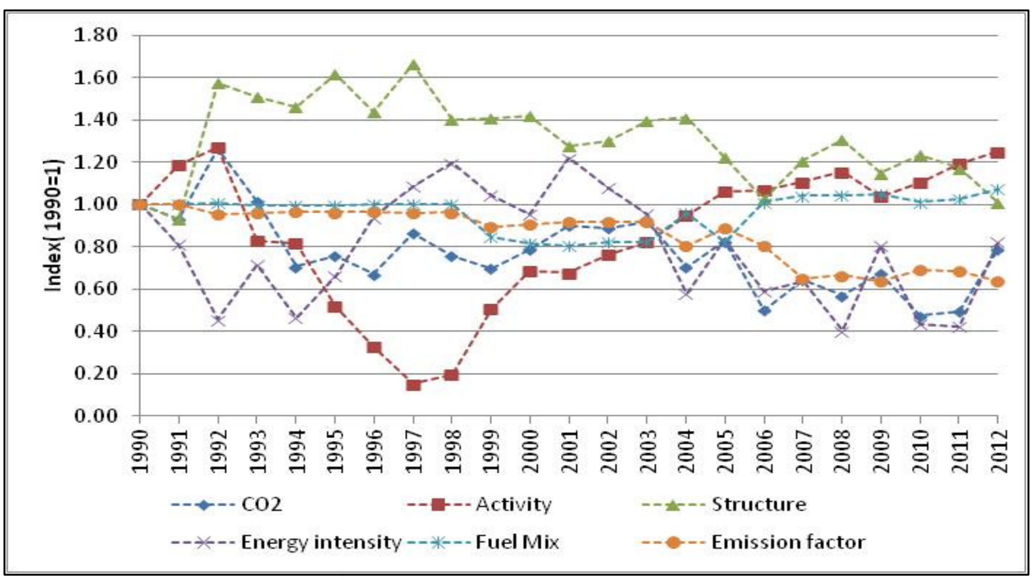


Figure 4.8 Results of decomposition analysis for iron and steel industry

The total CO_2 emissions caused by the non-ferrous industry have increased by 310% for the whole period. The main reason behind CO_2 emissions increase is the energy intensity rise by 3.4 times since 1990 as displayed in Figure 4.9. Furthermore, the share of coal has reached 91% from 47% in 1990. This combination caused significant boost in CO_2 emissions caused by the industry.

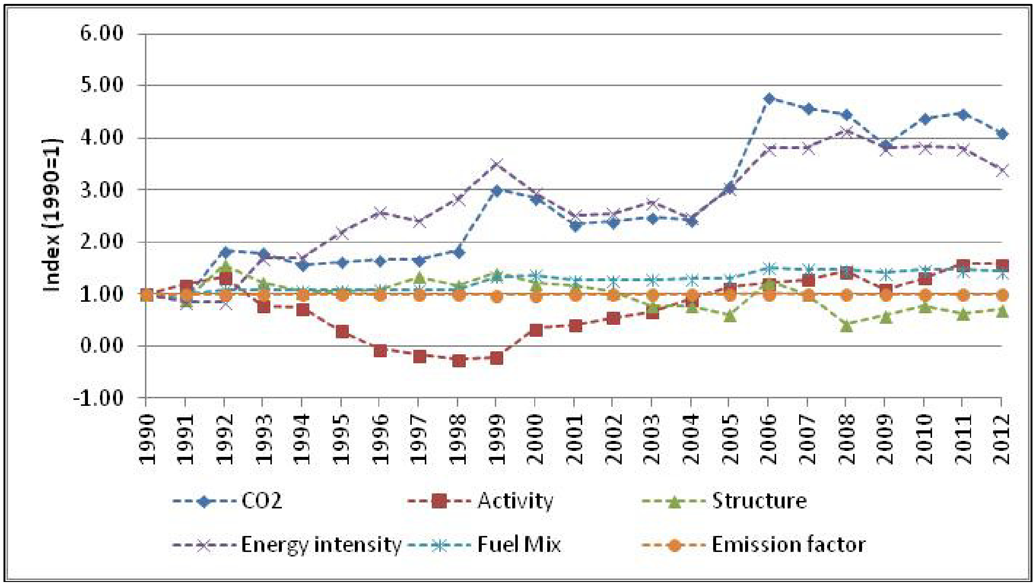


Figure 4.9 Results of decomposition analysis for non-ferrous metals industry

The total CO_2 emissions from chemical industry have declined by 62% since 1990. The main driving factor behind the decrease was the industrial structure effects that caused 83% decline as seen in Figure 4.10. The industry is the only sector where gas is the dominant fuel in the mix and consisted 88% of the total fuel mix in 2012.

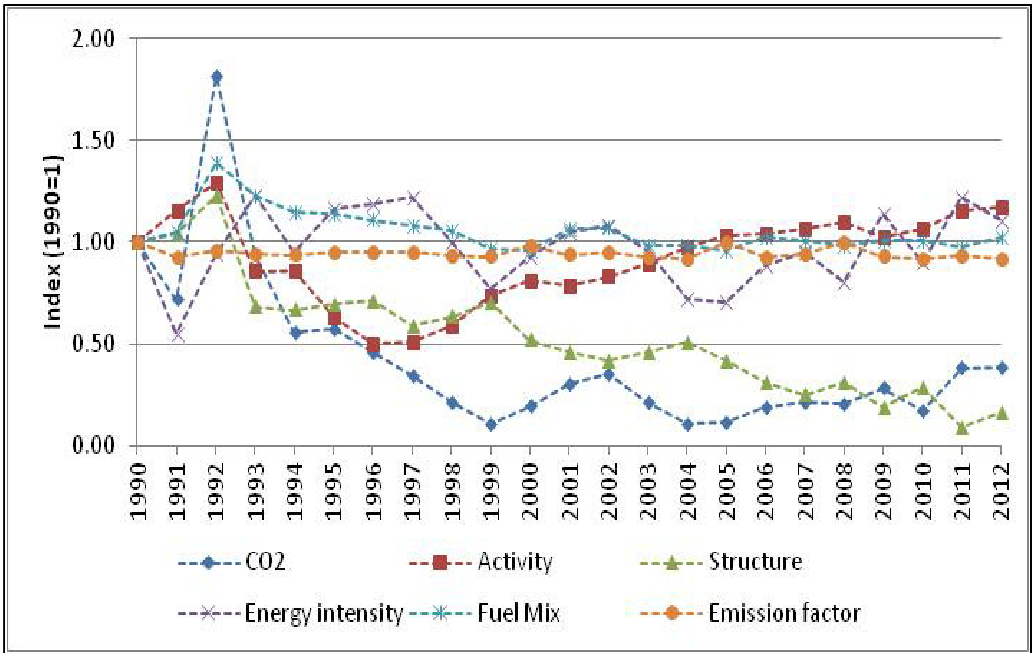


Figure 4.10 Results of decomposition analysis for chemical industry

The industrial output of coal, oil and gas industry has been increasing at the average rate of 13% annually since 1999 following the decline from 1992. Total CO_2 emissions caused by the industry have increased by 122% for analysis period. The main factor affecting the dynamics of CO_2 emissions from coal, oil and gas sector is the structure of industrial output in spite of improvements in energy intensity as shown in Figure 4.11. The industrial structure effect caused 277% increase in CO_2 emissions, while energy intensity factor pushed down emissions by almost 200% for the whole period. Furthermore, the results of the study most likely indicate that the industrial output of the coal, oil and gas sector highly depends on oil price fluctuations on the world market. This possibly explains energy intensity improvements of the sector despite increased fossil fuel consumption by 131% since 1990.

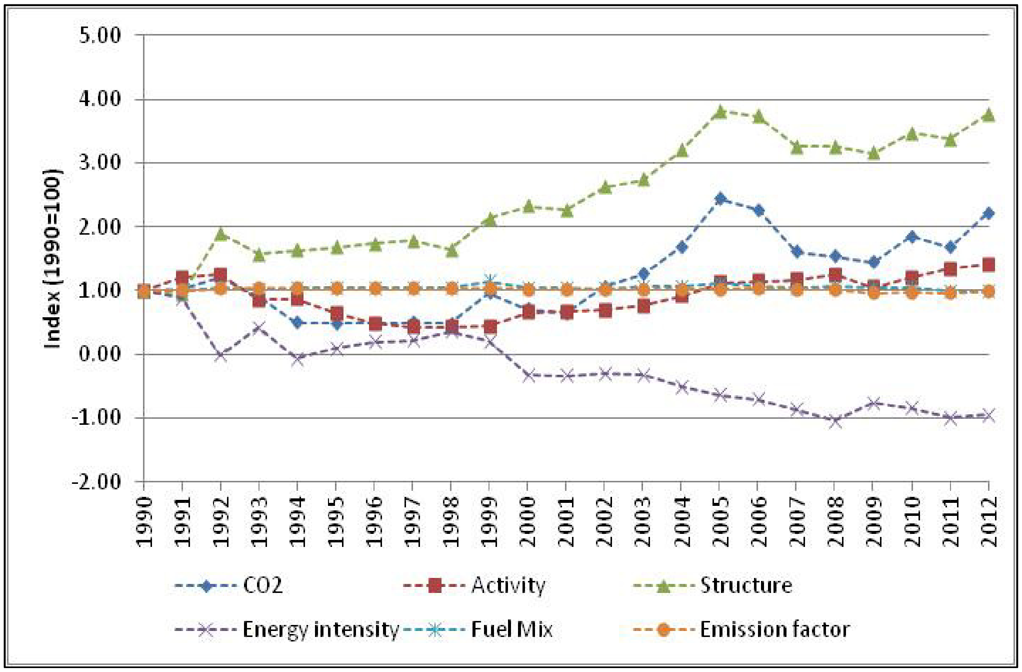


Figure 4.11 Results of decomposition analysis for coal, oil and gas industries

CO_2 emissions from the other sectors have increased by 41% since 1990. However, the emissions are below 1992 level when the industrial output and consequent environmental impact were at the peak as displayed in Figure 4.12. The biggest cause of CO_2 emissions increase from the industry was energy intensity factor, while structure effect was the main driving force for reduction. The industry has increased coal consumption by 91% since 1990.

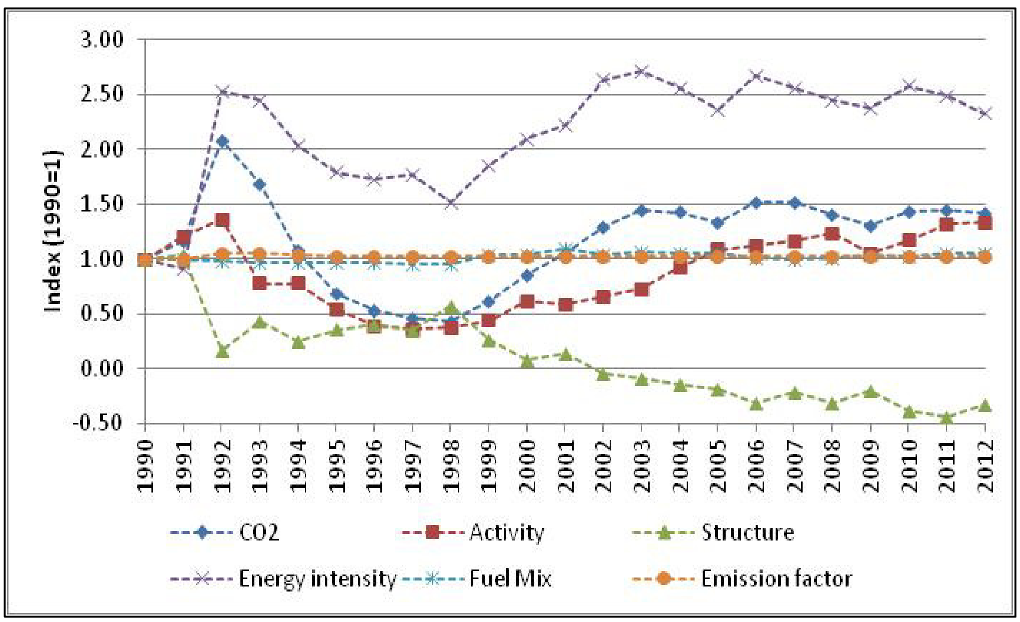


Figure 4.12 Results of decomposition analysis for other industries

From 1990 to 2012, CO_2 emissions related to fuel combustion by industry have decreased by 1%. By applying LMDI methodology it was identified that changes in industrial activity pushed up total CO_2 emissions from industry by 27% followed by structure effect by 5% and fuel mix with 3% increase, while changes in energy intensity and emission factor pushed down emissions by 32% and 4% respectively. Analysis of industries revealed that the relative CO_2 emissions reduction was achieved in chemical and iron and steel and power industries by 62%, 21% and 14% respectively since 1990. Meanwhile, CO_2 emissions caused by non-ferrous metals, coal, oil and gas and other industries have increased by 310%, 122% and 41% respectively. Furthermore, it was identified that changes in industrial activity was the main driving force in emissions increase in power and iron and steel industries; energy intensity in non-ferrous metals, other and chemical industries; and the structure effect has significantly pushed up CO_2 emissions in coal, oil and gas industry. The energy intensity was the main factor to push down CO_2 emissions from coal, oil and gas, iron and steel and power industries, while changes in industrial output structure pushed down emissions in non-ferrous metals, chemical and other industries.

Although Kazakhstan has achieved 33% increase in total industrial output since 1990, the growth occurred in power, iron and steel, non-ferrous metals and coal, oil and gas industries by 32%, 33%, 14% and impressive 769% respectively. On the other hand, chemical and other industries have dropped in size by 67% and 58% respectively.

Another important discovery from the analysis is the increase in coal consumption and reduction of oil presence in the fuel mix of the industry. In other words, coal, a fuel with a bigger environmental impact but cheaper cost, have become a main fuel for domestic industry, while oil and gas, major export commodities, have been sold on the world market. The fuel switch raises the questions of environmental justice and social equity in Kazakhstan.

4.4 Summary

The chapter proposes using the Logarithmic Mean Divisia Index (LMDI) method of Index Decomposition Analysis (IDA) to define the factors affecting industrial CO_2 emissions for the period 1990-2012. The industries under investigation are power, iron and steel, non-ferrous metal, chemical, other and combined coal, oil and gas industry. CO_2 emissions are decomposed to five explanatory factors: activity, output structure, energy intensity, fuel mix and emission factor.

The total CO_2 emissions related to fuel combustion by industry have declined by 1% since 1990, while total fossil fuel consumption has increased by 2% for the period. Fuel mix has transformed towards the dominance of coal, while consumption of oil has almost halved. The results of decomposition analysis identified that industrial activity, structure effect and fuel mix caused total industry CO_2 emissions increase, while energy intensity and emission factor lead to CO_2 emissions decline.

CO_2 emissions caused by non-ferrous metals industry, other industries and coal, oil and gas industries have increased since 1990. Meanwhile, chemical, iron and steel and power industries have achieved CO_2 emissions reduction for the same period. Changes in industrial activity have caused CO_2 emissions increase in power and iron and steel industries, energy intensity in non-ferrous metals, other and chemical industries, and output structure in coal, oil and gas industry. Improved energy intensity have caused CO_2 emissions reduction in coal, oil and gas and iron and steel industries, while industrial output structure in non-ferrous metals, chemical and other industries.

The results of the analysis suggest that the power sector has the biggest CO_2 emissions reduction and energy saving potential among the industries of Kazakhstan. Hence, there is a need to understand the structure of the industry and its environmental impact. Comprehensive assessment of environmental impact including all stages of the industry is necessary.

Chapter 5

Power Industry

Traditionally, heat and electricity has been generated by a mix of technologies, with coal, oil and gas burning power plants, together with hydropower, meeting the vast bulk of Kazakhstan's energy demand. The role of large SDPS, constructed during the Soviet time, is to utilize coal produced from nearby coal basins. Major power plants with installed capacities are listed in Table 5.1.

Table 5.1 Power plants with installed capacity over 250 MW

Owner	Region	Power Plant	Capacity MW
Kazakhmys	Pavlodar	Ekibastuz SDPS-1	4,000
Eurasian Energy Corporation	Pavlodar	Aksu SDPS	2,100
Samruk-Energo	Zhambyl	Zhambyl SDPS	1,230
Samruk-Energo	Pavlodar	Ekibastuz SDPS-2	1,000
Samruk-Energo	East Kazakhstan	Shulbinskaya HPP	700
Samruk-Energo	East Kazakhstan	Buhtarma HPP	675
Kazakhmys	Karagandy	Karagandy SDPS-2	660
Kazatomprom	Mangystau	MAEC Thermal Power Plant-2	630
Kazatomprom	Mangystau	MAEC Thermal Power Plant-3	625
Samruk-Energo	Almaty	Almaty Thermal Power Plant-2	510
Sevkazenergo	North Kazakhstan	Petropavl Thermal Power Plant-2	470
Pavlodarenergo	Pavlodar	Pavlodar Thermal Power Plant-3	470
Karagandy Energocenter	Karagandy	Karagandy Thermal Power Plant-3	395
Samruk-Energo	Almaty	Kapchagay HPP	365
Aluminium Kazakhstan	Pavlodar	Pavlodar Thermal Power Plant-1	350
Astana-Energy	Akmola	Astana Thermal Power Plant-2	350
Samruk-Energo	East Kazakhstan	Ustkamenogorskaya HPP	315
Samruk-Energo	Almaty	Moynak HPP	300
ArcelorMittal	Karagandy	Thermal Power Plant-2	290
Gefest	Karagandy	Karagandy SDPS-1	250

The power plants are unequally distributed throughout the territory of Kazakhstan. 50.5% of large scale power plants (42% of total power generating capacities) are located in Pavlodar region as indicated in Figure 5.1. It seems that major power plants are mainly located in the regions endowed with coal.

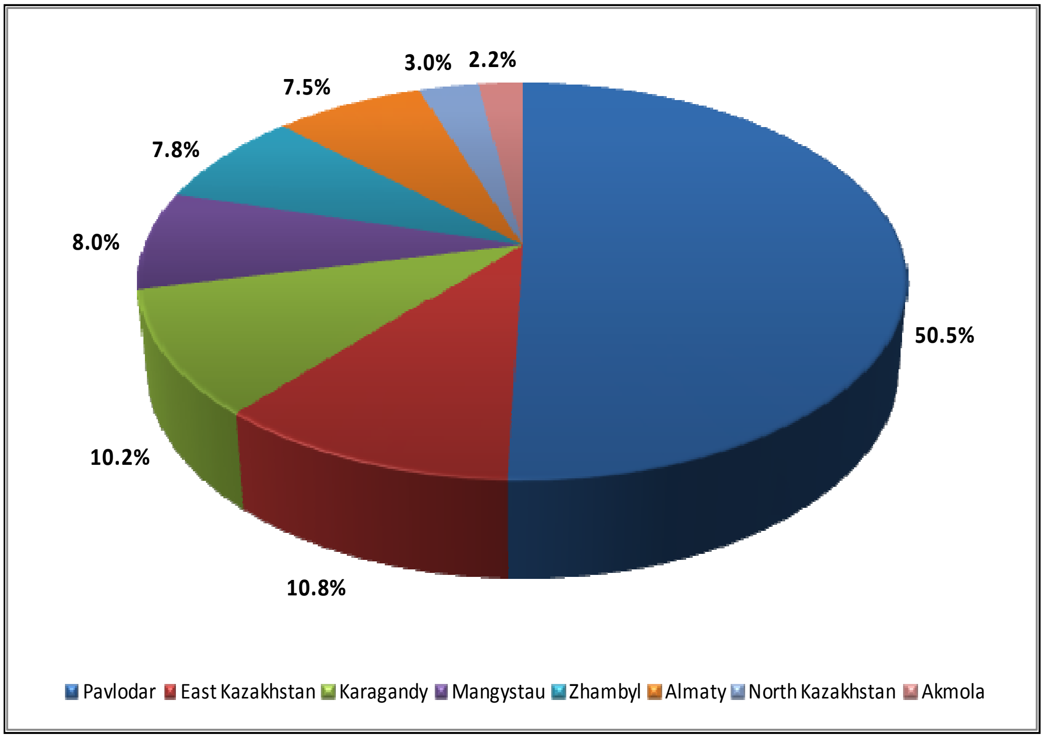


Figure 5.1 Regional distributions of large power plants

All generating capacities are the part of the unified power system of Kazakhstan, which consists of the following:

- National electrical grid of 110-220-500-1,150 kV operated by Kazakhstan Electricity Grid Operating Company (KEGOC);
- 8 power stations of national importance, which are responsible for the vast part of power production in Kazakhstan (Ekibastuz SDPS-1, Ekibastuz SDPS-2, Aksu SDPS, Karagandy SDPS-2, Zhambyl SDPS, Buhtarma HPP, Shulbinskaya HPP, Ustkamenogorskaya HPP) [131];
- 49 power plants integrated into national grid [131];
- 21 distribution utility companies [131].

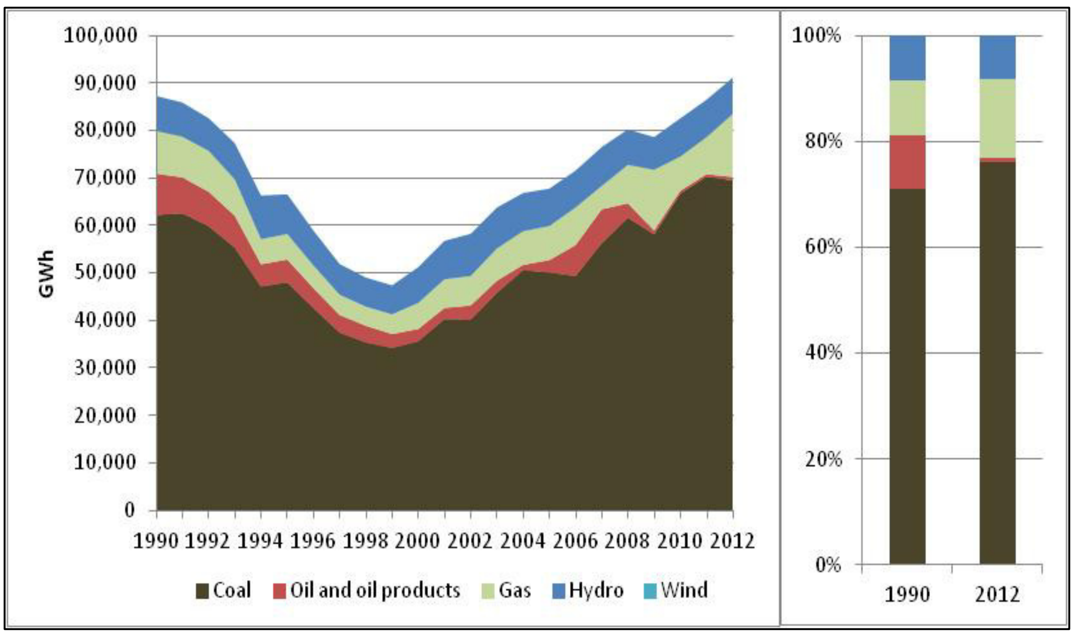
The following are the main problems of power production sectors:

- About 41% of total generating capacities are older than 30 years [132];
- Most of the existing capacities are obsolete and deterioration level has exceeded 70% [132];
- The thermal efficiency of coal-fired power plants does not exceed 30 - 32%, while the world practice has reached 42 - 53% , while the thermal efficiency of other fossil fired plants varies from 17.7 % to 37.7% [133];
- Deterioration of electrical grid and heat distribution lines by 73% and 63% respectively [134];
- Old, inefficient technologies of power generation;
- Extremely high environmental emissions associated with power generation ;
- Small share of renewable energy in the energy mix.

In order to increase investments into degrading power industry, the government of Kazakhstan has introduced "tariff in exchange for investments" approach. The method aims to encourage plant operators to promote fixed investments in exchange for electricity and heat tariffs increase. While the approach addresses renewal of the production capacities, the deterioration of distribution infrastructure leads to significant grid losses. For example, the heat distribution losses are slightly lower than 40%, which leads to increased budget costs and energy losses [134].

5.1 Electricity Generation

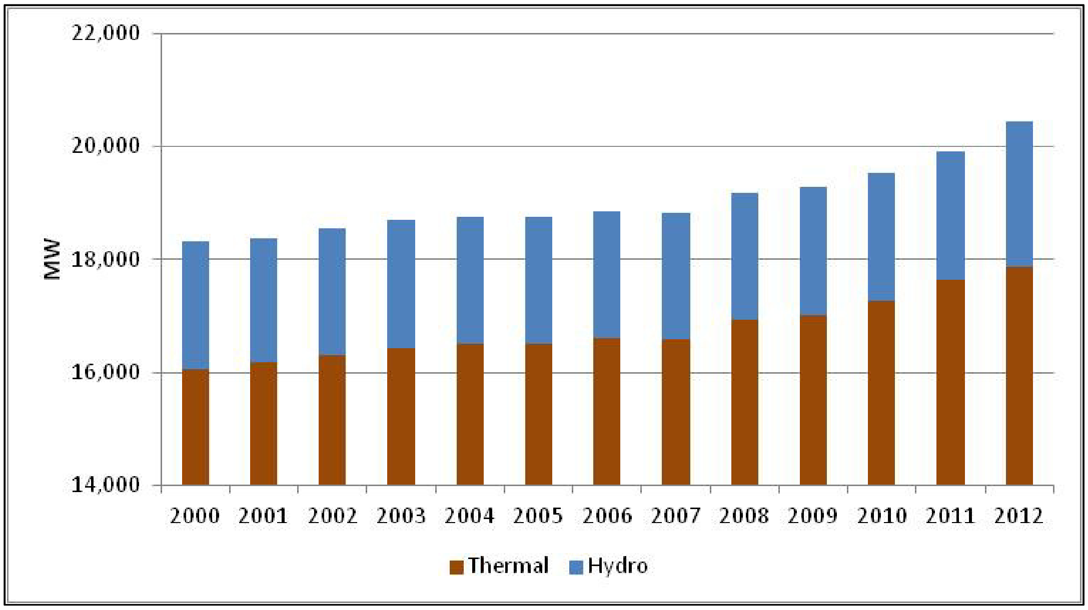
Traditionally, most of electricity generation comes from coal-fired power plants as seen in Figure 5.2. The share of coal in the fuel mix increased from 71% in 1990 till 76% 2012. Electricity production by wind was 3 GWh in 2012, less than 0.1% of the total electricity production. The share of oil and oil products reduced from 10% in 1990 till 1% in 2012. It is most probable that coal will remain the main fuel for power plants due to relatively low cost.



Data Source: IEA [22]

Figure 5.2 Electricity generation by fuel type

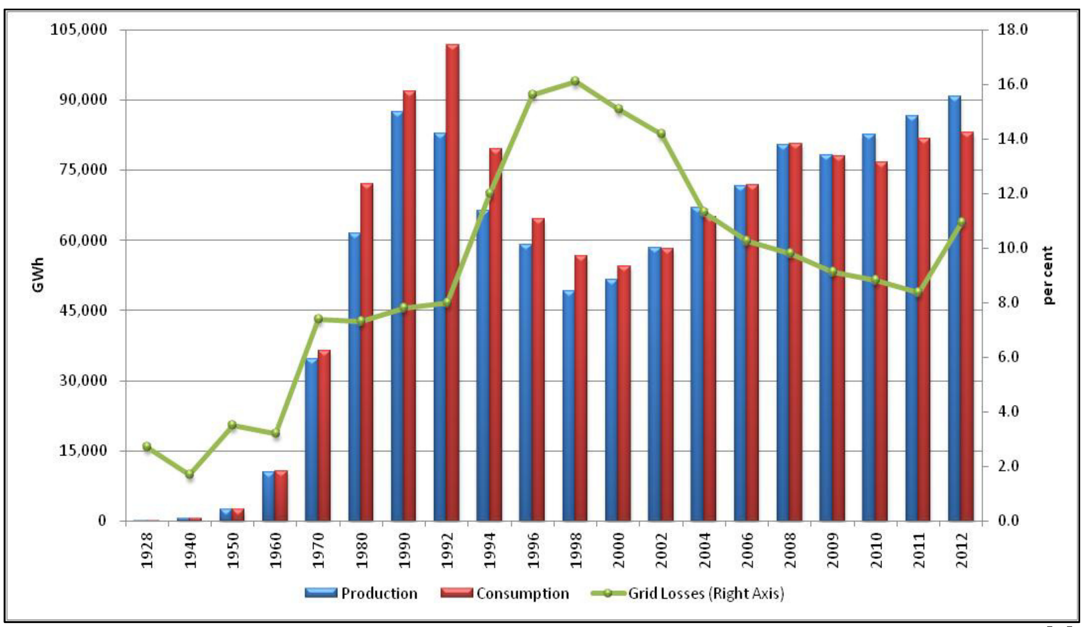
Installed capacities of electrical power plants have been steadily growing from year 2000 as presented in Figure 5.3. The average annual growth rate of total installed capacities from 2000 to 2012 was 0.9%. The growth rate of thermal power plants was 0.9% in the same period hydropower grew by 1.2%. The higher growth rate in hydropower capacities since 2010 was due to a number of newly constructed small and medium scale HPPs and the large Moinak HPP.



Data Source: the Committee on Statistics [6]

Figure 5.3 Installed capacities of electrical power plants

Until 2008, domestic production of electricity in Kazakhstan was not enough to satisfy its demand, particularly during soviet time as shown in Figure 5.4. The grid losses have reduced since 1996 due to improved grid infrastructure.



Data Source: the Committee on Statistics [6]

Figure 5.4 Historical data of electricity production and consumption

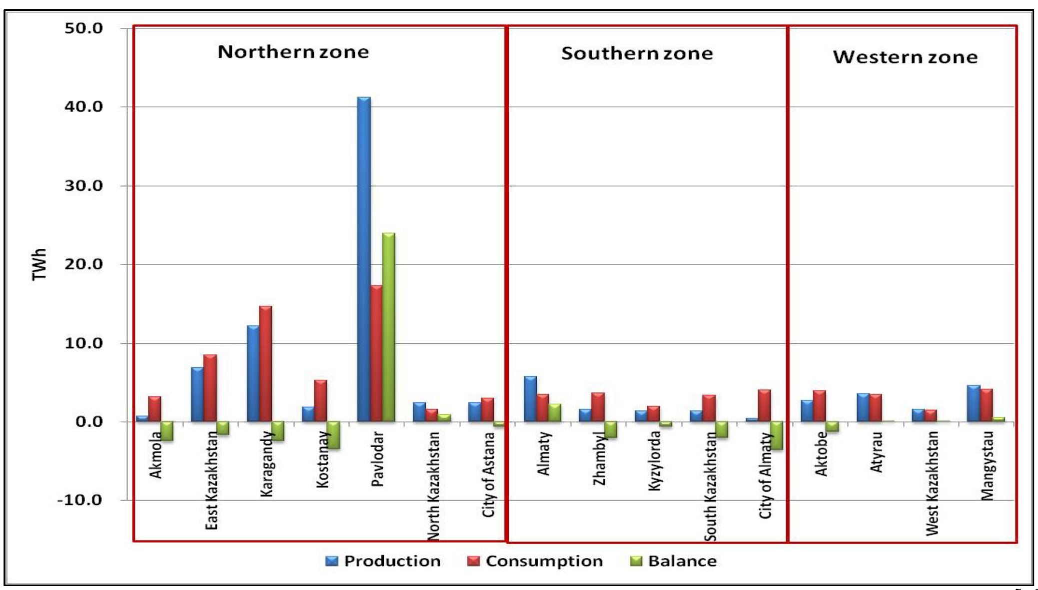
Kazakhstan is a net exporter of electricity as enlisted in Table 5.2. However, some parts of Kazakhstan have to import electricity from neighboring countries due to the lack of generating capacities to satisfy regional demand.

Table 5.2 Electricity Balance in Kazakhstan, GWh

Year	Production	Imports	Exports	Domestic Supply	Energy Industry Own Use	Losses	Final Consumption
2000	51,635.1	6,026.9	3,292.6	54,369.4	5797.0	6914.4	41658.0
2001	55,355.8	3,636.3	2,210.1	56,782.0	7128.4	6825.9	42827.7
2002	58,289.5	2,391.6	2,521.9	58,159.1	7056.3	7255.6	43847.2
2003	63,819.3	2,448.1	4,119.1	62,148.3	8389.9	7079.0	46679.5
2004	66,894.0	3,481.5	5,319.8	65,055.8	6463.8	6839.2	51752.8
2005	67,846.9	3,518.1	3,647.8	67,717.2	6531.7	6945.7	54239.8
2006	71,656.6	3,955.0	3,730.4	71,881.2	6893.8	6650.8	58336.6
2007	76,598.1	3,383.0	3,308.3	76,672.8	7083.8	7190.8	62398.2
2008	80,326.7	2,768.0	2,482.6	80,612.1	7727.2	7113.7	65771.1
2009	78,159.2	8,716.0	2,379.0	84,496.3	7540.4	6455.6	70500.3
2010	82,629.3	2,104.6	1,560.2	83,173.7	7769.5	6612.9	68791.2
2011	86,567.1	3,405.5	1,808.7	88,163.9	9213.5	6479.4	72470.9
2012	90,613.9	2,565.7	1,273.8	91,905.8	8934.9	8915.7	74055.2

Source: the Committee on Statistics [6]

National power system consists of three territorial zones: Northern, Western and Southern. Characteristics of the Northern zone are the presence of large HPPs and large scale coal-fired power plants running on coal. The Western zone depends on large reserves of oil and natural gas produced by the own region. The Southern zone lacks of significant energy sources and the power shortfall is compensated by the imports from the Northern zone and other Central Asian countries [135]. Electricity balances of the territorial zones are given in Figure 5.5. It is shown that 75% of electricity is produced in the Northern zone, while the shares of Southern and Western zones are 12% and 13% respectively.



Data Source: the Committee on Statistics [6]

Figure 5.5 Regional electricity balances in Kazakhstan in 2012

Electricity production is estimated to grow 1.2% by 2018 [126]. The expansion of existing capacities and distribution network will be required. It is possible that the increase of electricity production will come from thermal power in a short term, while large-scale development of renewable energy possible in a long-run.

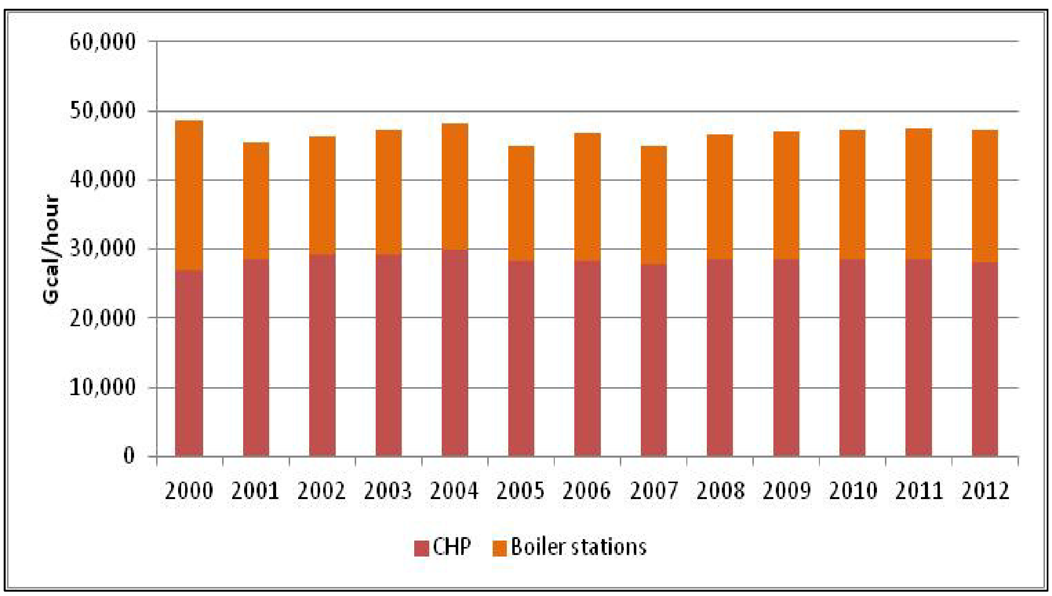
5.2 Commercial Heat Generation

Because of harsh climate of Kazakhstan in winter, a significant amount of energy (about 150 million Gcal annually) is utilized for heating purposes [136]. There are two types of heat producing power plants in Kazakhstan:

- Combined Heat and Power (CHP) plants;
- Boiler stations.

CHP plants are the dominant way of heat production due to significant economical and environmental advantages.

Figure 5.6 indicates the dynamics of installed capacities of heat producing power plants in Kazakhstan. Total installed capacities decreased on average by 0.2% annually in the period 2000-2012. Installed capacities of CHP plants on average have been growing by 0.4% annually, while boiler stations have been on fall by average 0.6% per year since 2000.



Data Source: the Committee on Statistics [6]

Figure 5.6 Installed capacities of heat producing power plants

Significant heat losses occur in the supply network and buildings. Low heat tariffs and associated low revenues present significant barriers for investments in upgrades and renovation [136]. Energy Sector Development Program to 2030 [137] expects heat consumption growth by 25% in urban areas during the period between 2005 and 2020. Therefore, installed capacities of both heat generating power plants and distribution network are expected to expand.

5.3 Life Cycle Assessment of Commercial Heat and Electricity Production

The purpose of the analysis is to determine environmental impacts from thermal power plants in Kazakhstan with regional breakdown. The course of the investigation is the system level analysis of the energy conversion chain within a system boundary. The impacts from each phase is calculated separately and summed up at the end [138].

In a country as large and as diverse as Kazakhstan, there is considerable regional variation in installed power generating capacity. The regional distribution of thermal power plant capacity varies considerably as presented in Table 5.3.

Table 5.3 Installed capacity of thermal power plants in 2005

Region	*Installed capacity, MW*	*Share of total, %*
Pavlodar	8,000	48.3
Karagandy	2,213	13.4
Mangystau	1,361	8.2
Zhambyl	1,308	7.9
Almaty	889	5.4
Akmola	456	2.7
Atyrau	432	2.6
North Kazakhstan	399	2.4
East Kazakhstan	366	2.2
Aktobe	358	2.2
Kostanay	229	1.4
Kyzylorda	216	1.3
South Kazakhstan	190	1.1
West Kazakhstan	153	0.9
Total	**16,570**	

Data Source: the Committee on Statistics [6]

70.4% of thermal power plants are installed in the Northern grid zone, followed by the Southern and Western grid zones with 15.7% and 13.9% respectively. This is due to the fact that some regions have abundant coal reserves whereas certain areas totally depend on oil products and natural gas. Several regions, particularly the southern region, rely on energy sources imported from other regions or from abroad. The environmental impacts of thermal power plants are usually dominated by the fuel production and combustion [41]. Regional fuel mix, hence, environmental burdens, air pollution in particular, vary region-to-region. Variations in regional fuel mix are presented in Figure 5.7.

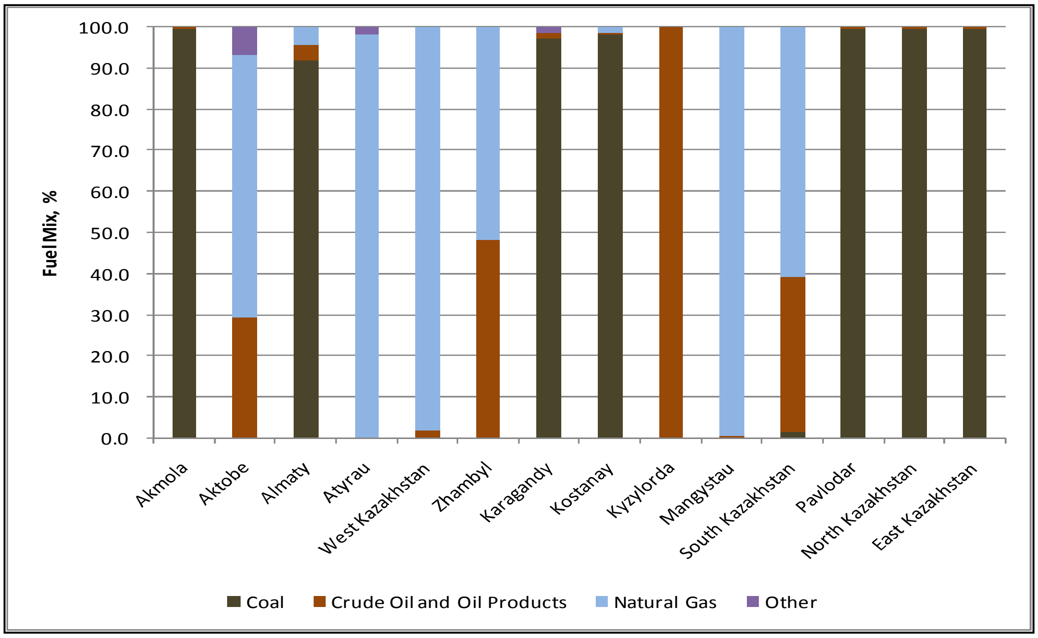


Figure 5.7 Estimated regional fuel mix in 2005

Regional assessment of environmental degradation caused by power sector allows developing effective strategic planning and policy-making. Furthermore, development of renewable energy projects in the area with higher environmental degradation would have greater environmental improving effect.

5.3.1 Goal and Scope

The goal of this study is to develop Life-Cycle Inventory (LCI) and estimate the potential reducing global warming and acidification effects for the regional electricity and heat production fuel mix in 2005. The functional units are 1 kWh of electricity (kWh_e) and 1 kWh of heat (kWh_t) produced in all 14 regions of Kazakhstan in year 2005 due to data availability. The scope of emissions covers carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), nitrogen oxides (NO_x) and sulfur dioxide (SO_2). The impact categories are: Global Warming Potential (GWP), Acidification Potential (AP) and natural resources (fuel) consumption for each region. Fuel consumption per kWh implies regional generating efficiency of thermal power plants, where higher values of fuel consumption would indicate lower generating efficiency and vice-versa. GWP and AP in 100 years time horizon are estimated using the following coefficients:

Table 5.4 Global warming and Acidification potentials of various gases

Impact Category	Species	Reference	Coefficient
Global Warming	CO_2	CO_2 equivalent	1
	CH_4		21
	N_2O		310
Acidification	SO_2	SO_2 equivalent	1
	NO_x		0.7

Sources: Houghton et al., 1995 [163]; Azapagic et al., 2004 [164]

Other air pollutants, emissions to water and solid wastes are not included into the scope due to a limitation of available data. System boundaries are pre-combustion and combustion processes in power generation system. Hydropower is excluded from the assessment due to relatively lower life-cycle environmental impact and lack of available data.

5.3.2 Data

The regional fuel mixes and regional commercial heat and electricity balances are acquired from "Techno-economic performance of power plants, hydroelectric power plants and boiler stations" annual report provided by the Committee on Statistics under Ministry of National Economy of the Republic of Kazakhstan [6]. Data in the report are collected from all economic entities in the power sector and separate fuel combustion data provided for electricity and heat produced. Total emissions from public electricity and heat production, data of fugitive emissions, emissions from petroleum refining, emissions caused by flaring from oil and natural gas production and total fossil fuels produced, distributed and refined are taken from GHG inventory submitted to UNFCCC [105].

5.3.3 Methodology

One of the methods to understand the energy supply system in a comprehensive manner is the Life Cycle Assessment (LCA) [142]. The method allows assessing environmental impacts associated with all stages of heat and electricity production. Adapted structure of LCA for the case of Kazakhstan is presented in Figure 5.8.

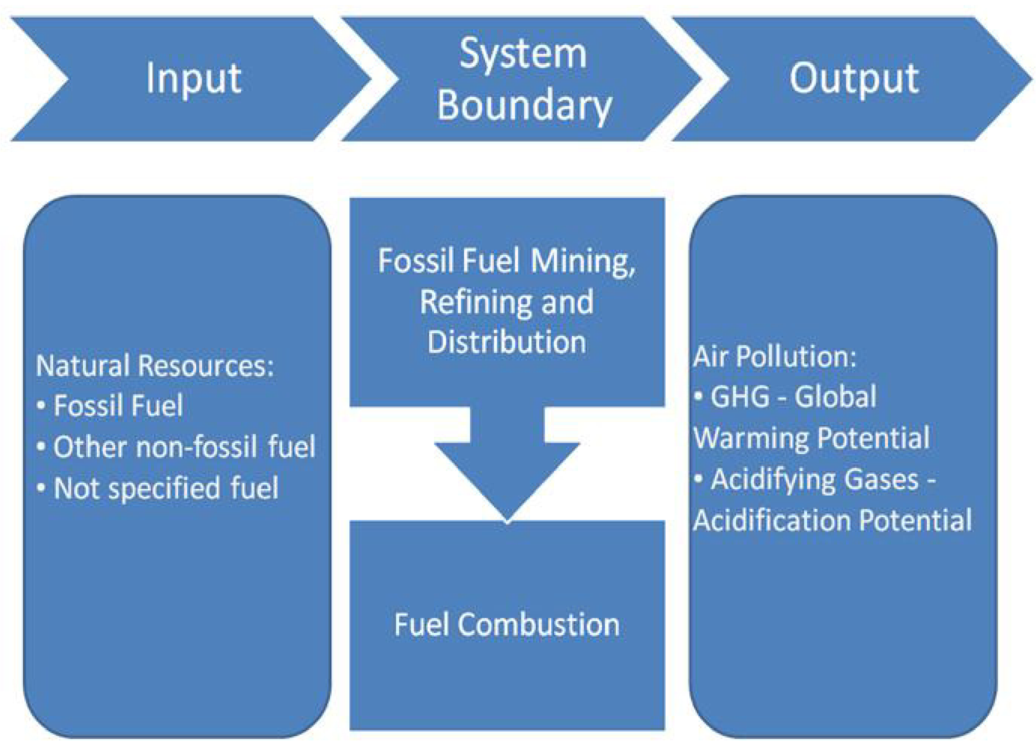


Figure 5.8 Structure of Life Cycle Assessment

In the power sector, the assessment should include extraction, processing and transportation of fuels, building of power plants, production of electricity and heat and waste disposal [143]. However, due to data availability issues, the system boundary is limited to fossil fuel extraction, processing and transportation and heat and electricity production. In the LCI phase of an LCA, all relevant data are collected and organized [144]. The outline of LCI is presented in Figure 5.9.

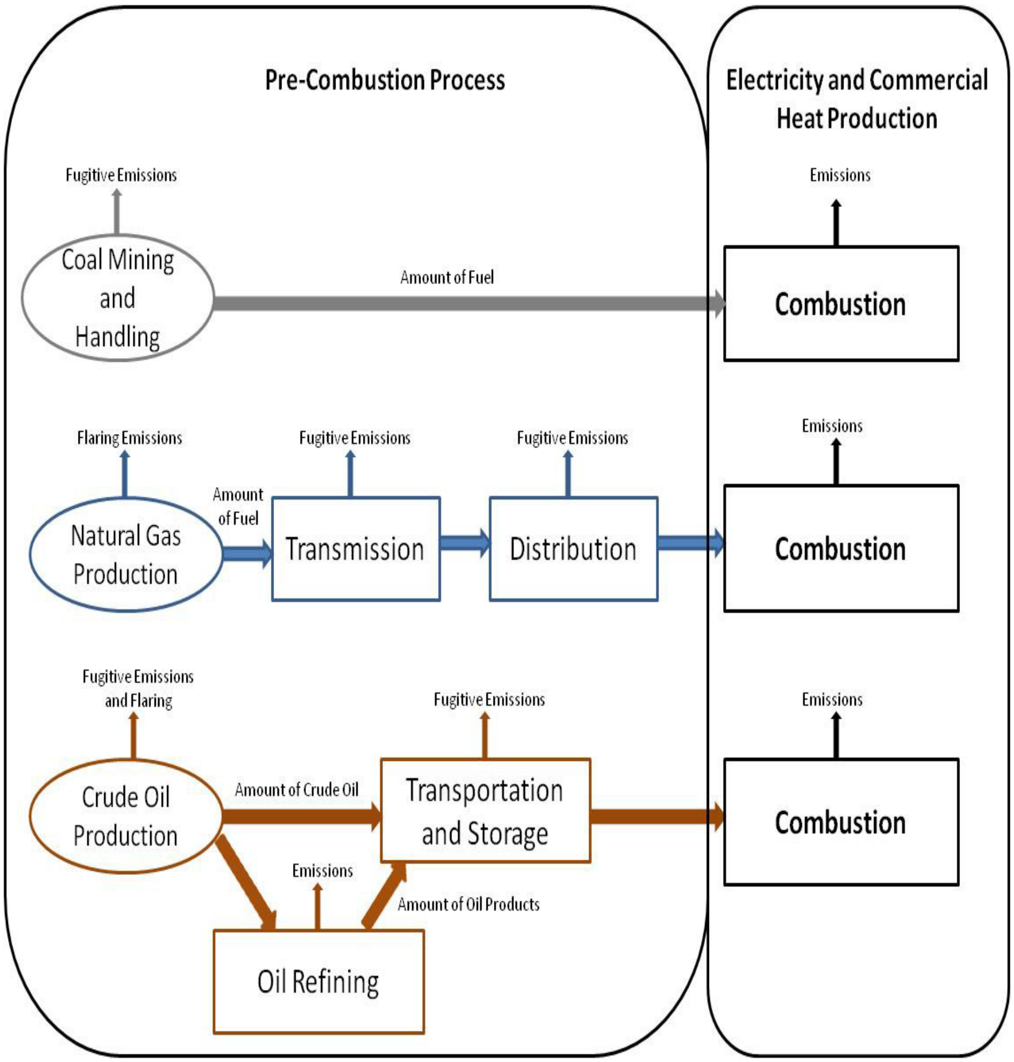


Figure 5.9 The outline of Life Cycle Inventory

5.3.4 Pre-Combustion

Pre-combustion process represents indirect emissions from electricity and heat production process. The phase combines all emissions associated with the extraction, processing, refining and transportation to the place of combustion. All activities and associated emissions included in LCI are listed in Table 5.5.

Table 5.5 Fugitive emissions from pre-combustion process

Segment	Major emission source
Oil and Gas Production Oil and Gas Wells Gathering lines Treatment facilities	Flaring; fugitive emissions from oil production.
Crude oil transportation and refining Pipelines Tankers Storage tanks Refineries	Fugitive emissions caused oil transportation by rail/sea; fugitive emissions caused by to oil refining process
Natural gas processing, Transportation, and Distribution Gas plants Storage reservoirs Transmission pipelines Distribution pipelines	Fugitive emissions from gas transportation (including transit); fugitive emissions from gas distribution.
Coal mining and handling Underground mines Surface mines	Fugitive emissions associated with mining and post-mining activities.

Source: IPCC Guidelines, 1995 [145]

Additionally, CO_2 and non-CO_2 emission intensities caused by fuel combustion during petroleum refining is estimated.

Pre-combustion emission intensities are estimated in two steps:

1) Total pre-combustion emissions related to each activity are estimated as follows:

$$\mathrm{E}_{\mathrm{PC}_{ij}} = \mathrm{EF}_i \times \mathrm{M}_{ij} \quad (5.1)$$

where $\mathrm{E}_{\mathrm{PC}_{ij}}$ is emissions related to pre-combustion activity associated with fuel *i* in region *j*;
M_{ij} is the total amount of fuel *i* consumed in region *j* in natural units;
EF_i is implied emission factor of pre-combustion activity related to fuel *i*.

2) Pre-combustion emission intensity is estimated as follows:

$$\mathrm{EI}_{\mathrm{PC}_j} = \frac{\sum \mathrm{E}_{\mathrm{PC}_{ij}}}{\mathrm{P}_j} \quad (5.2)$$

where $\sum \mathrm{E}_{\mathrm{PC}_{ij}}$ is the sum of emissions related to pre-combustion phase in region *j*;
P_j is electricity/heat produced in region *j*.

5.3.5 Combustion

Generally, emissions are estimated by multiplying fuel consumption by the corresponding emission factor [146]. Kazakh Scientific Research Institute for the

Monitoring of Environment and Climate (KazNIIMOSK), the agency responsible for the national inventories, has developed emission factors for the majority of domestically used fuels [147]. All three tiers presented in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [148] are used in Kazakhstan. In other word, IPCC default, country-specific and power plant specific emission factors are used for the national inventories.

CO_2 emissions from fuel combustion at thermal power plants are estimated by the following equation [149]:

$$E_{CO_{2ij}} = M_{ij} \times K_{1_i} \times NCV_i \times K_{2_i} \times 44/12 \quad (5.3)$$

where $E_{CO_2\,ij}$ is amount of emissions from fuel *i* in region *j* in tons;
M_{ij} is the total amount of fuel *i* consumed in region *j* in natural units;
K_{1_i} is the fraction of carbon which is oxidized during combustion of fuel *i*;
NCV_i is the net calorific value of fuel *i*;
K_{2_i} is the carbon emission factor of fuel *i*;
44/12 is conversion ratio of carbon to carbon dioxide.

CO_2 intensity is estimated as follows:

$$EI_{CO_{2j}} = \frac{\sum E_{CO_2\,ij}}{P_j} \quad (5.4)$$

where $EI_{CO_{2j}}$ is CO_2 intensity in region *j* in gCO_2/kWh.

Non-CO_2 emissions are estimated using the following equation:

$$E_{non-CO2_{ij}} = M_{ij} \times NCV_i \times K_{3_i} \quad (5.5)$$

where $E_{non-CO2_{ij}}$ is amount of emissions from fuel *i* in region *j* in tons;
K_{3_i} is non-CO_2 emission factor of fuel *i*.

Intensity of non-CO_2 emissions is estimated as follows:

$$EI_{non-CO_{2j}} = \frac{\sum E_{non-CO_2\,ij}}{P_j} \quad (5.6)$$

where $EI_{non-CO_{2j}}$ is non-CO_2 intensity in region *j* in gnon-CO_2/kWh.

Due to the lack of the statistical data and number of assumptions, error is unavoidable. The quality of the analysis is evaluated by error term. The estimation of the term is equated as follows:

$$Error_z\,(\%) = \left|\frac{E_{est_z} - E_{rep_z}}{E_{rep_z}}\right| \times 100 \quad (5.7)$$

where $Error_z$ is estimation error term for pollutant z in %;

E_{est_z} are total estimated emissions of pollutant z;
E_{rep_z} are reported emissions in the National Inventory of pollutant z.

Net calorific values, CO_2 and non-CO_2 emission factors of fuel i are provided in Appendix IV.

5.3.6 Results and Discussion

Table 5.6 shows fuel consumption to produce electricity of 1 kWh_e. Country-wide average consumption is 10.0 MJ/kW_e. The highest values are observed in Karagandy and Mangystau regions; 11.82 MJ/kW_e and 11.48 MJ/kW_e respectively. The lowest values are in East Kazakhstan, Almaty and Aktobe regions; 5.0 MJ/kW_e, 6.71 MJ/kW_e and 6.81 MJ/kW_e respectively.

Table 5.7 indicates fuel consumption to produce heat of 1 kWh_t. Country-wide average consumption is 4.29 MJ/kWh_t. The fuel consumption observed in Kostanay and South Kazakhstan regions; 5.34 MJ/kWh_t and 5.18 MJ/kWh_t respectively. The lowest values are in Atyrau and Mangystau regions; 3.60 MJ/kWh_t and 3.61 MJ/kWh_t respectively.

The contributions of all 14 regions of Kazakhstan to global warming are estimated in percentage of total life-cycle emissions related to electricity production. The results in Figure 5.10 indicate that 76.1% of GHG emissions are from Pavlodar and Karagandy regions, where share of thermal power plants are the highest. On the other hand, West Kazakhstan, Kyzylorda and South Kazakhstan have the least contribution to global warming.

Estimated life-cycle GHG intensity related to electricity production is shown in Figure 5.11. The country-wide average value is 989.7 gCO_2e/kWh_e. The biggest life-cycle GHG intensities are observed in Karagandy, Pavlodar and North Kazakhstan due to the fact that coal is the dominant fuel in the regional fuel mix. On the contrary, Aktobe region has by far the lowest life-cycle GHG intensity. Additionally, process contribution to global warming is estimated as shown in Figure 5.12.

The contributions to acidification of all regions are displayed in Figure 5.13. The results are similar to GHG emissions with Pavlodar region as the biggest contributor to acidification. On the other hand, Aktobe, West Kazakhstan, South Kazakhstan and Kyzylorda regions have the least contribution.

The life-cycle acidifying gases intensity related to electricity production are displayed in Figure 5.14. The results indicate that country-wide average is 6.2 gSO_2e/kWh_e. Karagandy, Pavlodar and North Kazakhstan have the highest intensities, while Mangystau, Atyrau and Aktobe have the lowest. The process contribution to acidification is displayed in Figure 5.15.

On the whole, life-cycle environmental impact related to electricity production is the highest in the regions where fuel mix is predominantly comprised of coal. On the contrary, the regions where oil products and natural gas are main fuel consumption have the least environmental impact. The results are also presented in the form of map in Figure 5.16 and 5.17.

Table 5.6 Natural resources consumption to produce 1 kWh of electricity

Region	Natural Resources Input, TJ					Electricity Production
	Coal	Oil and Oil Products	Natural Gas	Other Not Specified Fuel	Total	MJ/kWh_e
Akmola	15,252.64	67.61	0.00	0.00	15,320.25	7.73
Aktobe	0.00	4,581.48	9,158.79	0.00	13,740.27	6.81
Almaty	20,586.05	907.24	1,075.64	0.00	22,568.93	6.71
Atyrau	0.00	485.40	24,144.67	0.00	24,630.07	10.12
West Kazakhstan	0.00	166.23	8,380.62	0.00	8,546.85	10.53
Zhambyl	0.00	5,916.48	6,317.92	0.00	12,234.40	9.60
Karagandy	131,989.24	2,080.63	0.00	2,127.25	136,197.13	11.82
Kostanay	12,105.36	66.70	176.13	0.00	12,348.19	7.66
Kyzylorda	0.00	4,786.53	0.00	0.00	4,786.53	10.27
Mangystau	0.00	153.11	33,426.26	0.00	33,579.37	11.48
South Kazakhstan	63.83	1,177.05	1,901.55	0.00	3,142.44	8.47
Pavlodar	285,668.82	913.16	0.00	0.00	286,581.98	10.31
North Kazakhstan	18,833.92	89.22	0.00	0.00	18,923.14	9.79
East Kazakhstan	7,381.62	44.93	0.00	0.00	7,426.55	5.00
Total/Average	**491,881.49**	**21,435.77**	**84,581.58**	**2,127.25**	**600,026.09**	**10.00**

Table 5.7 Natural resources consumption to produce 1 kWh of commercial heat

Region	Natural Resources Input, TJ					Heat Production
	Coal	Oil and Oil Products	Natural Gas	Other Fuel	Total	MJ/kWh$_t$
Akmola	29,315.79	1,744.20	0.00	0.00	31,059.99	4.69
Aktobe	44.00	15,415.65	4,307.45	0.00	19,767.10	3.70
Almaty	24,979.58	6,398.26	14,451.52	0.00	45,829.36	3.96
Atyrau	0.00	2,006.98	8,456.82	0.00	10,463.79	3.60
West Kazakhstan	13.34	21.42	12,022.66	0.00	12,057.42	3.86
Zhambyl	394.35	1,125.50	5,832.52	0.00	7,352.38	4.01
Karagandy	68,279.69	5,669.24	864.70	5,621.07	80,434.71	4.89
Kostanay	12,993.86	923.45	10,990.14	0.00	24,907.45	5.34
Kyzylorda	108.04	2,144.82	0.00	0.00	2,252.85	3.91
Mangystau	0.00	63.67	11,303.04	0.00	11,366.71	3.61
South Kazakhstan	1,606.20	2,250.62	2,458.66	0.00	6,315.48	5.18
Pavlodar	57,606.74	889.43	0.00	4,247.76	62,743.93	4.27
North Kazakhstan	11,348.64	656.41	0.00	10.14	12,015.20	4.56
East Kazakhstan	33,472.49	1,457.98	0.00	0.00	34,930.46	4.07
Total/Average	**240,162.72**	**40,767.62**	**70,687.52**	**9,878.98**	**361,496.83**	**4.29**

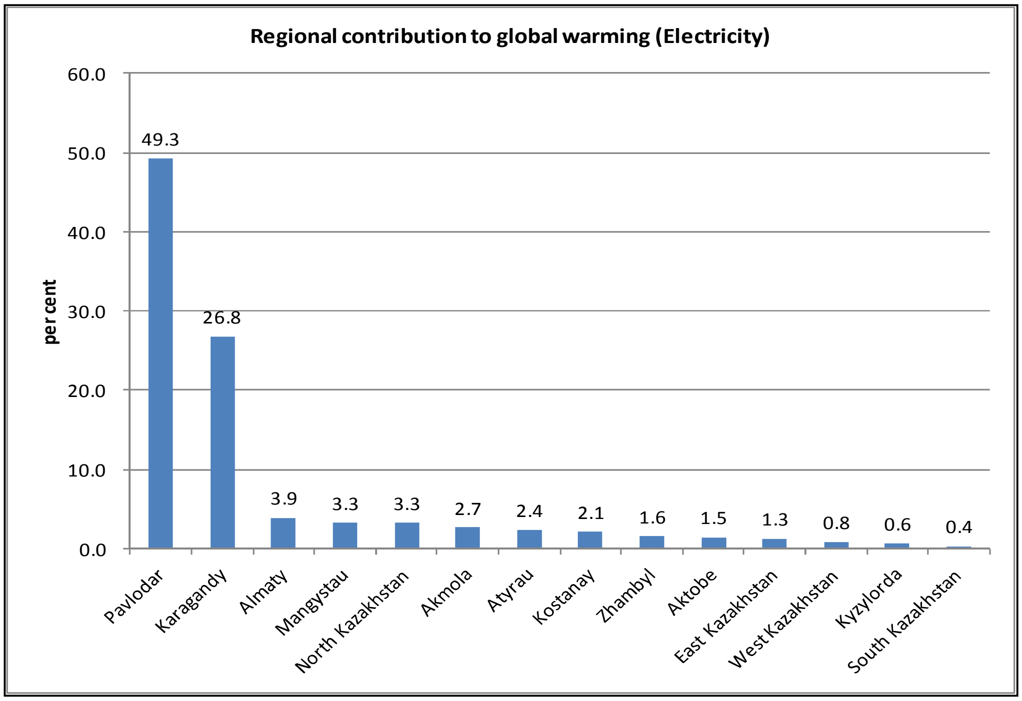


Figure 5.10 Regional contribution to global warming related to electricity generation

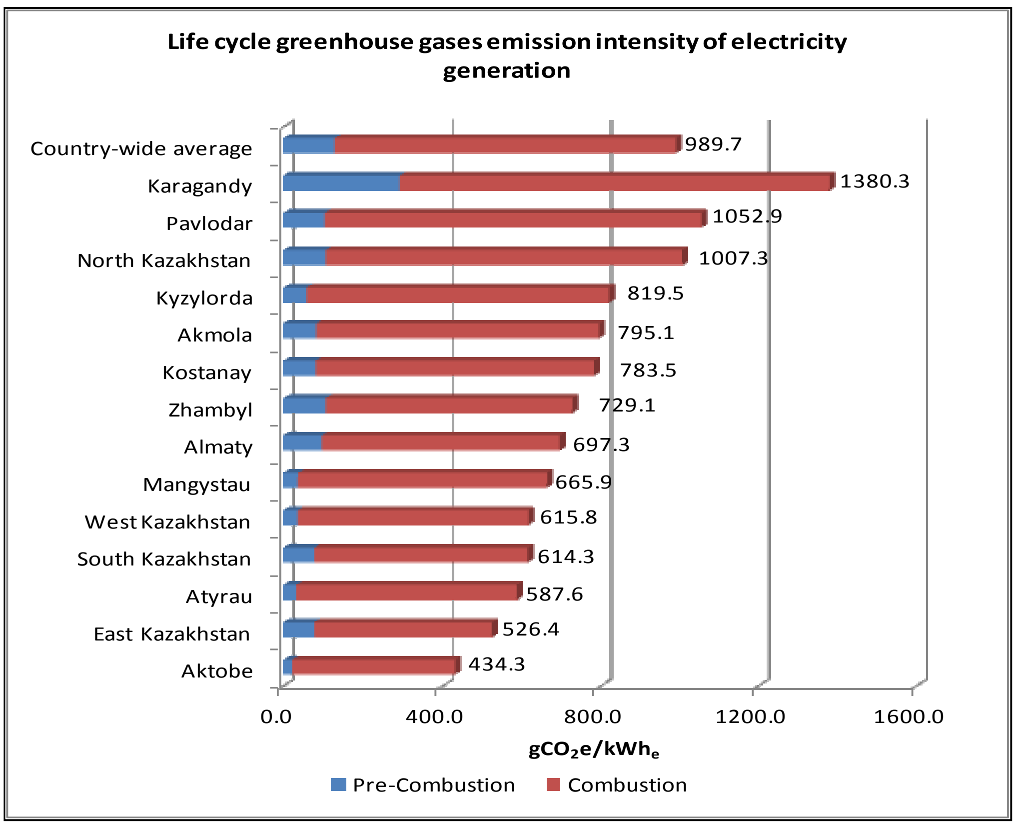


Figure 5.11 Life-cycle GHG intensity related to electricity generation

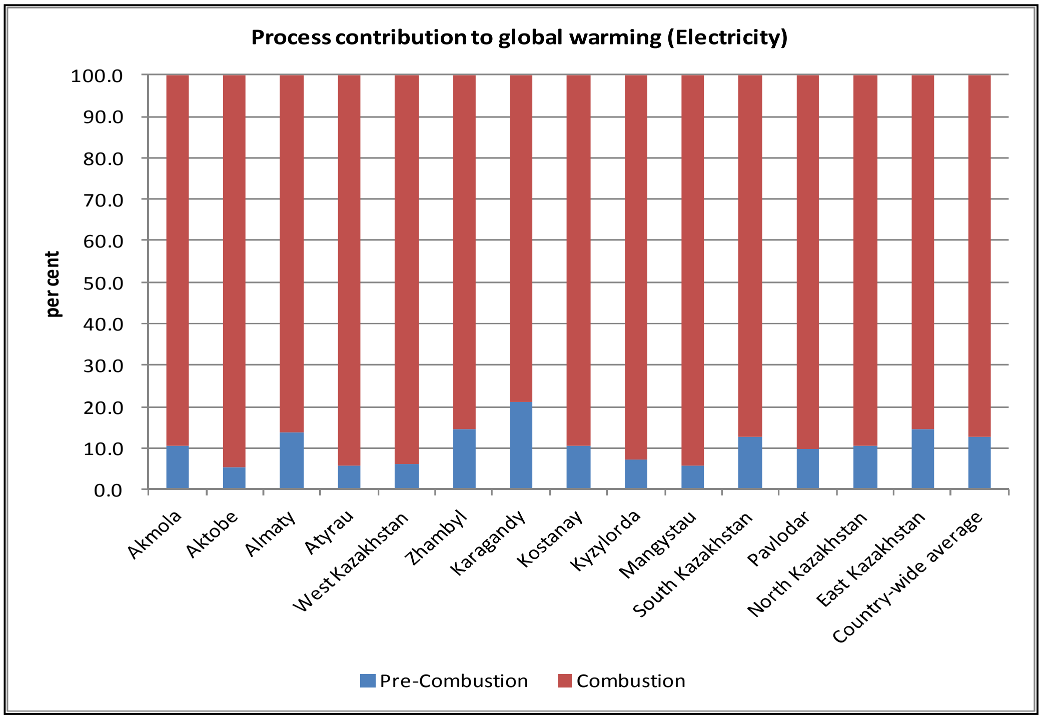


Figure 5.12 Process contribution to global warming related to electricity production

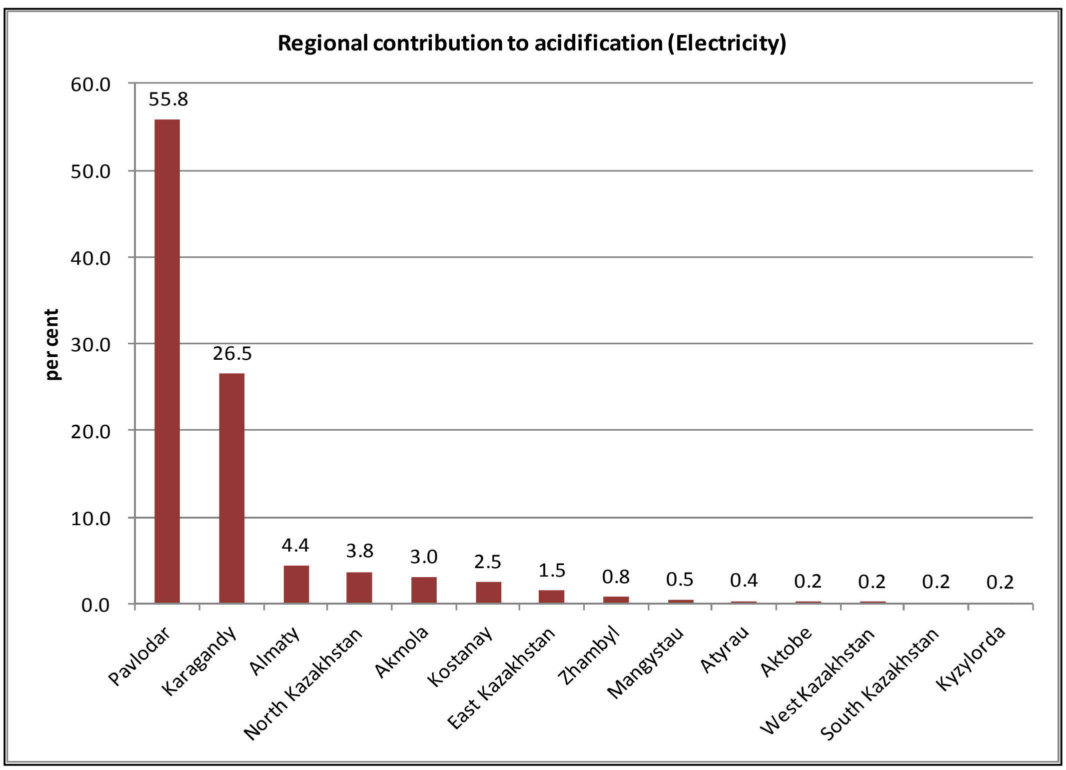


Figure 5.13 Regional contribution to acidification related to electricity production

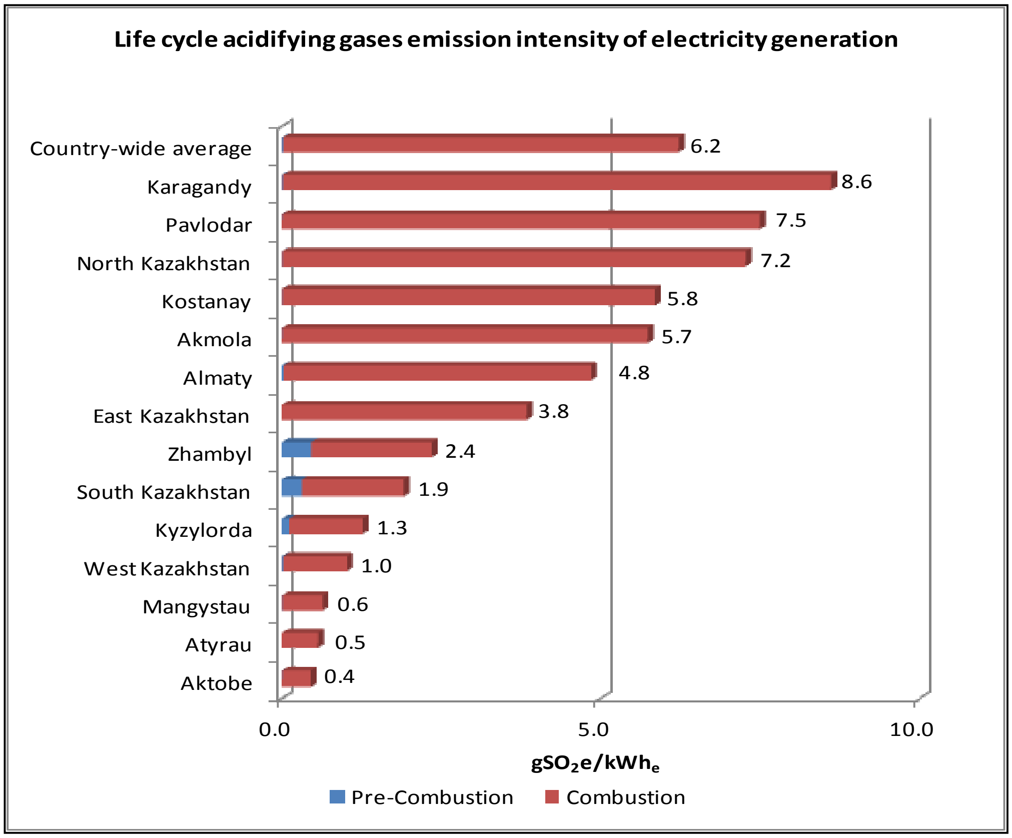


Figure 5.14 Life-cycle acidifying gases intensity related to electricity generation

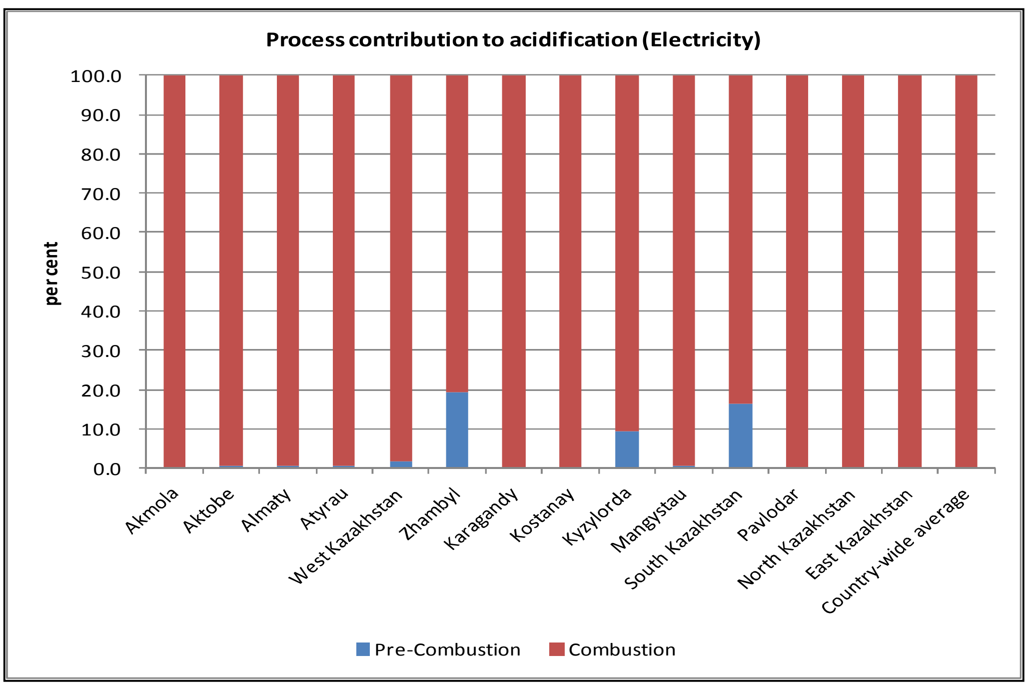


Figure 5.15 Process contribution to acidification related to electricity production

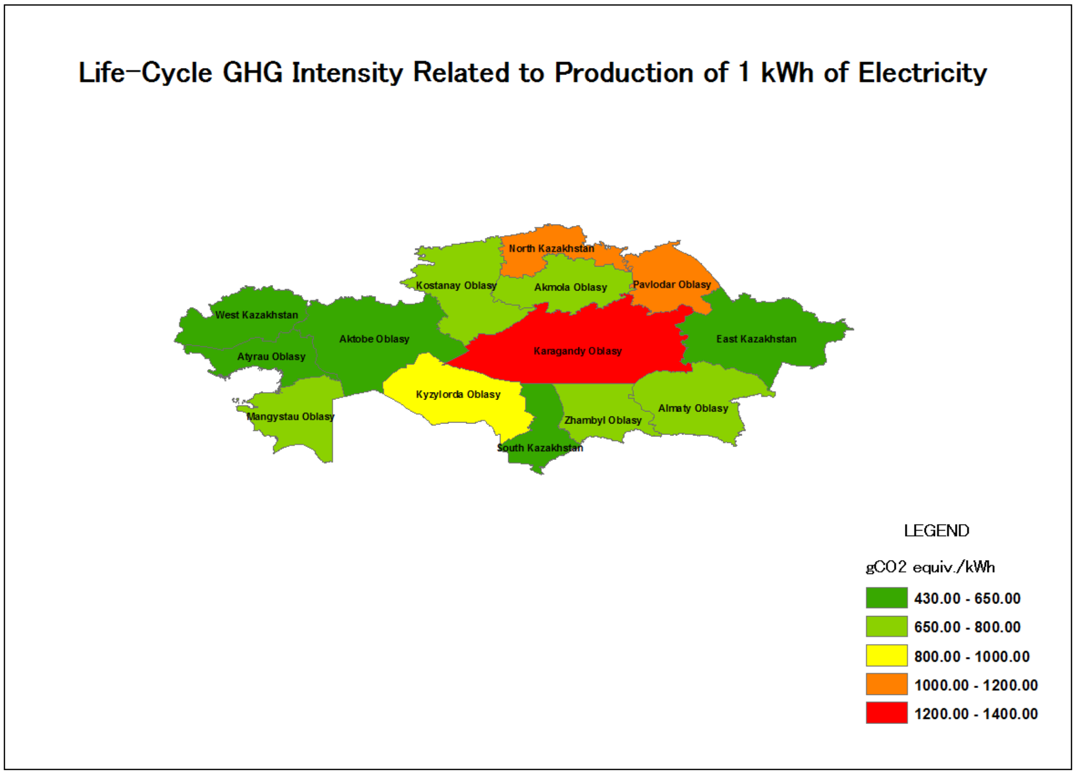


Figure 5.16 Map of regional life-cycle GHG intensity related to electricity production

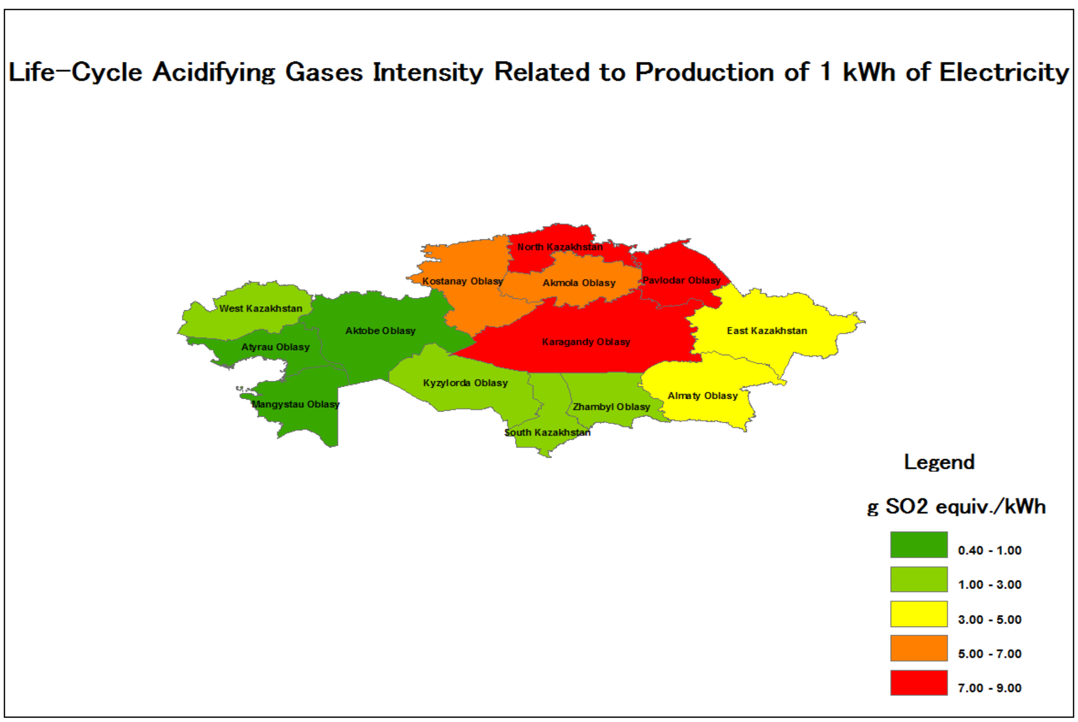


Figure 5.17 Map of regional life-cycle acidifying gases intensity related to electricity production

The results of regional contribution to global warming related to heat generation indicate that 44.5% of GHG emissions are from Pavlodar and Karagandy regions as shown in Figure 5.18. On the contrary, Kyzylorda region accounts only 0.6% of total GHG emissions.

Estimated life-cycle GHG intensity related to heat production is seen in Figure 5.19. The country-wide average value is 539.89 gCO_2e/kWh_t. The biggest life-cycle GHG intensity is observed in Karagandy, while Mangystau region has by far the lowest life-cycle GHG intensity. Additionally, process contribution to global warming is estimated as shown in Figure 5.20.

The contribution to acidification of all regions is displayed in Figure 5.21. The results indicate that Karagandy and Pavlodar in total have significant contribution, while Atyrau, West Kazakhstan and Mangystau have the least contribution to global warming.

The life-cycle acidifying gases intensity related to heat production is displayed in Figure 5.22. The results indicate that country-wide average is 2.31 gSO_2e/kWh_t. Akmola has the highest intensity, while Mangystau has the lowest. The process contribution to acidification is displayed in Figure 5.23.

On the whole, life-cycle environmental impact related to heat production is the highest in the regions where fuel mix is predominantly comprised of coal. Furthermore, these regions have harsh climate conditions; hence, demand for space heating is higher than in other regions. On the contrary, the regions in western Kazakhstan, where oil products and natural gas are main fuel, have significantly lower environmental impact. The results are also presented in the form of map in Figure 5.24 and 5.25.

The accuracy of the estimation is determined by error term in Table 5.8. The highest variations are in CH_4 and SO_2 emissions estimations. The estimated emissions of NOx have the lowest error term.

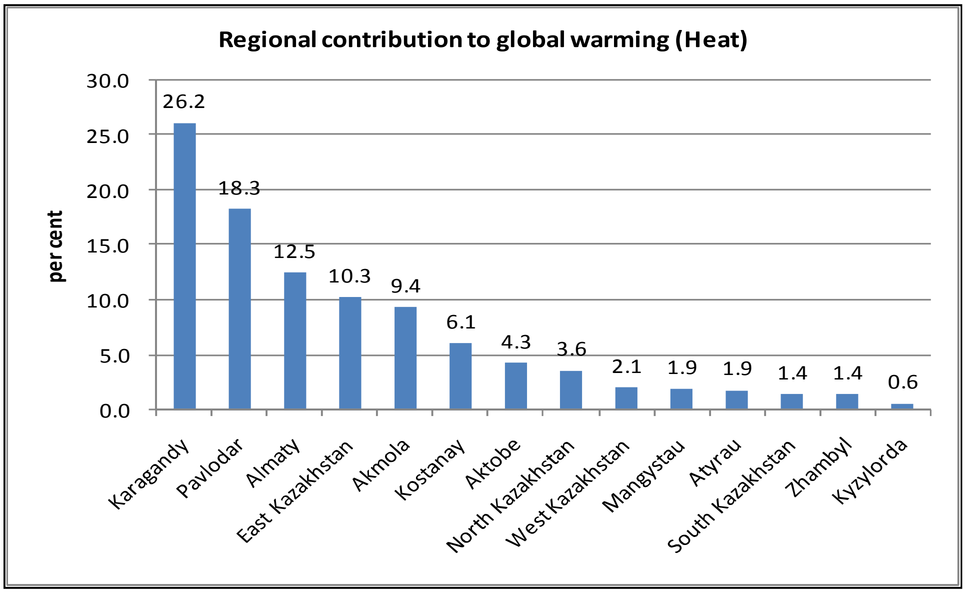


Figure 5.18 Regional contribution to global warming related to heat generation

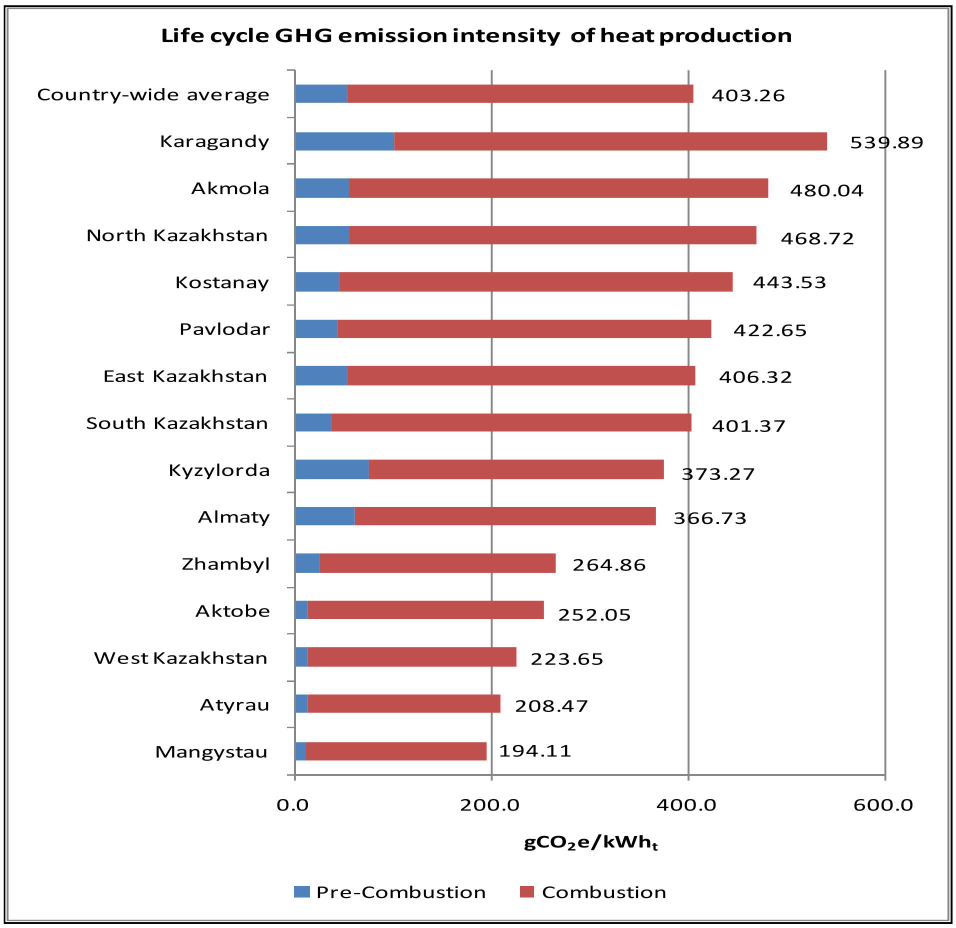


Figure 5.19 Life-cycle GHG intensity related to heat generation

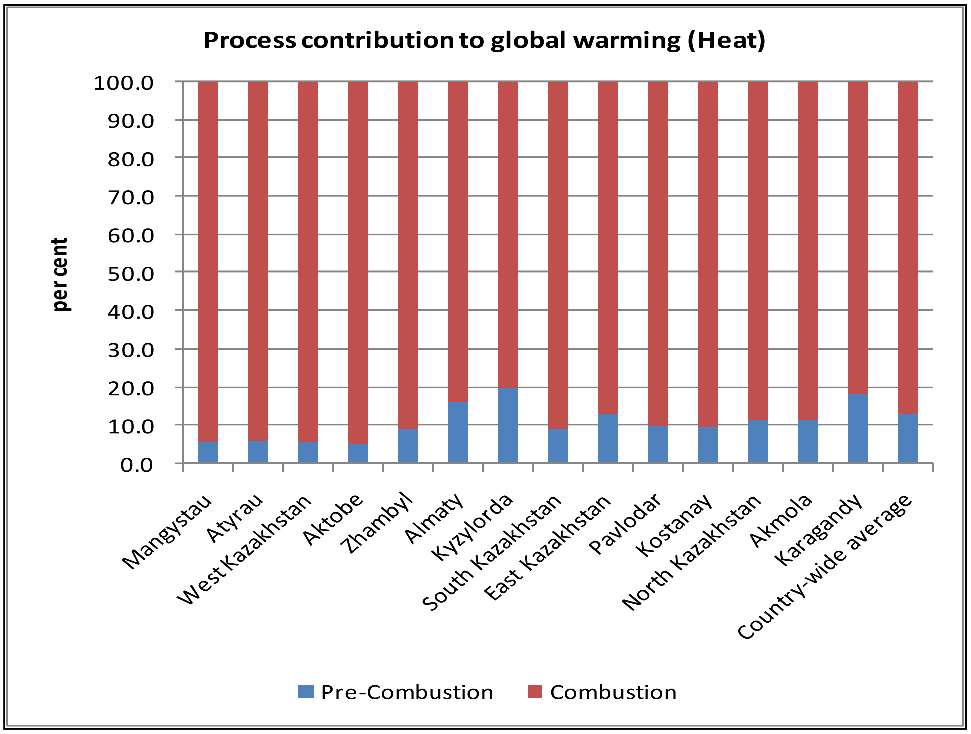


Figure 5.20 Process contribution to global warming related to heat production

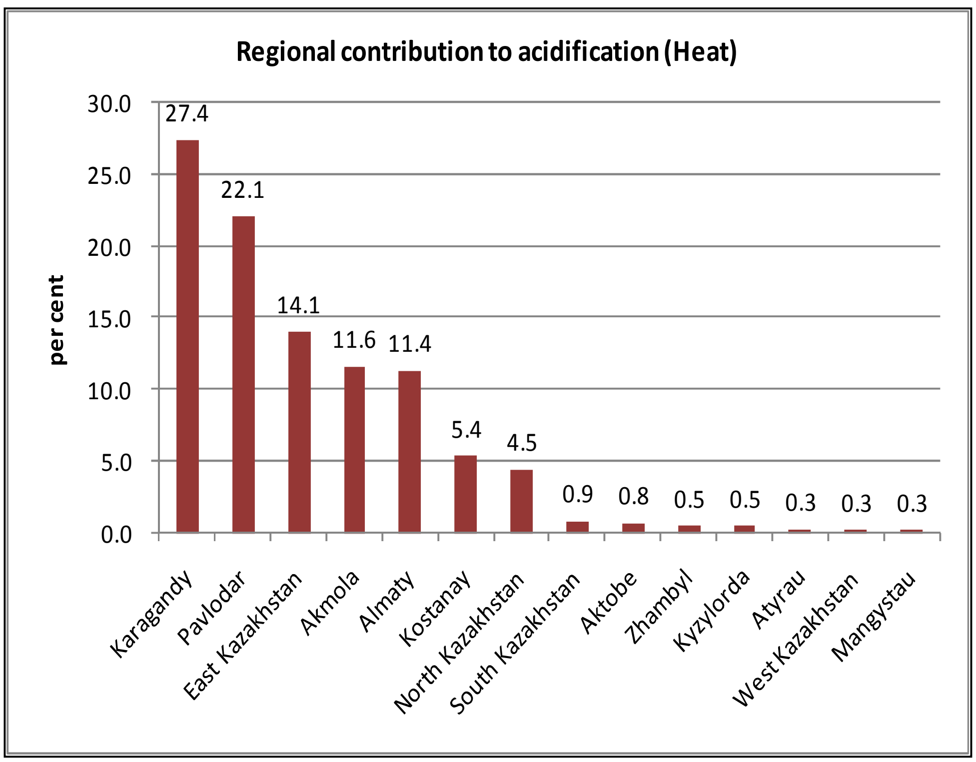


Figure 5.21 Regional contribution to acidification related to heat production

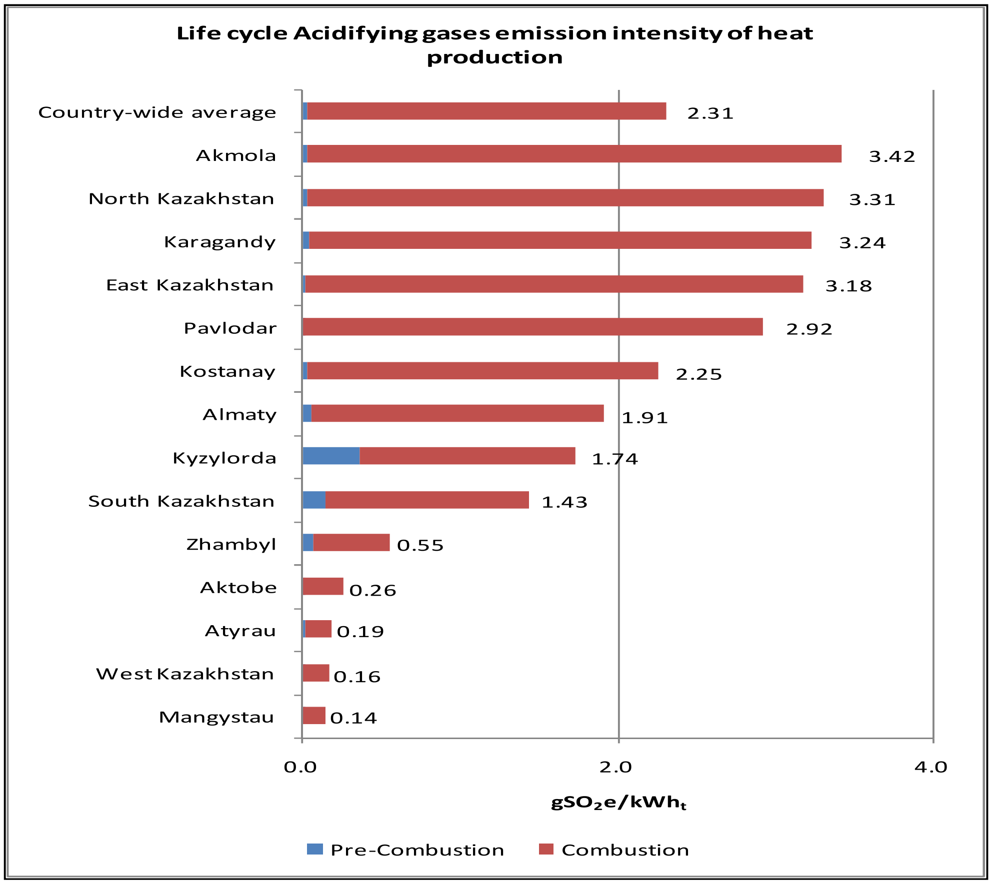


Figure 5.22 Life-cycle acidifying gases intensity related to heat generation

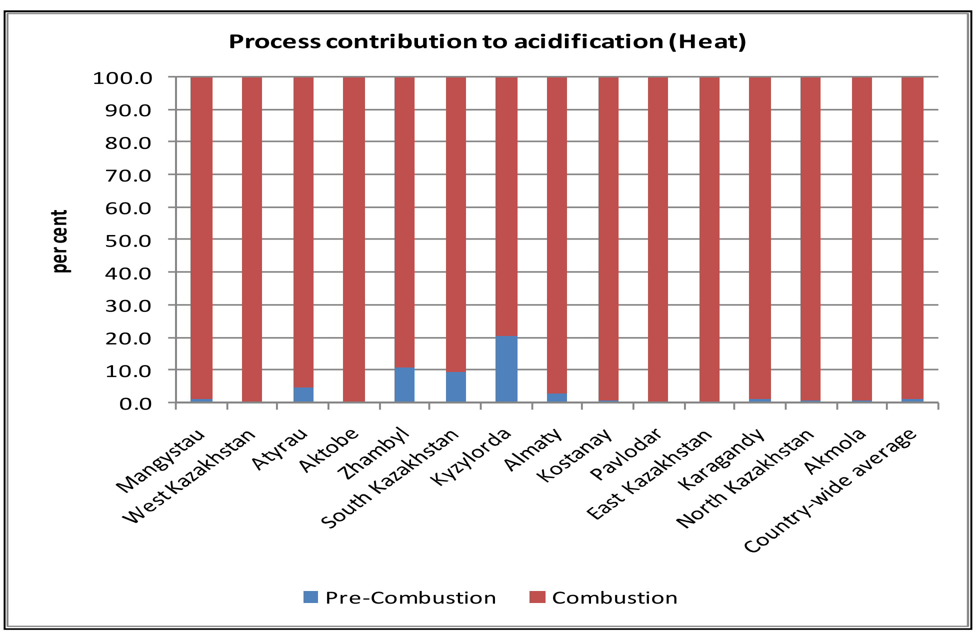


Figure 5.23 Process contribution to acidification related to heat production

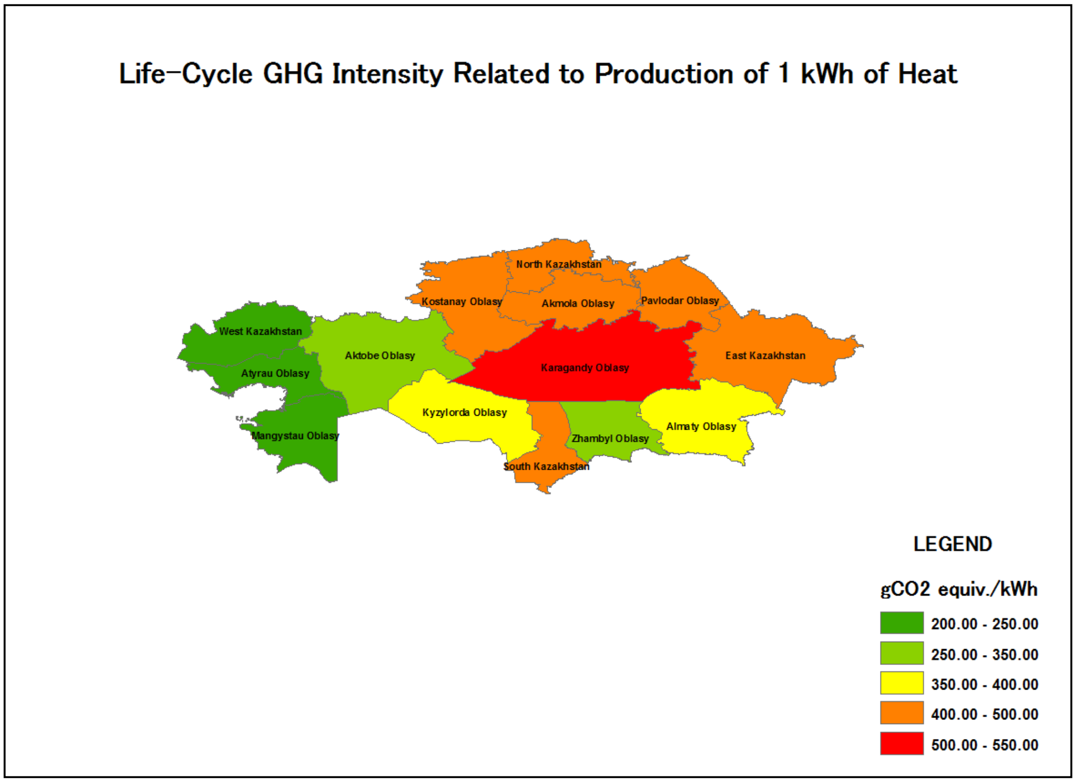


Figure 5.24 Map of regional life-cycle GHG intensity related to heat production

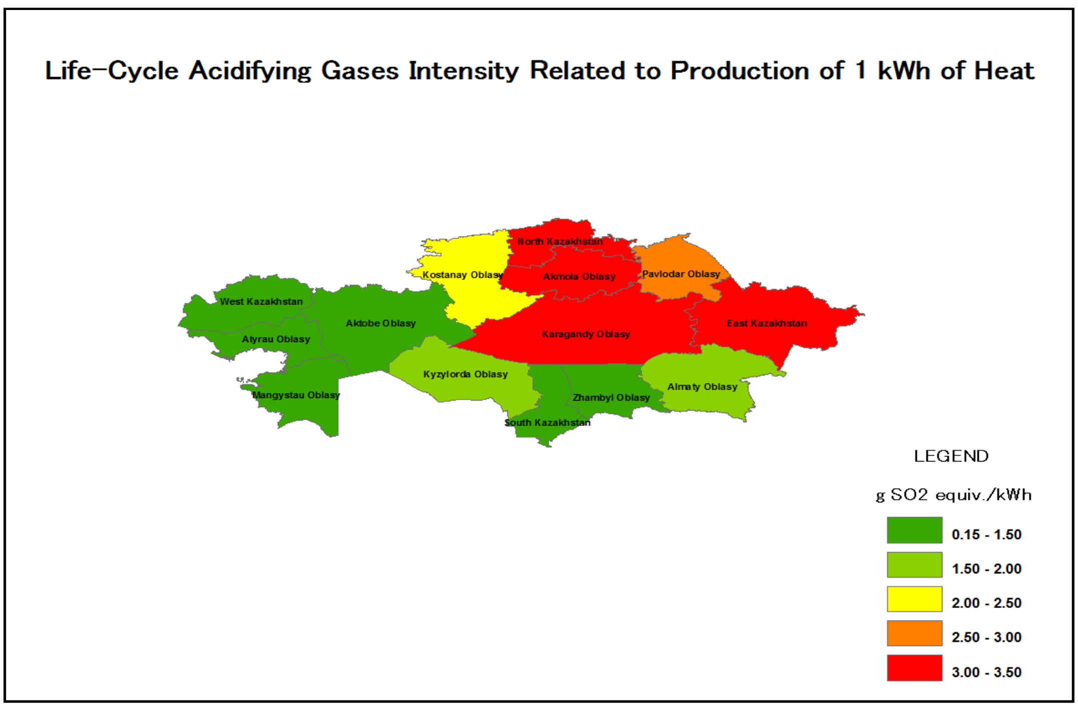


Figure 5.25 Map of regional life-cycle acidifying gases intensity related to heat production

Table 5.8 The results of error term estimation

Species	Reported, Gg	Estimated, Gg	Error term, %
CO_2	75,492.00	80,893.54	7.16
CH_4	0.98	1.07	9.41
N_2O	1.15	1.08	6.39
NO_x	162.93	160.63	1.41
SO_2	417.14	451.40	8.21

The results of assessment clearly show that there is a large variation of regional emissions and intensities. Therefore, the use of country-wide average intensity for emissions reduction potential assessment of a new technology or policy does not reflect the actual situation. Hence, the regional emissions intensity should be used for such assessment due to the size and diversity of the regional energy systems.

5.3.7 External Costs of Power Production

Climate change policies are, although primarily intended to reduce GHG emissions, often have other co-benefits [150-151]. Inclusion of the co-benefits can have significant impacts on the cost effectiveness of environmentally friendly technologies.

Environmental pollution and GHG emissions from the use of fossil fuels constitute a threat to health, the environment and sustainable economic growth. Several studies [152-157] have indicated that it is cost effective to consider such impacts during planning phase of energy systems than to pay for the resulting damage. The negative environmental effects of fossil-fired thermal power plants have traditionally not been reflected on the cost of electricity and heat in Kazakhstan.

One of the most comprehensive methodologies to attribute monetary values to the external costs is the European Union's ExternE projects [158]. However, the existing studies suggest that the co-benefits in developing and emerging countries are probably more significant than those in developed countries [159-160]. Given the similar energy system that highly depends on coal consumption, external cost factors of pollutants from thermal power plants in China are the most suitable for the case of Kazakhstan. Benefit transfer method [161] is used to transfer external costs for China to Kazakhstan:

$$\mathrm{E_{P(Kazakhstan)}} = \mathrm{E_{P(China)}} \times \left(\frac{\mathrm{PPP_{Kazakhstan}}}{\mathrm{PPP_{China}}}\right)^{\gamma} \tag{5.8}$$

where $\mathrm{E_P}$ is the external cost factor for airborne pollutant P, PPP is the GNI per capita adjusted for PPP and γ is the income elasticity, which assumed to be 1.0, giving the benefit transfer ratio 1.728. External cost factors for China are acquired from Zhang et al. (2007) [162] (Appendix IV). Exchange rate used for calculation is USD/KZT 186.

The estimation of external costs of electricity production associated with emissions of CO_2, NOx and SOx outlines the significant differences among pollutants and pollutants as well as regions. The external costs associated with CO_2 emissions are considerably higher than associated with NOx and SOx emissions. The regions with higher share of coal in the fuel mix impose higher external costs than other regions as seen in Figure 5.26. The total country-wide average external costs related to electricity production account for 23.18 KZT/kWhe.

Like electricity, the external costs of commercial heat production associated with emissions of CO_2, NOx and SOx outlines the significant differences among pollutants and pollutants as well as regions. The external costs associated with CO_2 emissions are considerably higher than associated with NOx and SOx emissions. The regions with higher share of coal in the fuel mix impose higher external costs than other regions as seen in Figure 5.27. The total country-wide average external costs related to power production account for 9.18 KZT/kWh_t.

Primarily coal consuming regions have significantly higher environmental impact. Consequently, the external energy costs of power generation differ from region to region. It is most likely that coal production and consumption cause the highest socio-environmental damage.

Precise estimation of country-specific external costs of energy production is a lengthy multidisciplinary process that requires significant funds and involvement of a large team of scientists. It is unlikely that assessment of socio-environmental damages will take place in Kazakhstan in near future. In order to fill the knowledge gap in this field, assessment of a long-term relationship between coal industry and respiratory health is proposed.

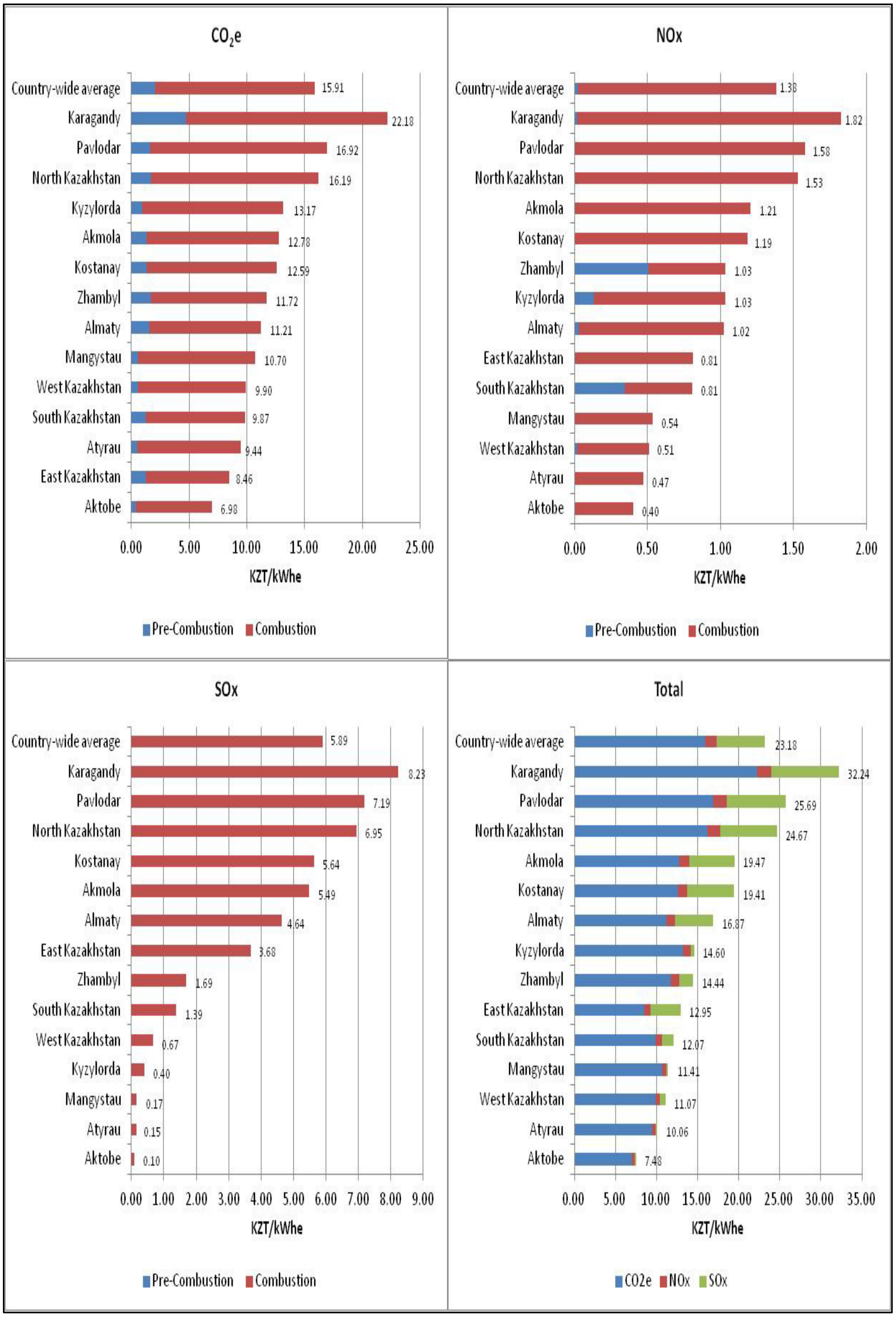


Figure 5.26 The results of external costs estimation related to electricity production

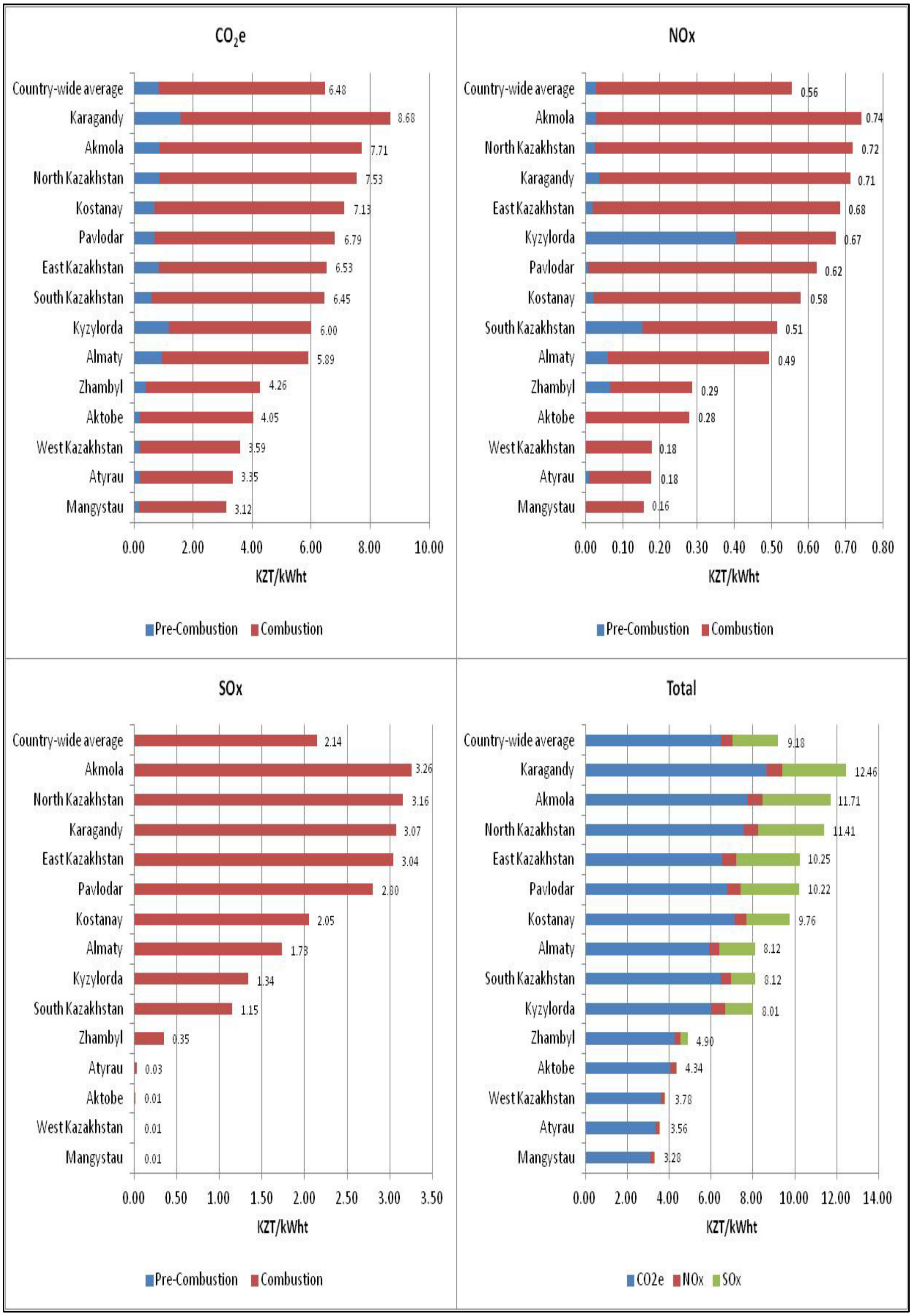


Figure 5.27 The results of external costs estimation related to heat production

5.4 Health Effects of Coal: A Long-Run Relationship Assessment of Coal Production and Respiratory Health in Kazakhstan

World oil and natural gas prices turned the hydrocarbons into the valuable commodities and the source of the national revenue, while the domestic demand is satisfied by locally produced coal. Hence, the negative effects of coal production and consumption in Kazakhstan should be assessed. Furthermore, the causes of the carbon intensity of the Kazakh industry should be investigated. With exception of western Kazakhstan, where oil and gas are the main products used for the power production, in all other parts of the country coal is the primary source for the power generation and space heating.

Coal is being actively replaced by cleaner sources of energy worldwide and Kazakhstan is among countries implementing a low-carbon development strategy and designing a law aimed at promoting renewable energy. Despite this fact, Kazakhstan is most likely to maintain the current status quo with regards to the coal consumption due to significantly low cost of extraction and transportation. It makes coal a dominant source of energy in the country.

Due to the unequal distribution of the reserves of fossil fuel in Kazakhstan, there are areas in the country where coal is the only source of energy, particularly in the heating season. This fact also produces large seasonal cost variations in such areas. Individual residences, where no centralized heating system is available, burn coal in self-made coal stove to heat their homes. Coal combustion in the residential sector for space and water heating is not inventoried as point sources. However, this process is the main source of the indoor air pollution in coal-dependent regions of Kazakhstan. Most domestic coal stoves are of poor quality as shown in Figure 5.28.

Figure 5.28 Typical home-made coal stoves used for space heating in rural areas of Kazakhstan without centralized heating system

Visible cracks and dirt deposits on the stoves may indicate the presence of indoor air pollution. Furthermore, the low temperature of the combustion and short chimneys may indicate that air pollution disperses downward and increases near the ground. Hence, the pollution is localized and causes a degradation of the regional environment.

Respiratory diseases, like asthma and other chronic obstructive pulmonary disease, claim over 50 thousand lives annually in Kazakhstan according to national statistics [6]. Respiratory diseases are the most commonly diagnosed diseases in Kazakhstan, and account for 42% of the total registered diseases [6]. The statistics indicate that respiratory disease causes substantial burden on the economy and health of the country. In 2004, the disability-adjusted life year (DALY), an overall disease burden measure, due to non-communicable respiratory diseases was the 9th biggest in the world, or 1.6 times bigger than world average [163]. Although there are different causes of respiratory diseases, the coal industry is very often the main cause in regions, where coal is the main fuel [164].

The existing research on air pollution and health deterioration are mainly regional and city level studies [165-169]. The studies indicate a strong relationship between air pollution and induced health problems in the short- and long-term. The existing studies [170-171] also support the evidence of the relationship between health conditions and air quality. Furthermore, studies on indoor air pollution impact on health in developing countries [172-173] also prove the connection between the variables. Most of the regional and national studies have identified that poor people, ethnic minorities, children and elderly people are most vulnerable to air pollution impacts. Ren & Tong (2008) made a thorough overview of recent epidemiology research developments and methodological issues on health effects of ambient air pollution [174].

Health impacts of coal industry from various locations worldwide are comprehensively described by Finkelman et al. (2002) [175]. The examples provided in the study suggest that coal-related health problems are becoming serious issue in emerging and developing countries, where cheap coal is the main fuel for the economies. Generally, the studies about the coal industry impact on health and well-being of people could be divided by life cycle stages of coal: mining and storage [176-178], combustion at the power plants [179-180] and full life cycle [181-182].

The literature on health effects of the coal industry in Kazakhstan primarily describes the health status of the coal miners [183]. Dahl & Kuralbayeva (2001) indicated that the coal production and use are the main causes for the environmental degradation in the industrial regions of Kazakhstan [184]. Kenessariyev et al. (2013) estimated the mortality attributed to air pollution caused by total suspended particles in 11 cities across Kazakhstan [185]. The study utilized a log-linear concentration response function to estimate air pollution attributed mortality with other mortality causes in the country. The study revealed that the premature mortality caused by air pollution in Kazakhstan is significantly higher than in Russia and Ukraine. It was suggested that coal consumption was the main cause of such result. Furthermore, the results indicated that Almaty had the highest number of deaths attributed to air pollution in Kazakhstan. Despite the limitations of the study (such as significant uncertainties, use of total mortality without looking at the causes and not including other pollution compounds) it lays a basis for a scientific foundation for further studies on air pollution effects in Kazakhstan. To the best knowledge of the author, there is no research about the possible impact of the coal production and use on the respiratory health in

Kazakhstan.

The empirical analysis presented here helps to define which factor is the main cause of growing number of respiratory diseases in Kazakhstan. The variables tested are production of commonly produced fossil fuel and the number of automobiles in Kazakhstan. In this study, fossil fuel production data is used instead of consumption data as coal industry has negative impact on respiratory health throughout the entire life cycle.

5.4.1 Methodology

The empirical assessment is based on testing long-term relationship between registered respiratory disease instances and production of different fossil fuels (coal, oil and natural gas) and number of automobiles in Kazakhstan, while utilization of the Vector Error Correction Model (VECM) helps to define the short-term dynamics of the variables.

For testing purposes, all data was converted into natural logarithms and the results can be interpreted in growth terms. The analysis is performed using ordinary regression analysis as follows:

$$LRD_t = \begin{cases} \beta_1 + \beta_2 LCP_t + u_t \ \text{(I)} \\ \beta_3 + \beta_4 LOP_t + u_t \ \text{(II)} \\ \beta_5 + \beta_6 LGP_t + u_t \text{(III)} \\ \beta_7 + \beta_8 LA_t + u_t \ \text{(IV)} \end{cases} \tag{5.9}$$

where LRD_t , LCP_t , LOP_t , LGP_t and LA_t represent natural logarithms of total respiratory diseases, coal production, oil production, natural gas production and number of automobiles for year t respectively. This step allows to select the independent variable that creates long-term equilibrium with dependent variable LRD. In other words, it aims to define which of the causes of air pollution has the biggest impact on respiratory diseases in the long-term.

In order to test short-run dynamics of the variables, the VECM is utilized. The analysis is performed in four steps:

a) Verification of the order of the integration of the variables as the co-integration test is only valid for variables of the same order of integration. The Augmented-Dickey-Fuller (ADF) [99] and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) [186] tests are used for the purpose. While ADF test is a test for a unit root, the KPSS test is designed on the basis of the null hypothesis that a series is stationary. The KPSS test compliments the results of ADF test due to short time series data. The KPSS test is defined as the sum of deterministic trend (t), a random walk (r_t) and a stationary error term as follows [187]:

$$y_t = \xi t + r_t + \varepsilon_t \tag{5.10}$$
$$r_t = r_{t-1} + u_t \tag{5.11}$$

where ε_t is error term of the first equation, which is assumed to be stationary and u_t is an error term of the second equation, which is assumed as a series of identically distributed independent random variables of expected value equal to zero and constant variation $\hat{\delta_u}^2$. The null hypothesis assumes that δ_u^2 of the random walk process r_t=0; if ξ=, the null hypothesis states that y_t is stationary around r_0; if $\xi \neq 0$, the null hypothesis means that y_t is stationary around a linear trend; if $\delta_u^2 > 0$, then y_t is non-stationary and a unit root is present.

b) When all of the series are integrated at the same order, the Johansen maximum likelihood method [100] is used to test the co-integration between the variables. The co-integration of variables indicates the presence of long-run equilibrium relationship between the variables.

c) The VECM is used to correct disequilibrium in the co-integrated relationship by means of error-correction term (ECT), as well as test for presence and direction of long- and short-run Granger causality among co-integrated variables. The VECM for the model (5.9-I) is specified as follows:

$$\Delta LRD_t = \gamma_{10} + \sum_{i=1}^{m_1} \gamma_{11i} \Delta LRD_{t-i} + \sum_{i=1}^{n_1} \gamma_{12i} \Delta LCP_{t-i} + \delta_1 \mathrm{ECT}_{t-1} + \mu_{1t} \quad (5.12)$$

$$\Delta LCP_t = \gamma_{20} + \sum_{i=1}^{m_2} \gamma_{21i} \Delta LRD_{t-i} + \sum_{i=1}^{n_2} \gamma_{22i} \Delta LCP_{t-i} + \delta_2 \mathrm{ECT}_{t-1} + \mu_{2t} \quad (5.13)$$

where

$$ECT_{t-1} = LRD_{t-1} - \alpha_0 - \alpha_1 \mathrm{LCP}_{t-1} \quad (5.14)$$

The sign Δ is the first-difference operator; the optimal lag lengths m_i and n_i are determined using the AIC process; and coefficients δ_1 and δ_2 measure the speed of return to equilibrium of the variables LRD and LCP respectively.

d) In the last step, the quality and robustness of the VECM model presented is assessed. Known problem with the AIC-based VECM model is the possible model misspecification caused by unstable parameters [96, 188]. Hence, the parameters consistency needs to be addressed by using the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests.

5.4.2 Data

This study collects annual data on total respiratory diseases, coal production, oil production, natural gas production and number of automobiles for the period between 1990 and 2009. The data source for respiratory disease is the medical statistics database developed by MedInform Ltd. [189]. Information on oil and natural gas production is derived from the BP Statistical Review of World Energy [30], while data on coal production is taken from the Committee on Statistics of the Republic of Kazakhstan [6]. Summary statistics of variables used in the study are given in Table 5.9.

Table 5.9 Summary statistics of variables, 1990-2009

Variable	Mean	SD	CV (%)
Total respiratory diseases	4,220,490.95	639,033.59	15.14
Coal production (thousand tons)	92,918.61	21,105.11	22.71
Oil production (million tons)	41.55	19.90	47.91
Natural gas production (billion m^3)	9.51	4.64	48.81
Number of automobiles (thousand)	1689.39	585.80	34.68

Note. CV is the coefficient of variation.

The trends of time series shown in Figure 5.29 and indicate steady decline in all series from the beginning in 1990 to almost the end of 1990s and start to increase in 2000, with natural gas production exhibiting the most related variation and respiratory disease exhibiting the least related variation as displayed in Table 1. Oil and natural gas production for export is the main source of the economic growth in Kazakhstan and has significantly increased since 1990, while coal production volumes are still lower than in the pre-independence period (1990-1991). About 50% of natural gas and almost 90% of all oil produced in Kazakhstan go for export [30], while coal is predominantly for domestic use. Growing population wealth resulted in a significant increase of the number of cars in the 21st century, and number of total diagnosed respiratory diseases has been steadily increasing too since 2000.

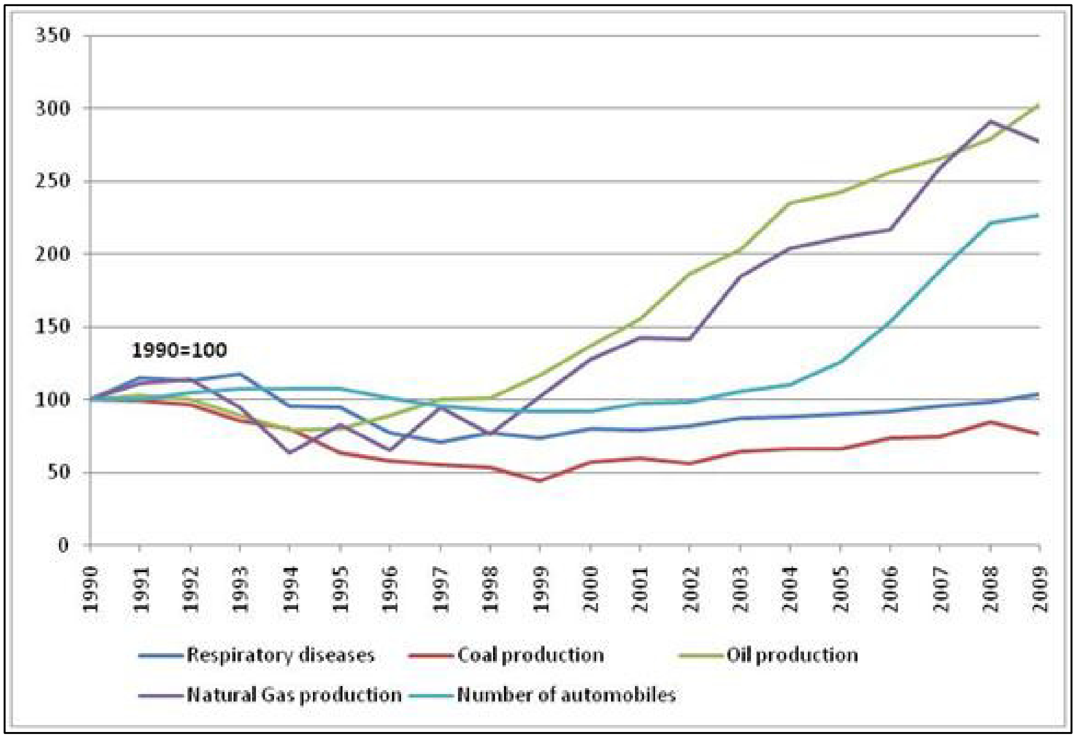


Figure 5.29 The series plots of total respiratory diseases, fossil fuels production and number of cars in Kazakhstan, 1990-2009

5.4.3 Empirical Findings

The results of regression analysis indicate that coal production has a much greater impact on respiratory diseases than other variables. Coal production contributed to the increase of the respiratory diseases to 81.8%, followed by road transport which contributed to only 14.2% of the respiratory diseases as shown in Table 5.10.

Table 5.10 Coefficients of Equation 5.9

Model	Independent variables						
	LCP	LOP	LGP	LA	Intercept	R^2	95% CI
(5.9-I)	0.603*** (8.980)				8.365*** (10.916)	0.818	0.462-0.744
(5.9-II)		0.007 (0.089)			15.221*** (55.916)	0.001	-0.150-0.163
(5.9-III)			0.059 (0.823)		15.117*** (95.425)	0.036	-0.09-0.211
(5.9-IV)				0.198 (1.724)	13.784*** (16.260)	0.142	-0.043-0.439

Note: Numbers in parenthesis indicate *t*-statistics. *** indicate a 1% level of significance. CI – confidence interval.

The insignificance of the oil and natural gas impact on respiratory disease could be explained by the fact that the fossil fuel is the primary source of the export and coal is the main domestic fuel of the economy. Furthermore, it is likely that the variable LA is more significant for urban areas.

The time series properties of LRD and LCP are checked through both ADF and KPSS unit root tests. The results of both tests indicate that both series appear to contain unit root in their levels but stationary in their first difference, indicating that they are integrated at order one i.e. $I(1)$ as displayed in Table 5.11.

Table 5.11 Results of unit root tests

	ADF test		KPSS test	
Variable	Level	1st difference	Level	1st difference
LRD	0.745	-2.577**	0.569***	0.070
LCP	-0.570	-3.793***	0.322***	0.072

Note. ** and *** indicate that the null hypothesis is rejected at 5% and 1% level respectively. The optimal lag lengths are selected using AIC.

The results of Johansen's co-integration test the presence of co-integration between the variables as seen in Table 5.12. The results indicate that there is a long-run equilibrium relationship between respiratory diseases and coal production, and the normalized co-integrating vector with respect to LRD is (1, 0.603) as in Table 5.10. This implies that 1% increase in coal production results in 0.603% increase in respiratory diseases. Hence, the respiratory diseases appear to be coal production elastic. The evidence of co-integration also indicates that the estimated model (5.9-I) does not lead to spurious regression results, and the estimated parameters are super-consistent.

Table 5.12 Results of Johansen's co-integration test

Variables: LRD and LCP					
Eigenvalue	**Trace Statistic**	**5% critical value**	**Max. Eigen Statistic**	**5% critical value**	**Number of co-integration**
0.946	47.528**	15.495	43.777**	14.264	None
0.221	3.751	3.841	3.751	3.842	At most 1

Note. The optimal lag lengths are selected using AIC. ** indicates the rejection of a null hypothesis at 5% level of significance.

The existence of co-integration between the variables indicates that Granger causality exists at least in one direction [96]. However, it does not indicate the direction of causality. The VECM helps to define the directions of causal relationship. The short-run F-statistics, long-run t-statistics and joint F-statistics for Equations (5.12-5.14) are reported in Table 5.13.

Table 5.13 Results of causality tests

Dependent variables	**Source of causation**				
	Short-run *F*-statistics		**Long-run *t*-statistics**	**Joint short-run and long-run *F*-statistics**	
	ΔLRD	**ΔLCP**	**ECT**	**ΔLRD/ECT**	**ΔLCP/ECT**
ΔLRD		4.755**	-3.918**		9.471**
ΔLCP	4.211*		-1.778	4.018*	

Note. The optimal lag length is four. * and ** indicate 10% and 5% level of significance respectively.

The short-run dynamics suggest bidirectional causality from coal production to respiratory diseases and vice-versa. However, the significance of the causal relationship from coal production to respiratory diseases seems to be stronger. The estimated coefficients for ECT indicate the presence of unidirectional causality from coal production to respiratory diseases in the long-run. The joint statistics indicate Granger endogeneity and presence of strong causality from coal production to respiratory diseases. Significantly higher lag length (4 years) defined by AIC process (the most common lag length for annual time series is one) could be partially explained by the nature of the variables as the development of respiratory diseases requires exposure period to air pollution.

CUSUM and CUSUMSQ statistics plots for the variables LRD and LCP are presented in Figures 5.30 and 5.31. As it can be seen, both statistics are well within the critical bounds of 5% significance. This implies that the estimated coefficients of the VECM model are stable for duration of the estimation period. Hence, the results of the Granger causality tests based on the VECM model can be used for policy decision-making [96].

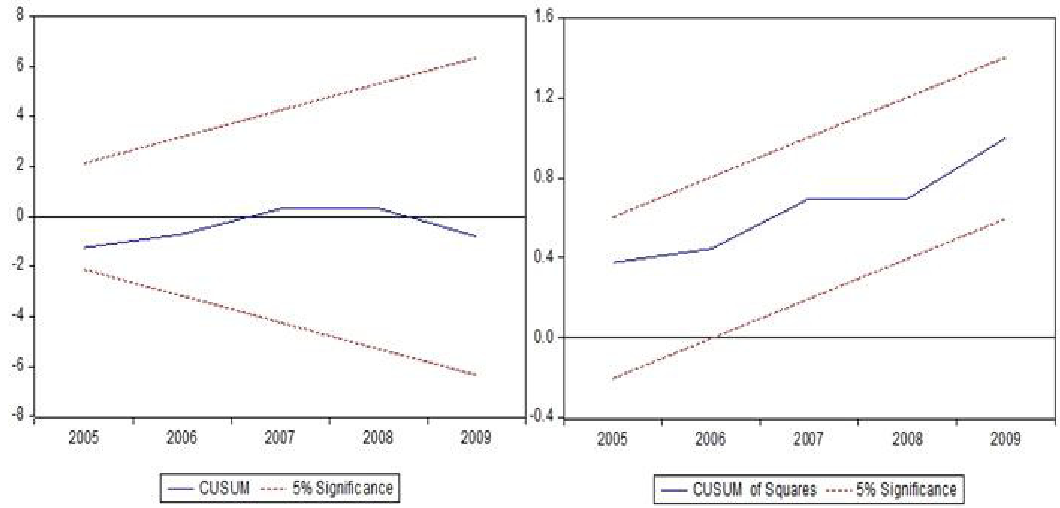


Figure 5.30 Plot of the CUSUM and CUSUMSQ statistics for a variable LRD

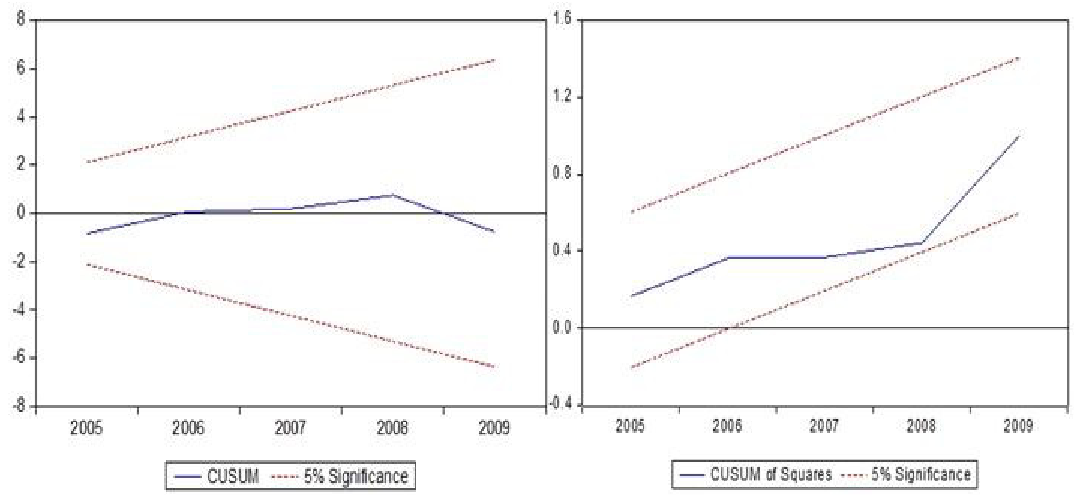


Figure 5.31 Plot of the CUSUM and CUSUMSQ statistics for a variable LCP

The results of the study indicate that among the main sources of air pollution, coal production has the biggest impact on the growing number of respiratory diseases in Kazakhstan. Furthermore, it found strong short-run and long-run Granger causality running from coal production to respiratory diseases. The results of the study could be used to better define and incorporate relevant environmental policies into Kazakhstan's development strategies.

This is a first attempt to define the relationship between the air pollution caused by coal production and respiratory health in Kazakhstan at a national level. This study should not be treated as epidemiology research on health effects of air pollution. Unlike existing epidemiology studies on the topic, this study does not intend to estimate effects of various air pollutants (particulate matters, ozone or any other pollutant) on health outcomes (health admissions or deaths). The study investigates long-term equilibrium and short-term dynamics of coal production and respiratory diseases in Kazakhstan.

The results of the research prove that the coal industry is not only the main source of global warming pollutants, but also contributes to the environmental burden of respiratory diseases in Kazakhstan. Hence, it verifies the hypothesis of coal industry's significant contribution to overall health risk attributed to air pollution proposed by Kenessariyev et al. (2013). Similar to the study conducted by Kenessariyev et al. (2013), this study also contains a relatively large uncertainty. However, the history of environmental problems in Kazakhstan and the results of the studies call to act based on the precautionary principle – in the absence of scientific certainty of damage of the action, the burden of the proof should be on the industry that stands to profit [190].

Furthermore, the results of the analysis verify the hypothesis suggested by Colagiuri and Morrice (2013) that coal-related health problems constitute a resource curse based on the evidence from Australia [191]. The extent of the problem is probably higher in less developed countries like Kazakhstan. It is likely that further reliance on coal would cause significant hike in a number of people with respiratory health problems.

Renewable energy presents the most effective way to reduce socio-environmental damage by directly substituting coal in the energy mix. Hence, the development of renewable energy projects in Kazakhstan would not only reduce emissions of hazardous substances, but would also have co-benefit in the form of improved respiratory health of the population.

5.5 Potential of Renewable Energy in Kazakhstan

The government of Kazakhstan has been pursuing the development of renewable energy in response to concerns regarding emissions from aging thermal power plants. The utilization of available renewable energy sources has been prioritized in the light of aspirations to achieve emissions reduction target. Kazakhstan has a significant potential in terms of renewable energy sources, particularly hydropower, wind and solar power, but only a small part of this potential is currently being tapped [136]. Currently, hydropower is used for producing electricity and insignificant amount of heating wood is used in heat production by heat-only boiler stations. The government forecasts construction of new medium and small capacity HPPs and construction of wind power plants.

Kazakhstan's Second National Communication to the Conference of the Parties of the UNFCCC (2009) [192] identified that renewable energy development alongside with energy efficiency is identified as the best emissions reduction technology. The use of that scenario could lead to reduction of 40-50 million tons of CO_2 by 2024. Other effective measures to mitigate GHG emissions include use of effective technologies and fuel price change.

A law on Support of the Use of Renewable Energy Sources was passed by Kazakhstan's Parliament in 2009 [193-194]. The law establishes a full regulatory framework for renewable energy sources in the country. The aims of the law are the expansion of renewable energy sector and attraction of private investments to renewable energy production by reserving land, obliging electricity transmission companies, and concluding long-term contracts for covering the transmission losses [194]. In 2014, the decree of the government of Kazakhstan on Approval of Fixed Tariffs established the following feed-in tariffs (FIT) on renewable energy: wind power – 22.68 KZT/kWh, PV – 34.61 KZT/kWh, small hydro – 16.71 KZT/kWh and biogas – 32.23 KZT/kWh [195]. This measure is expected to assist faster penetration of renewable energy technologies.

Kazakhstan's Second National Communication to the Conference of the Parties of the UNFCCC (2009) [192] estimated the preliminary costs of the carbon emissions reduction by various mitigation technologies in KZT/tCO_2. The development of small hydropower and wind energy alongside with the construction of gas turbine and steam gas power station is expected to be economically attractive option. The results of the estimation are indicated in Table 5.14.

Table 5.14 The preliminary cost assessment of the reduction of carbon emissions in the power sector of Kazakhstan

Mitigation technology	The preliminary cost, KZT/tCO_2
Restoration of existing thermal power plants	2,500-4,000
Promotion of energy saving measures	2,000-4,000
Construction of gas turbine and steam gas power stations: - Gas turbine power stations - Combined cycle gas turbine stations	 1,000-1,500 500-800
Development of renewable energy: - Small HPP - Wind power	 800-1,500 1,000-2,000

Source: National Communication to the UNFCCC, 2009 [192]

Despite the presence of the law, there is a lack of thorough understanding of the mechanisms among the local executive bodies in regions, utility companies, and financial organizations. Hence, the mechanisms of support do not function, and the law does not provide intended support to the developers of renewable energy in Kazakhstan. Therefore, authorized bodies in the area of support of renewable energy sources utilization are recommended to strictly follow their obligations described in the law [196].

The study conducted by Menegaki (2013) indicates that renewable energy could have a positive effect to growth in the countries with the resource curse conditions [197]. Furthermore, unlike oil and gas resource, renewable energy lowers possibility of a conflict over energy resources [198]. Furthermore, development of renewable energy could have overall positive effects on energy security. Hence, development of renewable energy in Kazakhstan is particularly important.

5.5.1 Solar Energy

The climate of Kazakhstan is continental with significant solar radiation. The number of sunshine hours is about 2200–3000 per year and the solar radiation is around 1300–1800 kWh/m^2 per year, which makes development of solar energy viable. Potential of solar energy in Kazakhstan is estimated at the level of up to 1 trillion kWh per year [199]. Potential of the use of solar energy for heating amounts 13 million Gcal/year [136]. However, there is a large variation in annual sunshine hours among the regions of Kazakhstan. Over 3,000 hours of sunshine per year are observed in South Kazakhstan and Kyzylorda region. On the other hand, the sunshine hours in North Kazakhstan are around 2,100. Therefore, development of solar power in southern part of the country could be economically attractive. The estimated potential of solar power in the various parts of Kazakhstan is provided below:

Table 5.15 Solar energy potential in the regions of Kazakhstan

City	Region	kW/m²/year	kW/m²/day		
			Mean	June	December
Shymkent	South Kazakhstan	1,780	4.88	7.95	1.65
Aktau	Mangystau	1,442	3.95	6.71	0.98
Astana	Akmola	1,297	3.55	6.47	0.83
Semey	East Kazakhstan	1,441	3.95	6.74	1.05
Taldykorgan	Almaty	1,703	4.76	7.40	1.58

Source: National Communication to the UNFCCC, 2009 [192]

Nowadays, the use of PV panels in residential sector is becoming popular, particularly in rural and remote areas of the country with limited access to the grid. The combination of significant solar irradiance and low population density makes solar power attractive technology option for emissions reduction. In 2011, Kazakhstan commenced construction of solar cells plant in Astana. Solar panels with the capacity of 60 MW will be produced annually with the expansion of production up to 100 MW [200]. The use of domestically produced raw materials is planned. The project should become a basis for expansion of solar power technology in Kazakhstan.

5.5.2 Biomass and Geothermal Energy

There is a large potential for development of energy production from biomass. There is an enormous amount of waste in the agro-industry of Kazakhstan. The theoretical amounts of available resources of biomass for utilization in energy production are 40 million tons of cereal straw, 3-5 million tons of cane and 3-5 million tons of other biomass, respectively. The net amount of available biomass is estimated to be around 30 million tons. This amount is equivalent to 18 million tons of coal equivalent of energy per year and the estimated emissions reduction from the use of biomass is 45 million tons of CO_2 per year [201]. The regional potential of biomass energy is presented below:

Table 5.16 Regional distribution of potential of biomass

Territorial zone	Region	Available biomass, million tons
Southern	Almaty	4.5
	Zhambyl	
	South Kazakhstan	
	Kyzylorda	
	Karagandy	
	East Kazakhstan	
Northern	Kostanay	35
	North Kazakhstan	
	Akmola	
	Pavlodar	
Western	Aktobe	2.5
	Atyrau	
	Mangystau	
	West Kazakhstan	

Source: Kim V., 2010 [201]

The use of biomass is considered as an option for providing remote villages and farmers with energy and in a number of settlements use of biogas from manure has been conducted [136]. First bioethanol plant in Former Soviet Union was opened in North Kazakhstan region in 2006 [202]. The plant was supposed to utilize wheat to produce bioethanol. However, due to the financial crisis, the project was shutdown in 2011. Despite the enormous potential of biomass energy in Kazakhstan, currently only small amount of heating wood is used for production of heat at heat-only boiler stations.

The middle- and low-temperature thermal water resources are available in some regions of Kazakhstan. Theoretical potential of geothermal energy comprises 317.6 trillion tons of coal equivalent (tce), and technically available (up to a depth of 5 kilometers) potential of thermal water resources are assessed as 4.1 trillion tce with the following temperature ranges [192]:

- 8-20 °C – 281 trillion tce;
- 20-40 °C – 332 trillion tce;
- 40-60 °C – 903 trillion tce;
- 60-90 °C – 1,239 trillion tce;
- More than 90 °C – 1,356 trillion tce.

Generally, introduction of geothermal energy is not a priority at the moment, primarily due to high investment requirements and relatively lower potential. The resource is expected to develop in the near future [136].

5.5.3 Hydropower

Generating capacity of hydroelectric power plants consists of only 12% of the total capacities. While optimal share of HPP in energy system is 15 - 20% to cover peak loads. Theoretical potential of hydropower in Kazakhstan is 170 billion kWh/year, of which 23.5 billion kWh/year are considered economically viable [203]. Water availability, hence potential of hydropower is unequally distributed as seen in Table 5.17.

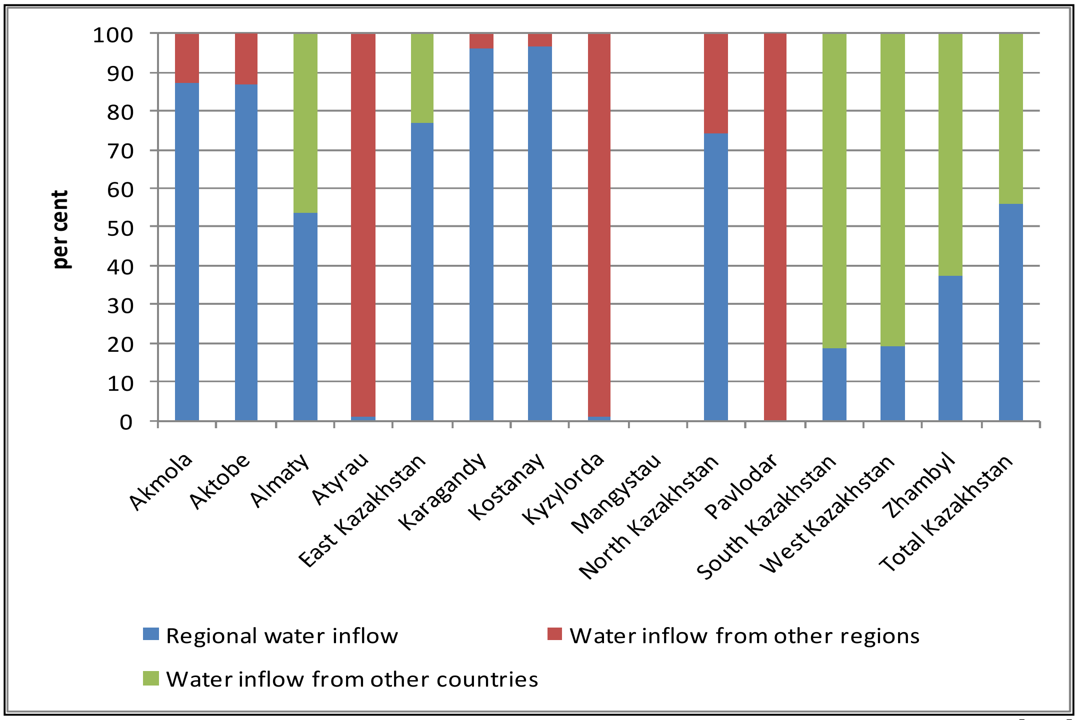
Table 5.17 Long-term regional surface water availability in km³

Region	Regional water inflow	Inflow from other regions	Inflow from other countries	Total
Akmola	1.93	0.28	0.00	2.21
Aktobe	2.83	0.42	0.00	3.25
Almaty	14.51	0.00	12.36	26.87
Atyrau	0.06	6.52	0.00	6.58
East Kazakhstan	27.54	0.00	8.11	35.65
Karagandy	1.71	0.07	0.00	1.78
Kostanay	1.49	0.05	0.00	1.54
Kyzylorda	0.11	8.12	0.00	8.23
Mangystau	0.00	0.00	0.00	0.00
North Kazakhstan	0.76	0.26	0.00	1.02
Pavlodar	0.05	29.07	0.00	29.12
South Kazakhstan	3.34	0.00	14.58	17.92
West Kazakhstan	1.67	0.00	7.06	8.73
Zhambyl	1.56	0.00	2.59	4.15
Total	**57.56**		**44.70**	**102.26**

Source: National Atlas of the Republic of Kazakhstan [204]

The studies [205-208] indicate that most of the hydropower resources are in the eastern part of Kazakhstan (Eastern Kazakhstan and Pavlodar regions) and account for 72.06 billion kWh or 41.8% of total resources, followed by southeastern part (Almaty region) with 71.56 billion kWh or 41.5% of total resources. The southern part of the country (Zhambyl, South Kazakhstan and Kyzylorda regions) has hydropower potential of 23.2 billion kWh or 13.4% of total resources.

Almost all water basins of Kazakhstan are formed to a degree by the trans-boundary rivers originating in China, Kyrgyzstan, Uzbekistan and Russia. Hence, Kazakhstan is largely dependent on its neighbors in terms of water resources. The distribution of regional surface water inflow by source is shown in Figure 5.32.



Source: National Atlas of the Republic of Kazakhstan [204]

Figure 5.32 Distribution of total regional surface water inflow by source

An intensive economic development of western China and Central Asian republics caused a growth in water demand and reduction of water inflow to the country. The conflict of interests has created water crisis in the region, in which Kazakhstan, situated downstream, is in a losing situation [209]. This is the main constraint for development of large scale HPPs in Kazakhstan. Therefore, development of small and mini HPPs on mountain rivers of the southern Kazakhstan is a preferable option [210].

5.6 Summary

This chapter intends to determine environmental impacts from power production with regional breakdown and assessment of external costs. As a part of assessment of socio-environmental damages, a long-term relationship between coal production and consumption and respiratory health is analyzed. Potentials of renewable energy by type are provided.

First, in order to assess environmental impacts associated with all stages of power industry, Life Cycle Assessment technique is applied. Life-Cycle Inventory is developed for 1 kWh of electricity (kWh_e) and 1 kWh of heat (kWh_t) produced in all 14 regions of Kazakhstan in year 2005. The emissions accounted are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) in pre-combustion and combustion phases of power production. Global Warming Potential, Acidification Potential and natural resources consumption are estimated.

The results of LCA of power sector with regional breakdown shows the existence of significant variations in environmental impact of power generation between the regions. It was identified that regions with large coal consumption in power production have large GHG and acidifying gases life cycle intensity. While, regions with predominantly natural gas utilization for power production tend to have lower environmental impact.

Second, external costs of power production are estimated using external cost factors of pollutants from thermal power plants in China due to similar dependence on coal consumption. The costs are estimated using the results of LCA analysis. Like the LCA results, external costs are higher in coal consuming regions. Both electricity and heat external costs associated with CO_2 emissions are considerably higher than associated with NOx and SOx emissions. The total country-wide average external costs related to electricity and heat production are 23.18 KZT/kWhe and 9.18 KZT/kWh_t respectively.

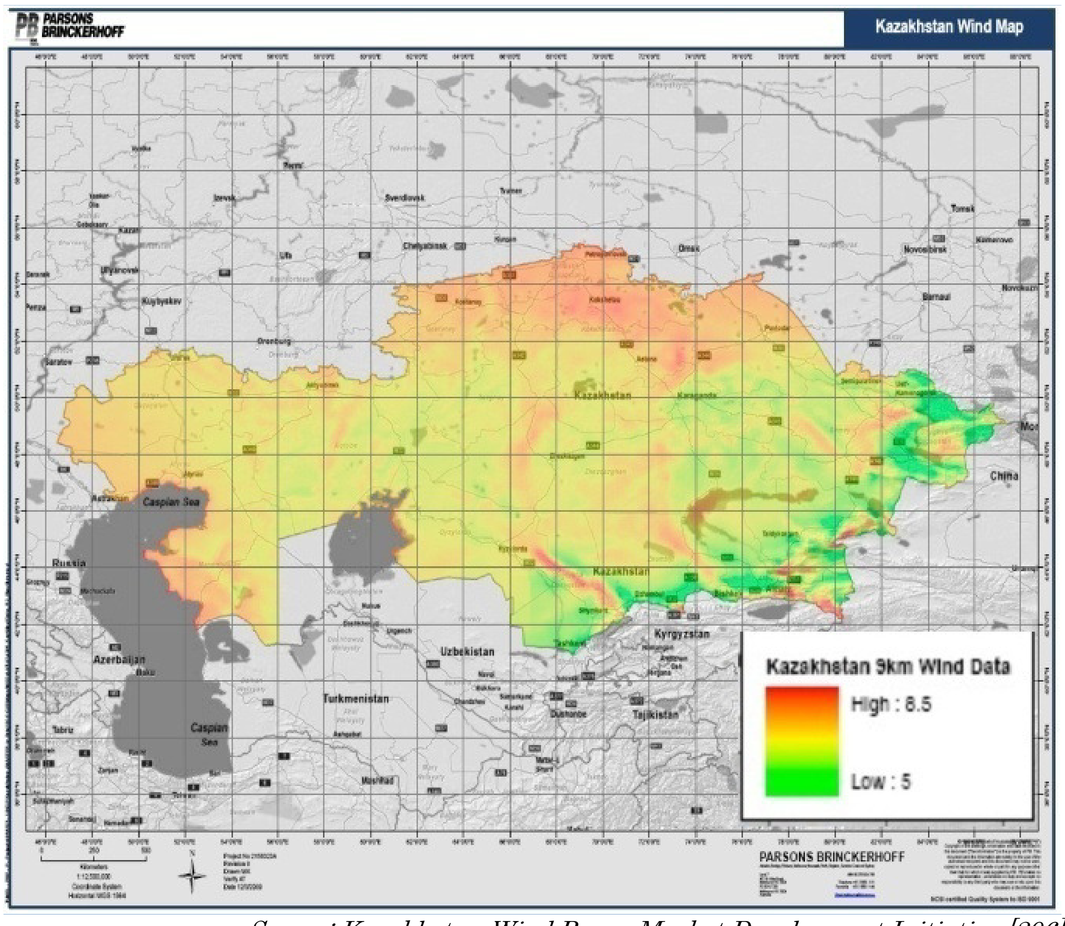
Third, econometric methods are utilized to examine the relationship between the coal industry and the respiratory health in Kazakhstan during the country's independency period using annual national data. The study investigates long-term equilibrium and short-term dynamics of coal production and respiratory diseases in Kazakhstan by applying the Vector Error Correction Model (VECM). The empirical results show that the respiratory diseases appear to be elastic relative to the coal production, and the strong long-run and short-run Granger causality running from coal production to respiratory diseases. The presence of causal relationship could be useful to define effective policies to reduce the health effects of coal industry in Kazakhstan. Development of renewable energy could co-benefit in the form of improved respiratory health of the population.

Finally, technical potentials of renewable energy by type are provided. The existing studies indicate that development of small- and medium- scale hydropower plants as solar power could be feasible. However, among the renewable energy technologies, wind power is the most economically viable and environmentally preferable alternatives to fossil fuels of Kazakhstan. Hence, it is important to estimate the technical and economical potential as well as environmental improving effect of wind power technologies in Kazakhstan.

Chapter 6

Wind Power in Kazakhstan

Kazakhstan is endowed with exceptional wind resources, which are sufficient for the introduction of industrial scale wind farms. Particularly strong winds are observed around Caspian Sea, in steppes and mountain gaps and passes. Maximum wind speeds on most of the territory during winter months reaches 40-45 m/s and 20-35 m/s in spring and autumn [211]. Average wind speed throughout Kazakhstan at 80 meters above ground level is 6-7 m/s as shown in Figure 6.1.



Source: Kazakhstan-Wind Power Market Development Initiative [206]

Figure 6.1 Wind Map of Kazakhstan

About 50% of Kazakhstan's territory has average wind speeds about 4-5 m/s at a height of 30 meters, the minimum figure for good technical potential wind energy development [212]. The wind resources in most of the sites are comparable to a good open site in Northern Europe [213]. The vast territory and low population density enables development of the industrial scale wind energy. The estimated wind power potential is about 1,820 billion kWh per year [203].

The United Nations Development Program (UNDP) and Global Environmental Facility (GEF) started the project titled "Kazakhstan-Wind Power Market Development Initiative" as a part of Government strategy of fulfilling its commitments to the UNFCCC utilization of the country's wind resources [206]. According to the National Wind Power Development in Kazakhstan [214], the annual output of wind generated electricity is planned to be 900 million kWh by 2015 and reach 5 billion kWh annually by 2024. However, due to the lack of active support from the government as well as abundant primary energy sources, the development of wind power in Kazakhstan is slower than the expected target.

Nevertheless, the recent changes in the climate change policy and obligations of Kazakhstan to reduce its carbon emissions would bring back the government attention to development of wind power. In this study, the potential analysis, environmental improving effect and multi-criteria assessments of wind power in Kazakhstan have to be performed to support the decision-making of the Government.

6.1 Wind Climates and Local Winds

Climate of Kazakhstan is continental with cold winter and hot summer seasons [215]. The climate gradually changes from steppe to desert zone from north to south of the country with large daily and annual temperature variations. Kazakhstan is situated in four climate zones: forest-steppe, steppe, semi-desert and desert.

"Voeikov axis", a high pressure band of air, lies along the 50^{th} parallel. It is the southwestern spur of the Siberian anticyclone. This band of high pressure becomes a wind divide on the flat area of the country in winter: to the north from the band south and southwest winds dominate the area, to the south from the band north and northeastern directed winds dominate the area [216]. The wind speed slows down with the distance from the band.

Strong winds with yearly velocity above 5 m/s are observed on the central steppe watershed of Kazakhstan. On all sides away from this maximum, especially southwards, the wind strength gradually diminishes, and only in the west it almost merges with the littoral Caspian maximum on the Mangyshlak Peninsula [215]. 23 local winds of Kazakhstan are listed in the global winds database, which could be divided into four categories [211]:

1) Open space winds (Zhosaly, Sileti, and others);
2) Sukhovei hot winds around large water reservoirs (Caspian Sea, Blakhash Lake, Alakol Lake, and others);
3) Winds of mountain pass/gaps (Zhetysu (Djungar) Gate, Shelek Corridor, Zhangyztobe, Kordai, and others);
4) Winds of middle range mountains and hills (Yereymentau, Ulytau, Karkaraly, Mugadzhar, and others).

Characteristics of major local winds and possible risks to wind turbines are provided in Table 6.1.

Table 6.1 Major local winds and potential risks to wind energy development

Name	Description	Source	Potential risks
Afghan wind	Hot wind in the upper Amudarya River, caused by aerodynamic acceleration of warm air masses from the southwest and compressed between the spurs of Hissar range from one side, and cold approaching from the northwest. Average speed is 17-25 m/s.	Dostaiuly, 1998 [217]	Erosion of wind turbine blades due to the large masses of sand the wind is carrying.
Balkhash bora	Cold and dry wind blowing from Shyngystau range towards Balkhash Lake. Cold air masses accumulated in northeast meet warm air masses from southwestern side of the range, often occurs in the cold season (November – March). The wind speed may reach 40-60 m/s.	Akhmetov, 1999 [218]	Ice accretion on the blades of wind turbine. Damage to the parts of wind turbine due to extremely high wind speed.
Kordai wind	The wind blows between Zhetizhol and Kindiktas ridges. It occurs when cold air masses enter the pass between the ridges. Due to the geographic location of the pass, 93% of all time the wind blows from northeast. The maximum observed speed in summer – 28 m/s, spring and autumn – 34 m/s and winter – 40 m/s.	Omarbekov, 2004 [219]	Damage to the parts of wind turbine due to extremely high wind speed.
Shelek wind	Strong wind along watercourse of Ili River. It occurs due to the movement of cold air masses around mountain glacier from east to west.	Konyratbay, 2004 [220]	Damage to the parts of wind turbine due to extremely high wind speed.
Zhetysu (Djungar) Gate	Extremely strong wind between Birliktau and Mailytau ridges. Direction of the wind: south, southeastern in the winter; north, northwestern in the summer. Maximum wind speed in the winter: 60-80 m/s.	Zhaubasova, 2001 [215]	Damage to the parts of wind turbine due to extremely high wind speed.

Kazakhstan's variable climate imposes operational risks to wind turbine performance in the future. Namely, extremely low temperatures in winter, particularly in the northern regions, may cause ice accretion issues. Frequent sandstorms in southern regions may evoke erosion of wind blades.

6.2 Potential Assessment

Wind energy is characterized by a high variability, hence two important aspects in the installation of wind energy conversion system: wind evaluation and wind characterization at different sites [222]. In order to estimate the wind energy potential of a site, the wind data collected from the location should be properly analyzed and interpreted [223]. Nine sites located in various parts of the country are recognized as particularly perspective by UNDP/GEF within "Kazakhstan – Wind power market development initiative" [213,223]. The potential assessment of the sites was already done with the wind atlas methodology and the technical characteristics of 1.65 MW Vestas V82 wind turbine generator (WTG) [224]. However, in the light of possible expansion of wind power in Kazakhstan, the potential assessment of the sites for large wind farms installation has to be done.

6.2.1 Data

Ten minute time series wind speed data of each location, measured using similar equipment configurations at multiple levels, have been statistically analyzed [212]. Each site recorded approximately twelve months of data. One year wind data recorded at the site is sufficient to represent the long term variations in the wind profile within an accuracy level of 10 percent [225-226].

6.2.2 Methodology

Wind speed distribution is a critical factor in wind power assessment. The Weibull distribution is more versatile among various probability functions used in wind industry [226-227]. The general form of the two parameter Weibull distribution for wind speed is given [223]:

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-\left(V/c\right)^k} \tag{6.1}$$

where $f(V)$ is the probability of observing wind speed V, k is the Weibull dimensionless shape factor and c is the scale factor.

Wind availability is the amount of time over certain period (12 months in this study) when the wind farm can produce electricity or in other word, the probability of wind speed to be within the operational threshold $f(3.5) < f(V) < f(25)$.

The wind speed near the ground changes with height. Therefore, equation is needed to predict the wind speed at one height in terms of the measured speed at another height. The most common expression for the variation of wind speed with height is given [227]:

$$\frac{V_2}{V_1} = \left(\frac{h_2}{h_1}\right)^m \tag{6.2}$$

where V_2 and V_1 are the mean speeds at heights h_2 and h_1, respectively and m is an exponent correction.

Different wind turbines have different power output curve. In most literature, the following equation is used to estimate the electrical power output of the wind turbine [227]:

$$P_e = \begin{cases} 0 & V < V_c \\ P_{eR}\dfrac{V^k - V_c^k}{V_R^k - V_c^k} & V_c \le V \le V_R \\ P_{eR} & V_R \le V \le V_F \\ 0 & V > V_F \end{cases} \tag{6.3}$$

where P_{eR} is the rated power output, V_c is the cut in wind speed, V_R is the rated wind speed and V_F is the cut off wind speed. In this study, the wind farms with installed capacity of 300 MW (100 turbines x 3.0 MW) for each sites and the total capacity of 2,700 MW (300 MW x 9 sites) are assumed. Table 6.2 contains technical information of the wind turbine required for the power output estimation.

Table 6.2 Technical data of V90-3MW wind turbine

Turbine Type	Vestas V90-3MW
Hub Height	80 m
Rated Power Output	3000 kW
Cut in Wind Speed	3.5 m/s
Rated Wind Speed	15 m/s
Cut off Wind Speed	25 m/s

Source: Vestas [228]

In order to predict the output of a wind farm, it is necessary to estimate a range of potential energy losses. The categories of energy loss of wind farms are: wake losses, power curve degradation, turbine shutdown hysteresis, availability, electrical losses and other losses. The site specific overall wind farm losses are acquired from the literature [224,229] and indicated in Table 6.3.

Table 6.3 Overall wind farm losses

Candidate site	Overall wind farm losses (%)
Arkalyk	14.8
Astana	15.1
Fort Shevchenko	13.3
Karabatan	14.8
Karkaraly	15.3
Kordai	12.2
Shelek	17.1
Yereymentau	13.6
Zhuzimdik	13.6

6.2.3 Results and Discussion

The calculated monthly mean wind speed values for the available time series data of nine locations are presented in Figure 6.2. It can be seen that the highest speeds for most of the locations occur during the winter months of December, January and February. Additionally, some high speed values are observed during May. On the other hand, the wind speeds of summer season (June, July and August) are the lowest. Coincidentally, the electricity peak demand in Kazakhstan is observed during the winter season [135], what makes introduction of wind energy important.

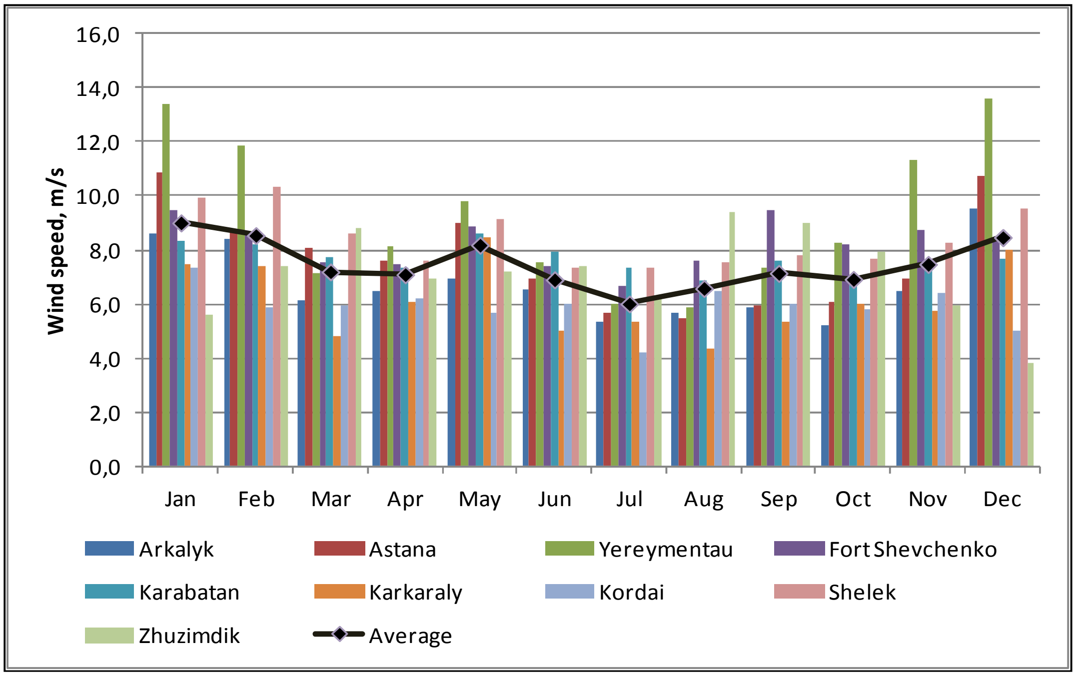


Figure 6.2 Seasonal wind speed variations at selected locations

The results of the power output estimation from the present study are summarized in Table 6.4. Appendix V provides detailed results of calculations.

Table 6.4 Wind energy output estimation based on the Weibull analysis

Site	V_{mean} at 80m, m/s	k	c, m/s	Annual net electricity output, MWh	Capacity Factor	Wind Availability
Arkalyk	6.8	2.11	7.12	484,713	0.18	0.82
Astana	7.7	2.16	7.02	593,513	0.23	0.86
Fort Shevchenko	8.2	2.21	8.11	636,719	0.24	0.92
Karabatan	7.7	2.92	7.80	603,291	0.23	0.89
Karkaraly	6.2	1.45	6.08	490,644	0.19	0.70
Kordai	5.9	1.29	6.47	461,093	0.18	0.67
Shelek	8.4	1.96	6.60	686,793	0.26	0.90
Yereymentau	9.2	1.86	8.82	783,477	0.30	0.90
Zhuzimdik	7.1	1.71	7.94	554,941	0.21	0.81
Total/Average	**7.5**	**1.96**	**7.33**	**5,295,184**	**0.22**	**0.83**

Based on the results of the study Yereymentau, Fort Shevchenko, Karabatan and Shelek have the best wind characteristics among the sites. In Arkalyk, Karkaraly and Kordai smaller power turbines could be utilized as the sites have lower wind characteristics. The sites could be divided into three groups according to the output potential:

- Highly potential sites with mean wind speed over 8.0 m/s and wind availability of 0.90 and over (Yereymentau, Fort Shevchenko and Shelek);
- Medium potential sites with mean wind speed over 7.0 m/s and wind availability of 0.80 and over (Karabatan, Astana, Zhuzimdik and Arkalyk);
- Low potential sites (Karkaraly and Kordai).

6.3 Environmental Improving Effect of Wind Energy

The environmental benefits of wind energy accrue through its displacement of electricity generation from conventional power plants, thereby displacing the adverse environmental effects of those generators [230]. Additionally, the large-scale use of wind power is essential if necessary reductions in GHG and other emissions from electricity generation are to be met; hence sustainable development and growth are to be achieved. Wind power causes no direct emissions and life-cycle environmental impact is significantly lower than most of the existing technologies [231]. Therefore, the technology could be considered as environmental improving by displacement of fossil fuel-fired power plants.

The environmental improving effect of wind power introduction in Kazakhstan is done for three scenarios of wind power expansion:

Scenario 1 – "Low" wind power expansion, when 30 MW (10 WTG x 3 MW) wind farms are installed in all nine candidate sites. Hence, total installed capacity of wind power in Kazakhstan reaches 270 MW and expected annual output from all sites is 529.5 GWh.

Scenario 2 – "Medium" wind power expansion, when 150 MW (50 WTG x 3 MW) wind farms are installed. Then, total installed capacity is 1,350 MW and annual output from all sites is 2,647.6 GWh.

Scenario 3 – "High" wind power expansion, when 300 MW wind farms are installed. Thus, total installed capacity is 2,700 MW and annual output from all sites is 5,295.2 GWh.

The environmental improving effect of wind power on life-cycle GHG (CO_2e) and acidifying gases (SO_2e) reduction is estimated for all nine sites for a base year of 2013. Emissions for a base year are estimated using life-cycle emission intensities for year 2005 and electricity produced in year 2013. The use life-cycle emissions instead of induced by combustion only enables to estimate the reduction potentials for entire life-cycle of the energy system.

The results of the analysis are presented in Table 6.5 and 6.6.

Table 6.5 GHG emissions reduction potential of wind energy in Kazakhstan

Site	Region	Existing		Scenario 1			Scenario 2			Scenario 3		
		GHG emissions, kt	Intensity, gCO2e/kWh	Emissions Reduction, kt	Intensity, gCO2e/kWh	Reduction potential, %	Emissions Reduction, kt	Intensity, gCO2e/kWh	Reduction potential, %	Emissions Reduction, kt	Intensity, gCO2e/kWh	Reduction potential, %
Arkalyk	Kostanay	1,409.5	783.5	38.0	762.4	2.7	189.9	677.9	13.5	379.8	572.4	26.9
Astana	Akmola	2,476.3	795.1	47.2	760.0	1.9	236.0	619.3	9.5	471.9	443.6	19.1
Yereymentau	Akmola	2,476.3	795.1	62.3	760.0	2.5	311.5	619.3	12.6	623.0	443.6	25.2
Fort Shevchenko	Mangystau	3,089.6	665.9	42.40	656.8	1.4	212.0	620.2	6.9	424.0	574.5	13.7
Karabatan	Atyrau	2,355.2	587.6	35.45	578.7	1.5	177.2	543.3	7.5	354.5	499.1	15.1
Karkaraly	Karagandy	17,829.8	1,380.3	67.7	1,375.1	0.4	338.6	1,354.1	1.9	677.2	1,327.9	3.8
Kordai	Zhambyl	1,296.1	729.1	33.6	710.2	2.6	168.1	634.5	13.0	336.2	540.0	25.9
Shelek	Almaty	2,967.8	697.3	47.9	686.1	1.6	239.5	641.0	8.1	478.9	584.8	16.1
Zhuzimdik	South Kazakhstan	472.8	614.3	34.1	570.0	7.2	170.4	392.8	36.1	340.9	171.4	72.1
Total Kazakhstan		82,226.2	989.7	408.6	963.9	0.5	2,043.1	944.6	2.5	4,086.3	920.5	5.0

Table 6.6 Acidifying emissions reduction potential of wind energy in Kazakhstan

Site	Region	Existing		Scenario 1			Scenario 2			Scenario 3		
		Acidifying emissions, kt SO_2e	Intensity, gSO_2e/kWh	Emissions Reduction, kt SO_2e	Intensity, gSO_2e/kWh	Reduction potential, %	Emissions Reduction, kt SO_2e	Intensity, gSO_2e/kWh	Reduction potential, %	Emissions Reduction, kt SO_2e	Intensity, gSO_2e/kWh	Reduction potential, %
Arkalyk	Kostanay	10.5	5.8	0.3	5.7	2.7	1.4	5.0	13.5	2.8	4.3	26.9
Astana	Akmola	17.8	5.7	0.3	5.5	1.9	1.7	4.5	9.5	3.4	3.2	19.1
Yereymentau	Akmola	17.8	5.7	0.4	5.5	2.5	2.2	4.5	12.6	4.5	3.2	25.2
Fort Shevchenko	Mangystau	2.9	0.6	0.04	0.6	1.4	0.2	0.6	6.9	0.4	0.5	13.7
Karabatan	Atyrau	2.2	0.5	0.03	0.5	1.5	0.2	0.5	7.5	0.3	0.5	15.1
Karkaraly	Karagandy	110.9	8.6	0.4	8.6	0.4	2.1	8.4	1.9	4.2	8.3	3.8
Kordai	Zhambyl	4.2	2.4	0.1	2.3	2.6	0.5	2.0	13.0	1.1	1.7	25.9
Shelek	Almaty	20.6	4.8	0.3	4.8	1.6	1.7	4.4	8.1	3.3	4.1	16.1
Zhuzimdik	South Kazakhstan	1.5	1.9	0.1	1.8	7.2	0.5	1.2	36.1	1.1	0.5	72.1
Total Kazakhstan		508.1	6.2	2.1	6.0	0.4	10.5	5.9	2.6	21.1	0.5	5.1

The results indicate that the biggest GHG emissions reduction in absolute terms could be achieved in Karkaraly and Yereymentau; lowest in Kordai and Zhuzimdik for all scenarios. The biggest acidifying gases emissions reduction could be achieved in Yereymentau and Karkaraly; lowest in Fort Shevchenko and Karabatan.

Across all 9 sites, total GHG emissions reduction potentials are:

- Scenario 1: 408.6 kt of $CO_{2}e$ or 0.5%;
- Scenario 2: 2,043.1 kt of $CO_{2}e$ or 2.5%;
- Scenario 3: 4,086.3 kt of $CO_{2}e$ or 5.0%.

Total acidifying emissions reduction potentials are for all 9 sites are:

- Scenario 1: 2.1 kt of $SO_{2}e$ or 0.4%;
- Scenario 2: 10.5 kt of $SO_{2}e$ or 2.6%;
- Scenario 3: 21.1 kt of $SO_{2}e$ or 5.1%.

The main factor that directly affects environmental improving potential of wind power is regional fuel mix, consequently emissions intensity. Therefore, highest emissions reduction potentials are in the region with coal as a dominant fuel. Additionally, the regions with oil and gas in the fuel mix have lower acidification reduction potential.

The total annual co-benefit of 83.1 billion KZT from development of all nine projects in Scenario 3 could be achieved. The total co-benefits from reduction of CO_{2e} emissions, SOx and NOx are 60.4, 17.7 and 5.0 billion KZT per annum respectively. There are significant differences in the volume of co-benefit among the candidate sites as seen in Figure 6.3. The biggest external cost reduction potentials are in Karkaraly and Yereymentau, while the lowest is in Kazarbatan. The average volume of co-benefit is 9.2 billion KZT per site.

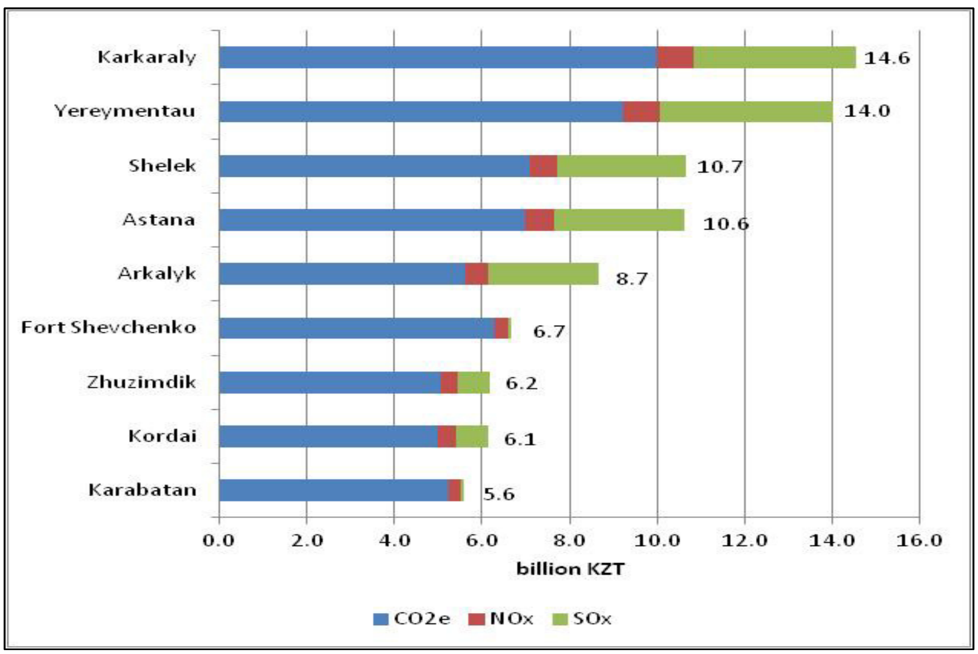


Figure 6.3 Co-benefit of wind power projects by pollutant

6.4 Cost of Wind Energy

The levelized cost of electricity (LCOE) generation is the indicator used when comparing electricity generation technologies or considering grid parity for renewable energy technologies [232-234]. The LCOE is the cost that, if assigned to every unit (kWh) of energy produced by the system over the analysis period, will equal the total life cycle cost (TLCC) [235]. The TLCC are the costs incurred through the ownership of an asset over the asset's time span [236]. The LCOE is estimated for all nine candidate sites in Kazakhstani tenge per kWh (KZT/kWh) and grid parity estimated by comparing with FIT and the existing regional tariffs.

The cost of electricity generated by wind installations includes initial investment, capital recovery factor and the costs of Operations and Maintenance (O&M). Additionally, the tax deductions and other payments should be also included. The following parameters for cost estimation are used [237-238, 195]:

- Capital investments of 1.25 million euro per MW of wind power capacity;
- O&M cost per MWh of electricity produced is 9 euro;
- Corporate tax rate is 20% and 1% of property tax;
- Annual land value tax is 54,000 euro;
- Annual inflation rate of 6% (as per IMF outlook) [IMF];
- Feed-in tariff (FIT) for wind power is 22.68 KZT/kWh;
- Tax holiday period is 5 years.

Additional assumptions to estimate LCOE are made as follows:

- Nominal discount rate is 7%;
- Depreciation period is 15 years;
- Project lifetime of 20 years;
- Exchange rate of euro to KZT is 211.

Estimation of LCOE is done in the following steps [234]:

1) The LCOE is estimated in constant values. Therefore real discount rate has to be estimated as follows:

$$d_r = \left[\frac{1+d_n}{1+e}\right] - 1 \quad (6.4)$$

where d_n is nominal discount rate;
e-inflation rate.

2) The straight line (SL) annual depreciation method is used:

$$D_t = \frac{CI}{N} \quad (6.5)$$

where CI is original cost of the capital investment;
N is depreciation period.

3) Total life-cycle cost is estimated as follows:

$$TLCC = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n} \quad (6.6)$$

where C_n is cost in period n including O&M cost;
N is analysis period (life time of wind farm);
d is annual discount rate.

4) TLCC after tax deductions:

$$TLCC = CI - (T \times PVDEP) + PVOM(1 - T) \quad (6.7)$$

where T is income tax rate;
PVDEP is present value of depreciation;
PVOM is present value of O&M costs.

5) Revenue required Before-Tax:

$$RR = [CI - (T \times PVDEP) + PVOM(1 - T)]/(1 - T) \quad (6.8)$$

6) Finally, the levelized cost of electricity (LCOE) is estimated as follows:

$$LCOE = \frac{TLCC}{Q} \times UCRF \quad (6.9)$$

where Q is annual electricity output, kWh;
$UCRF$ is the uniform capital recovery factor, equal to $\frac{d_r(1+d_r)^N}{(1+d_r)^N-1}$.

The results indicate that uniform capital recovery factor is 5.7% for all candidate sites. The summary of cost estimation is presented below:

Table 6.7 The levelized cost of wind energy in Kazakhstan

Site	Capacity MW	LCOE (KZT/kWh)		Existing tariffs FY 2015 (KZT/kWh)*	Wind FIT (KZT/kWh)
		After-tax	Before-tax		
Arkalyk	300	9.80	14.21	15.37	22.68
Astana	300	8.25	11.95	11.84	22.68
Fort Shevchenko	300	7.78	11.27	5.38	22.68
Karabatan	300	8.13	11.79	5.95	22.68
Karkaraly	300	9.70	14.06	11.59	22.68
Kordai	300	10.43	13.20	14.71	22.68
Shelek	300	7.31	10.59	14.01	22.68
Zhuzimdik	300	8.73	12.65	13.22	22.68
Yereymentau	300	6.57	9.52	14.24	22.68
Total/Average	**2,700**	**8.52**	**12.14**	**11.81**	**22.68**

**Source: the Committee on Statistic [6]*

The levelized costs of wind energy production are compared with existing electricity tariffs and FIT in Figure 6.4. The results indicate that LCOE in Astana, Fort Shevchenko, Karabatan and Karkaraly are higher than the existing tariffs. The existing wind FIT makes all sites economically attractive for potential investors.

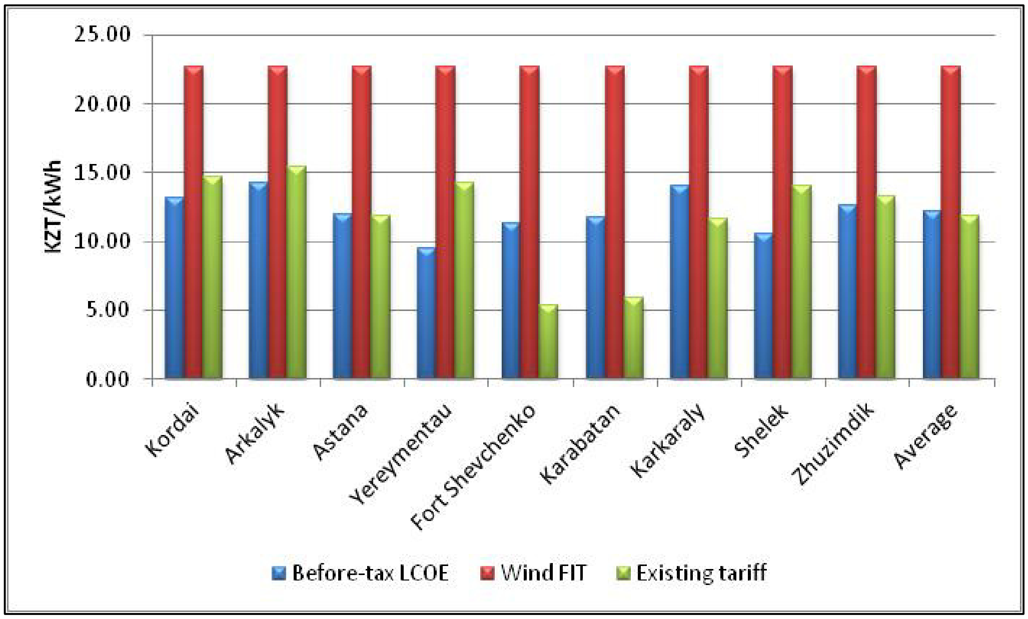


Figure 6.4 The levelized cost of wind energy and feed-in tariffs

The existing technical, economic and other socioeconomic differences between the candidate sites make it hard to compare the candidate sites directly. Application of multi-criteria analysis of candidate sites provides the methodology to assess them, taking into account the different criteria.

6.5 Multi-Criteria Analysis of Wind Power

This sub-chapter attempts to structure a complex problem of wind power development, considering multiple criteria. There are several other important factors - such as technical, environmental, social and economic- that should be taken into account while assessing wind power in Kazakhstan. In this regard, the well-known operational and decision support evaluation and approach suitable for addressing issues related to complex energy systems is Multi-Criteria Decision Analysis (MCDA). Generally, the MCDA for sustainable energy decision-making involves m alternatives evaluated on n criteria [239]. Strategic selection of wind farms is one of the most popular applications of MCDA nowadays [240-242]. To the author's knowledge there are no multi-criteria assessment of wind energy in Kazakhstan was carried out before. Therefore, it is the first attempt to apply MCDA methodology for assessment of wind power in Kazakhstan.

6.5.1 Criteria Selection

Choosing a proper site for a wind farm is critical to a successful project. The process is multi-dimensional, composed of various, often conflicting, criteria. Criteria selection is the core of decision making process. In particular, the results of information entropy weighting method are very sensitive to the set of criteria used. The following principles of criteria selection should be followed in energy decision making process [243]:

- *Systematic principle*. The criteria system should reflect the essential characteristics and the whole performance of the energy systems ;
- *Consistency principle*. The criteria should be consistent with the decision making objective ;
- *Independency principle.* The criteria should reflect the performance of alternatives from different aspects ;
- *Measurability principle*. The criteria should be measurable in quantitative value or qualitatively expressed ;
- *Comparability principle*. The decision making process is more rational when the comparability of criteria is obvious.

Additionally, the criteria should be normalized for a comparison reason and double counting should be avoided [244]. Criteria selected for multi-criteria assessment reflect all aspects of wind farm strategic placement. Criteria divided into technical, environmental and socioeconomic. The summary of selected criteria is presented in Table 6.8.

Table 6.8 Summary of evaluation criteria

Criteria	Type of criteria	Characteristics
C1 : Estimated power output	Technical	Higher is better
C2 : Annual Capacity factor	Technical	Higher is better
C3 : Classification of ice thickness	Technical	Lower is better
C4 : Seismic activity	Technical	Lower is better
C5 : Distance to grid network	Technical	Lower is better
C6 : Regional electricity balance	Technical	Lower is better
C7 : Regional life-cycle GHG intensity	Environmental	Higher is better
C8 : Vulnerable bird population	Environmental	Lower is better
C9 : Distance to township	Environmental	Higher is better
C10 : Respiratory disease morbidity	Socioeconomic	Higher is better
C11 : Regional GRP per capita	Socioeconomic	Lower is better
C12 : Existing electricity tariffs	Socioeconomic	Higher is better

6.5.2 Technical Criteria

Estimated power output. The candidate site with higher annual power output is preferable.

Annual Capacity factor. The candidate site with higher annual net capacity factor should have a higher priority.

Classification of ice thickness. Climate of Kazakhstan is continental, with hot, dry summers and cold winters. The air temperature decreases from south to north of the country and precipitation increases in this direction. All provinces of Kazakhstan are divided into 9 regions according to ice thickness from 1 to 9, where 1 is the lowest and 9 is the highest value of ice thickness [245]. Wind turbines installed in cold climates face icing issues over their service lifetime. The problems due to ice accretion on wind turbine blades are [246]:

- In severe cases of icing, complete stop of the turbine is observed;
- Disruption of aerodynamics;
- Overloading due to delayed stalls;
- Decreased fatigue life;

- Human safety risk.

Seismic activity. Some of the candidate sites are located in a seismic zone with high seismic activity. Earthquake leads to structural vibration and loads on the structure of wind turbine. Although modern wind turbine designs are well-suited for earthquakes [247], construction of wind farm in seismically active regions may have compliance issue with existing national seismic design code [248]. Hence, the cost of the project in such regions could become more expensive than the candidates in non-seismically active parts of the country. The seismic activity data for each site was collected from seismic design code and pre-feasibility study of the projects [237].

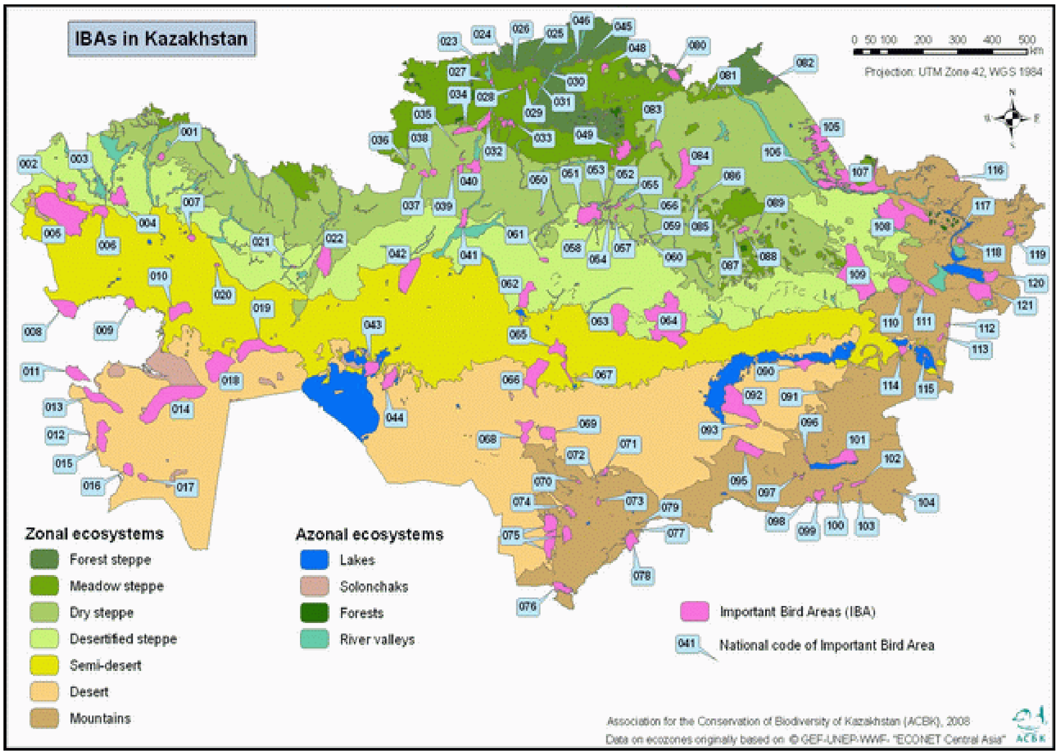
Distance to grid network. The distance to nearby appropriate electrical interconnect point is crucial for the site assessment. The criterion has impact on the cost of the project. Therefore, the sites located closer to a grid network are preferable. The data source of criterion is the pre-feasibility study of the projects [237]

Regional electricity balance. Wind power is an important step toward achieving regional electricity self-sufficiency. Therefore, the priority should be given to electricity importing provinces.

6.5.3 Environmental Criteria

Regional life-cycle GHG intensity. Wind farm installation in the regions with high life-cycle GHG intensity allows higher emissions reduction potential as a result of substitution of thermal power plants by wind farms.

Vulnerable bird population. Birds may collide with wind turbines, as they do with any structure on their route [223]. However, careful selection of appropriate sites can minimize the environmental effects of wind farms. The problem of how to select proper sites remains as bird migration routes may vary [249]. Therefore, it was decided that amount of vulnerable birds in Important Bird Areas (IBA) within 100 kilometers from the candidate sites should be used as criterion. An IBA is an area recognized as being globally important habitat for the conservation of bird population. 121 of them are located in Kazakhstan [250] as seen in Figure 6.5.



Source: Association for the conservation of biodiversity of Kazakhstan [123]

Figure 6.5 Location of IBAs in Kazakhstan

For Kordai candidate site IBA's located in the neighboring Kyrgyzstan were used. The bird population of species of A1 category (species of global conservation concern) and listed in Red Data Book of Kazakhstan was used. The details of the IBA's of concern are provided in Table 6.9.

Table 6.9 Vulnerable bird population within 100 km from the site

Candidate site	IBA name	Population
Arkalyk	Zharkol lakes	239
Astana	Alekseevskie steppe fine forests	248
Fort Shevchenko	Tyulen islands	22
	Aktau cliff faces	5,594
Karabatan	Delta of Ural river	1,900
	Lower reaches of Emba river	947
Karkaraly	Saumalkol lake	247
	Balyktykol lake	14
Kordai	Tokmak pheasant reserve	510
	Tulek valley	905
Shelek	Assy plateau	22
	Altyn-Emel national park	280
	Toraygyr ridge	59
	Upper Sharyn	52
Yereymentau	Iskrinskie pine forests	115
	Yereymentau mountains	816
	Irtysh-Karagandy waterworks 10	39
Zhuzimdik	Kenshektau mountains	99
	Kyzylkol lake	3,574
	Arystandy	500
	Shoshkakol lake	3,350

Source: Sklyarenko et al., 2008 [251]

Distance to township. In this study, the distance to township was used as the indicator of noise emission and visual impact on human well-being. The longer distance of a wind farm location from the township will help reduce the noise impact. Additionally, wind farms have impact on scenic beauty of the landscapes. They are often felt to be an important element in the landscape up to a distance of 5 km [223]. The data is collected from the pre-feasibility study of the projects [237].

6.5.4 Socioeconomic Criteria

Respiratory disease morbidity. Wind power has no emissions directly related to electricity production. Therefore, the technology improves regional air quality and helps to reduce regional respiratory diseases morbidity. Installation of wind farms with the aim to improve air quality and reduce higher morbidity is beneficial for all provinces. The data source is the Committee on Statistics [6].

Gross Regional Product (GRP) per capita. The large-scale deployment of wind power technology can bring significant, localized economic changes. Wind farms provide substantial benefit to the regional economy throughout their life-cycle by means of direct generation of jobs and indirect impacts on other economic sectors. Therefore, preference should be given to the candidates with lower GRP per capita. The data is acquired from the Committee on Statistics of Kazakhstan [6].

Existing electricity tariffs. This criterion plays a role of business driver for wind farm developers. Therefore, the higher tariffs are better for the project. The tariffs are acquired from the Committee on Statistics [6].

6.5.5 Methodology

Since no previous studies have been performed by multi-criteria analysis of energy alternatives in Kazakhstan, entropy information method [252] is used for weighting to neglect subjectivity in the process of decision making. Objective weights are derived by quantifying the intrinsic information of each evaluation criteria [253]. The standard deviation or entropy has been proposed by Zeleny (1982) as the measure for quantifying contrast intensity and thus deriving objective weights of criteria [254].

Each criterion has its own dimension and distribution. Hence, it is difficult to directly compare criteria and therefore they should be normalized. If the target value has a characteristic "higher is better", the original sequence can be normalized as follows [255]:

$$z_{ij} = \frac{x_{ij} - x_{imin}}{x_{imax} - x_{imin}} \quad (6.10)$$

where i=1,2…n is the number of evaluation criteria and j=1,2…,m is the number of candidate sites. x_{imin} and x_{imax} are the minimum and maximum values of ith criterion in all candidate sites respectively.

If "lower is better" is the characteristic of the criteria, the original sequence can be normalized as follows:

$$z_{ij} = \frac{x_{imax} - x_{ij}}{x_{imax} - x_{imin}} \quad (6.11)$$

Entropy information method is the objective weighting method, when the weight is based on the difference of data for the criteria. The steps of the entropy information weighting method are as follows [256]:

Define the best value of each index:

When the criterion is "higher is better", the best value is:

$$x_i^* = \max(x_{i1}, x_{i2}, \dots, x_{im}) \quad (6.12)$$

When the criterion is "lower is better", the best value is:

$$x_i^{**} = \min(x_{i1}, x_{i2}, \dots, x_{im}) \quad (6.13)$$

1) Define the proximity degree between x_i and the best value x_i^* or x_i^{**} depending on the type of criteria.
When the criterion is "higher is better", the proximity degree is:

$$D_{ij} = \frac{x_{ij}}{x_i^*} \quad (6.14)$$

When the criterion is "lower is better", the proximity degree is:

$$D_{ij} = \frac{x_i^{**}}{x_{ij}} \quad (6.15)$$

2) Normalize the indexes and calculate the weight of x_{ij}, which is the value of jth option the ith criteria:

$$d_{ij} = \frac{D_{ij}}{\sum_{j=1}^{m} D_{ij}} \tag{6.16}$$

where $\sum_{j=1}^{m} d_{ij} = 1$

3) Calculate the information entropy value of the ith criterion.
The information entropy indicates that how much the criteria reflect the information of the system and how great the uncertainty is. The equation is:

$$H_i = -\sum_{j=1}^{m} d_{ij} \ln d_{ij} \tag{6.17}$$

The larger H_i is, the less information is transmitted by the ith criterion. If $H_i = H_{imax} = \ln m$, the criterion would not transmit any useful information and it can be removed from further decision consideration [129]

4) Normalize H_i and get the weight of entropy value as follows:

$$h_i = \frac{H_i}{\ln m} \tag{6.18}$$

5) Calculate the evaluation weights:

$$w_i = \frac{1}{n - \sum_{i=1}^{n} h_i}(1 - h_i) \tag{6.19}$$

where w_i is a weight of criterion i
and $0 \leq w_i \leq 1$ and $\sum_{i=1}^{n} w_i = 1$.

6) Finally, calculate the weighted sum as follows:

$$S_j = \sum_{i=1}^{n} w_i z_{ij} \tag{6.20}$$

where S_j is a weight of candidate site j.

6.5.6 Results and Discussion

The distance to township, vulnerable bird population, distance to grid network, regional GRP per capita and seismic activity (C_9, C_8, C_5, C_{11} and C_4) weights are higher than 0.083, the average weight of the twelve criteria. The regional electricity balance, classification of ice thickness, existing electricity tariffs, regional respiratory diseases morbidity, regional life-cycle GHG intensity, estimated power output and capacity factor (C_6, C_3, C_{12}, C_{10}, C_7, C_1 and C_2) have lower contribution to the multi-criteria evaluation due to their low weights. The criteria sorting queue is $C_9 > C_8 > C_5 > C_{11} > C_4 > C_6 > C_3 > C_{12} > C_{10} > C_7 > C_1 = C_2$ as displayed in Figure 6.6.

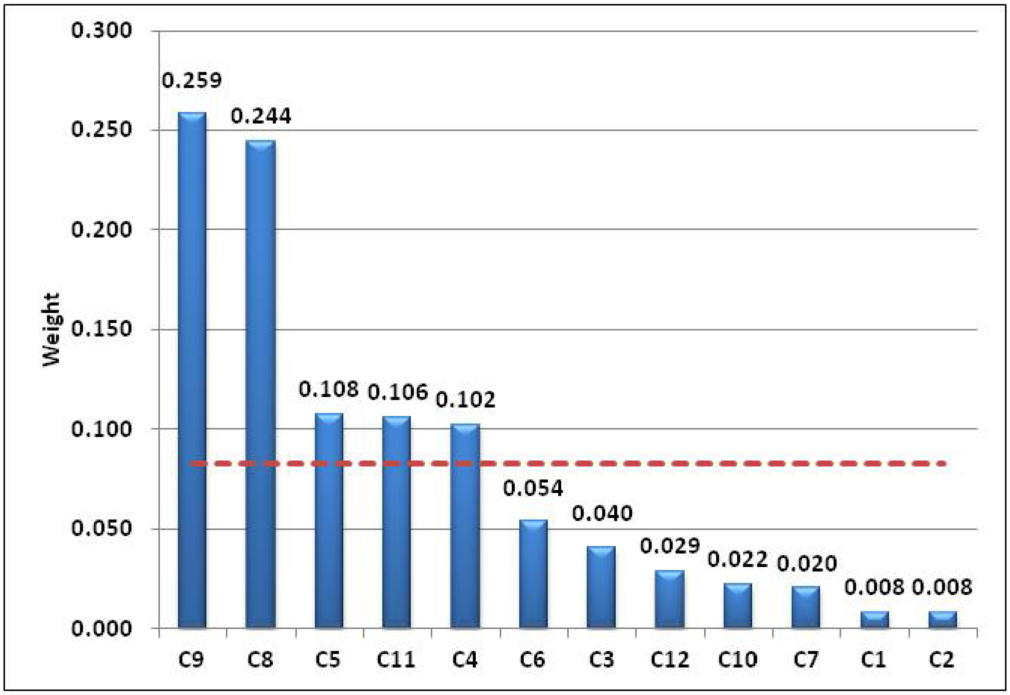


Figure 6.6 The objective weights of evaluation criteria

The weighted sums of the candidate sites are presented in Figure 6.7. The figure demonstrates that Kordai is identified as the best candidate site. Fort Shevchenko, Zhuzimdik and Karabatan have significantly lower results comparing to other candidate sites. It indicates that the sites have lower chances of success and steps to improve the projects should be taken. In Karabatan and Zhuzimdik, construction of wind farms farther from the township and detailed avian mortality risk assessment should be done. Two IBA's with significant amount of vulnerable bird species are located within 100 km from Fort Shevchenko candidate. Therefore, detailed avian mortality risk assessment should be carried out prior to the project commencement.

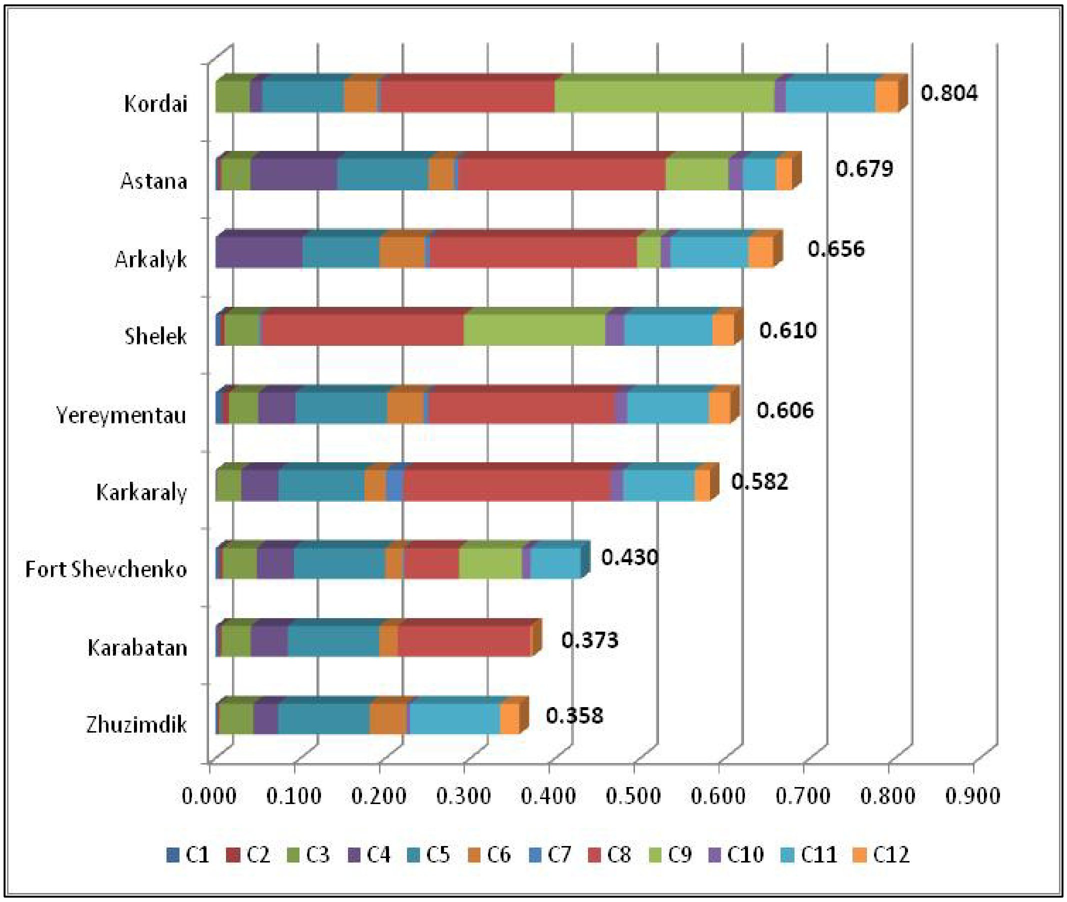


Figure 6.7 Results of multi-criteria assessment

The study attempts to structure a complex problem of wind power development, considering multiple criteria. The results of the analysis could be used to support wind power decision-making process in Kazakhstan. Furthermore, the results could assist the strategies aiming at transition to green development of Kazakhstan.

6.6 Summary

The chapter estimates technical potential of wind power, its environmental improving effect, cost of production and assess the candidate sites using the multi-criteria decision analysis technique. First, potential of nine sites located in various parts of the country using the two parameter Weibull distribution for wind speed and technical characteristics of Vestas V90-3MW wind turbine. The results of assessment indicate that the wind characteristics of the sites are suitable for industrial-scale wind farms. The sites could be divided into three groups according to their potential output: highly potential (Yereymentau, Fort Shevchenko and Shelek), medium potential (Karabatan, Astana, Zhuzimdik and Arkalyk) and low potential (Karkaraly and Kordai).

Second, environmental improving effect of wind power is estimated as a displacement of adverse environmental effects of electricity generation from conventional thermal power plants in Kazakhstan. The method utilizes the regional emission intensities from LCA of power production. The biggest GHG emissions reduction in absolute terms could be achieved in Karkaraly and Yereymentau; lowest in Kordai and Zhuzimdik for all scenarios. The biggest acidifying gases emissions reduction could be achieved in Yereymentau and Karkaraly; lowest in Fort Shevchenko and Karabatan. Total GHG and acidifying emissions reductions across all nine candidate sites are 4,086.3 kt of CO_2e (5.0%) and 21.1 kt of SO_2e (5.1%). Environmental improving effect of wind power is higher in coal-dominant regions and lower in the regions with dominant oil and gas in the fuel mix. In monetary terms, the total annual co-benefit of 83.1 billion KZT could be achieved by reducing the external costs of electricity production by conventional thermal plants.

Third, the Levelized Cost of Electricity method is utilized to estimate the cost of wind power production and assess the grid parity for all nine sites. The results indicate that LCOE in Astana, Fort Shevchenko, Karabatan and Karkaraly are higher than the existing tariffs, while the existing wind FIT makes all sites economically attractive for potential investors.

Finally, the wind power development is of particular importance for Kazakhstan's green growth. However, effective introduction of the wind projects requires multi-dimensional decision-making approach. All alternatives have location specific criteria such as technical, socioeconomic and environmental constraint. Since no previous studies have been performed by Multi-Criteria Decision Analysis (MCDA) of energy alternatives in Kazakhstan, entropy information method is used for weighting to neglect subjectivity in the process of decision making. The results indicate that the weights of distance to township, vulnerable bird population, distance to grid network, regional GRP per capita and seismic activity are higher than the average weight of the twelve criteria. Kordai is identified as the best candidate site, while Fort Shevchenko, Zhuzimdik and Karabatan have significantly lower scores.

Chapter 7

Green Growth Strategy of Kazakhstan

The growing energy demand sets the crucial challenge of economy-wide energy efficiency improvement. The government of Kazakhstan passed the Law on Energy Saving and Energy Efficiency, which sets 10% reduction targets by 2015 and 25% by 2020 [257]. Such improvements would contribute to reduction of Kazakh GHG emissions. Moreover, it is expected that hosting EXPO 2017 in Astana would help to promote renewable energy development across Kazakhstan [56].

In order to reduce the environmental burden and meet the international commitments, the government has developed the Concept of Transition to Green Economy. The strategy aims to promote efficient energy consumption and reduce GHG emissions. It sets the targets to reduce energy consumption by 50% from the 2008 level, cut CO_2 emissions caused by electricity production by 40% and increase the share of renewable energy in electricity production by 50% by 2050 [258].

The concept of "Green Growth" envisages an economic growth with a sustainable use of natural resources. The Concept of Transition to Green Economy is based on four major principles [259]:

- *Eco-efficiency.* When economic growth is achieved without significant environmental impact on all levels of the life cycle;
- *Resource management.* This principal implies the sustainable use of natural resources in the country;
- *Unity.* It suggests a more coherent development of all parts of Kazakh economy ;
- *Intersectionality.* This principal involves participation of all interested parts in decision-making process.

The suggested mechanisms to assist the transition are [259]: introduction of environmental taxation, sustainable production and consumption models, "Green Business" model and sustainable infrastructure.

The main approaches utilized in the Concept include:

- Social development by "green" jobs creation, sustainable agriculture, new technologies in power sector, waste processing and recycling and water management;
- Regional development by expansion of sustainable agriculture, expansion of renewable energy and water and soil management;
- Creation of favorable climate to attract private investments for implementation of the strategy.

The time frame for implementation of the Concept is 2013-2050. The Concept is expected to promote transition of Kazakh economy towards sustainable and innovative development. Significant domestic funds are allocated to implement the concept. In order to attract green investments and new technology transfer, Kazakhstan has launched Astana Green Bridge initiative [260].

7.1 Effect of Kazakh Emissions Trading Scheme (ETS) on Industrial Energy Intensities

The government of Kazakhstan has developed the Green Growth strategy in order to promote sustainable development and reduce the environmental impact of Kazakhstan's economy. These commitments have been reflected by the launch of the national initiative to establish a national Emissions Trading Scheme (ETS) [261]. The ETS is included in Kazakh Ecological Code to provide the governance and operational framework [Ecological Code]. Like the European Union (EU) emissions trading system (EU ETS), it is planned that Kazakh ETS will be a foundation of the country's policy to combat climate change.

Kazakh ETS is the first economy-wide scheme in Asia. Moreover, the ETS is the first case in major oil-exporting country. The regulators are Ministry of Energy and a state-owned joint stock company JSC Zhasyl Damu [262]. 55% of total national CO_2 emissions are covered and carbon price is 455 KZT in March, 2014 [263].

The sectors covered by the ETS include oil and gas sector, mining, metallurgy, the chemical industry and the power sector. The ETS covers companies with the annual CO_2 emissions exceeding 20,000 tons/year, and covers over 70% of total national CO_2 emissions. It allocates CO_2 emissions quotas at a range of 0% from the baseline in 2014 and 1.5% in 2015 in the Phase II. The baseline is calculated as average CO_2 emissions in 2011 and 2012 for all enterprises covered by the ETS. Information on covered sectors, number of enterprises and quotas are presented in Table 7.1.

Table 7.1 Sectors and quotas under the ETS

Sector	**Number of enterprises**	**Quota, Mt CO_2**	
		2014	**2015**
Power	60	93.4	92.0
Coil, oil and gas	66	23.4	23.0
Industry	40	38.6	38.0
Total	**166**	**155.4**	**153.0**

The ETS is designed as cap and trade policy tool, when the total volume of CO_2 emissions cannot exceed the cap (permit). Enterprises that need to increase their volume of CO_2 emissions must buy permits from those enterprises that require fewer permits. Industry sector is represented iron and steel, non-ferrous, chemical, mineral and other industries. Oil and gas industry is represented by oil and gas producing, refining, transport and distribution companies.

The main purpose of the ETS is to reward industrial innovation, energy efficiency, and provide strict environmental accountability of polluters without inhibiting economic growth. Hence, it is important to assess the effect of the ETS on industrial energy intensity in order to estimate its feasibility of emissions reduction targets at the industrial level.

7.1.1 Methodology

The main methodological challenge is that the ETS is based on enterprise level emission inventories, while the Greenhouse Gas (GHG) inventory is compiled using the national industrial level data. In order to overcome this issue, the enterprise level inventories were allocated according to its appropriate industry listed in the national GHG inventory. Due to the absence of GHG data from fuel consumption for mineral industry, the industries under investigation are limited to:

- Power industry;
- Coal industry;
- Oil and gas production and refining;
- Oil and gas transport and distribution;
- Iron and steel industry;
- Non-ferrous metals;
- Chemical industry.

It is proposed to use Logarithmic Mean Divisia Index (LMDI) method of the Index Decomposition Analysis (IDA) to decompose CO_2 emissions of the industries [129-130]. This study aims estimate required sectoral energy intensity improvements based on the decomposition analysis of CO_2 emissions into five explanatory factors as follows:

$$C_i = \sum_{i,j} C_{ij} = \sum_{i,j} Q_i \frac{E_i}{Q_i} \frac{E_{ij}}{E_i} \frac{C_{ij}}{E_{ij}} + \sum_i A_i = \sum_{i,j} Q_i I_i M_{ij} U_{ij} + \sum_i A_i \quad (7.1)$$

where C_i is the total CO_2 emissions (kt) by industry i, Q_i is total output by industry i in industry-specific units, E_i is total fuel combustion by industry i (TJ), E_{ij} is the fossil fuel combustion of fuel type j by industry i (TJ), A_i is CO_2 emissions (kt) caused by industrial (non-energy) activities by industry i, I_i is the energy intensity of industry i, M_{ij} is the fuel mix of industry i and U_{ij} is the CO_2 emission factor of fuel j consumed by industry i.

Total changes in CO_2 emissions between target year T (2014 and 2015) and baseline for industry i could be expressed as follows:

$$\Delta C_i = C^T - C^{base} = \Delta C_{out} + \Delta C_{int} + \Delta C_{mix} + \Delta C_{emf} + \Delta C_{act} \quad (7.2)$$

where ΔC_{out} is the changes in CO_2 emissions caused by changes in industrial output, ΔC_{int} is the changes in CO_2 emissions caused by changes in energy intensity, ΔC_{mix} is the changes in CO_2 emissions caused by fuel mix changes, ΔC_{emf} is the changes in CO_2 emissions caused by changes in emission factors and ΔC_{act} is the changes in CO_2 emissions caused by changes in the volume of non-energy activities. Where:

$$\Delta C_{out} = \sum_{i,j} w_{ij} \ln\left(\frac{Q_i^T}{Q_i^{base}}\right) \quad (7.3)$$

$$\Delta C_{int} = \sum_{i,j} w_{ij} \ln\left(\frac{I_i^T}{I_i^{base}}\right) \quad (7.4)$$

$$\Delta C_{mix} = \sum_{i,j} w_{ij} \ln\left(\frac{M_{ij}^T}{M_{ij}^T}\right) \quad (7.5)$$

$$\Delta C_{emf} = \sum_{i,j} w_{ij} \ln\left(\frac{U_{ij}^T}{U_{ij}^{base}}\right) \quad (7.6)$$

$$\Delta C_{act} = A_i^T - A_i^{base} \quad (7.7)$$

where w_{ij} is the logarithmic mean of CO_2 emissions by industry i and expressed as follows:

$$w_{ij} = \frac{C_{ij}^{T} - C_{ij}^{base}}{\ln C_{ij}^{T} - \ln C_{ij}^{base}} \quad (7.8)$$

It is suggested that industrial fuel mix and CO_2 emission factors do not change significantly over time. Hence, it is assumed that the abovementioned factors remain unchained, particularly giving the short time frame under investigation. Furthermore, energy saving potentials in relation to baseline year and Business-As-Usual (BAU) scenario are estimated. The BAU scenario considers resulted CO_2 emissions without energy intensity improvements.

7.1.2 Data

Industry level data on fossil fuel combustion, fuel mix, CO_2 emissions, implied emission factors for both energy and non-energy activities are acquired from Kazakhstan's national GHG inventory submitted to UNFCCC [105]. The baseline industrial outputs are taken from the Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan [6], while the industrial output outlook for FY2014 and FY2015 are acquired from the social-economic development forecast of the Republic of Kazakhstan 2014-2018 [264] and the National Concept of Development of Fuel and Energy Complex of Kazakhstan [126].Outlook of industrial production is provided below:

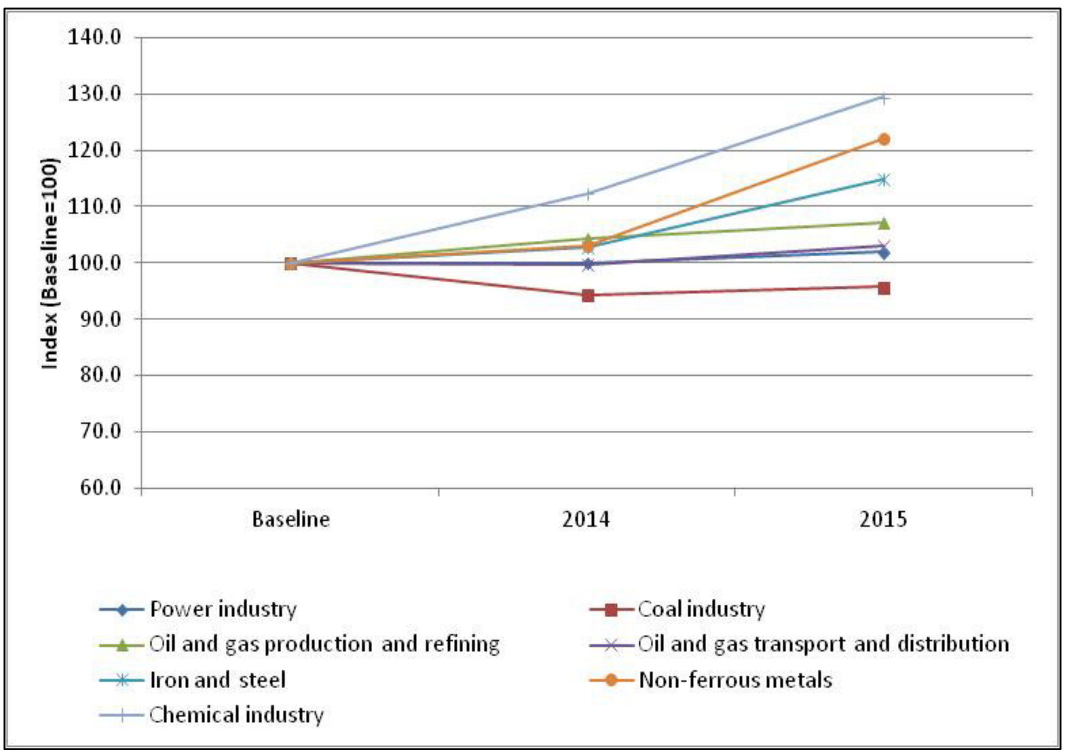
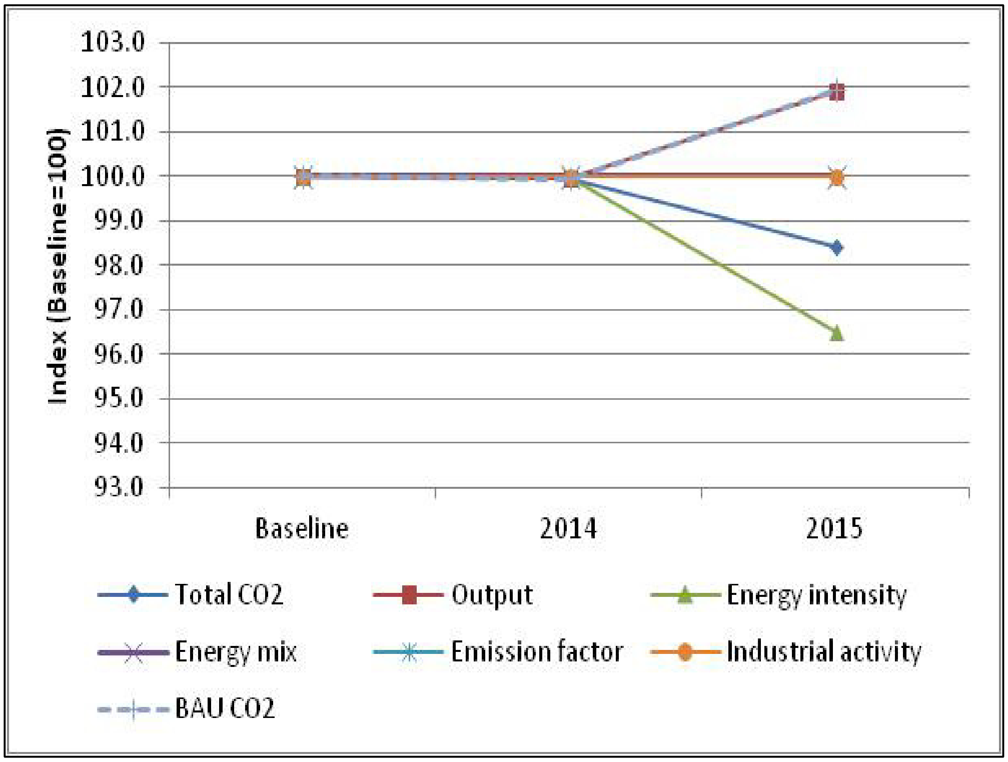


Figure 7.1 Industrial output outlook

7.1.3 Results and Discussions

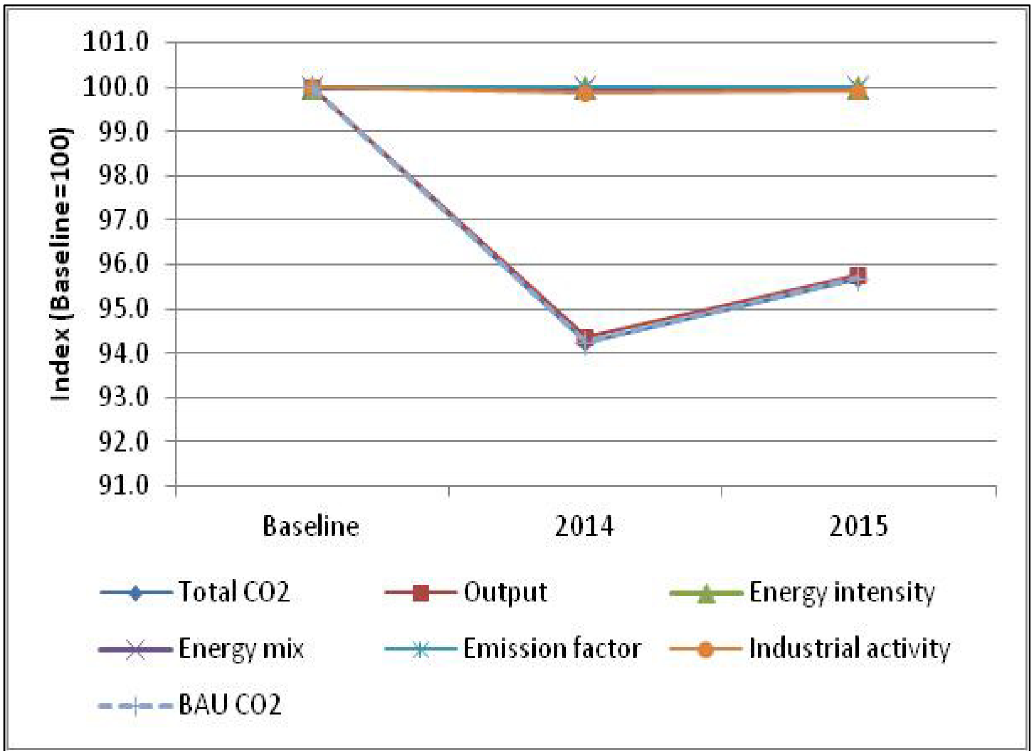
The results of the study are presented in indexed form to a baseline year in Figures 7.2 – 7.8. The outcomes of analysis indicate that apart from coal industry all other industries require energy intensity improvements to achieve the CO_2 targets set by the ETS. Hence, all other industries would require reducing energy intensities in order to meet the ETS targets.

The power production is likely to remain the biggest CO_2 emitter in Kazakhstan. The output is expected to increase by 1.9% by 2015 in relation to baseline year, while almost no change in production in 2014. Hence, CO_2 emissions from the sector would increase consequently. The sectoral energy intensity would need to be reduced by 3.5% comparing to the baseline year.



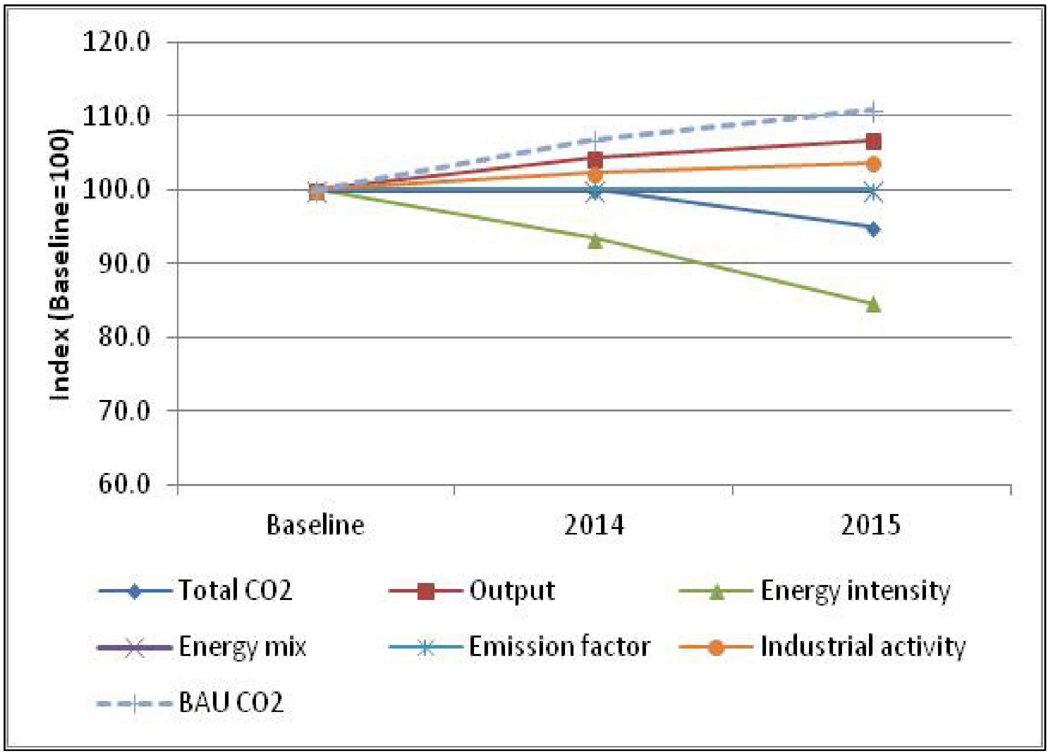
Figures 7.2 The results of decomposition analysis for power industry

Coal is the only industry expected to decline its output throughout 2014-2015 period. Production of coal is expected to decrease by 5.7% and 4.2% in 2014 and 2015 respectively. Thus, the capped CO_2 emissions due to declined output are expected to be 573 kt and 430 kt in 2014 and 2015 respectively.



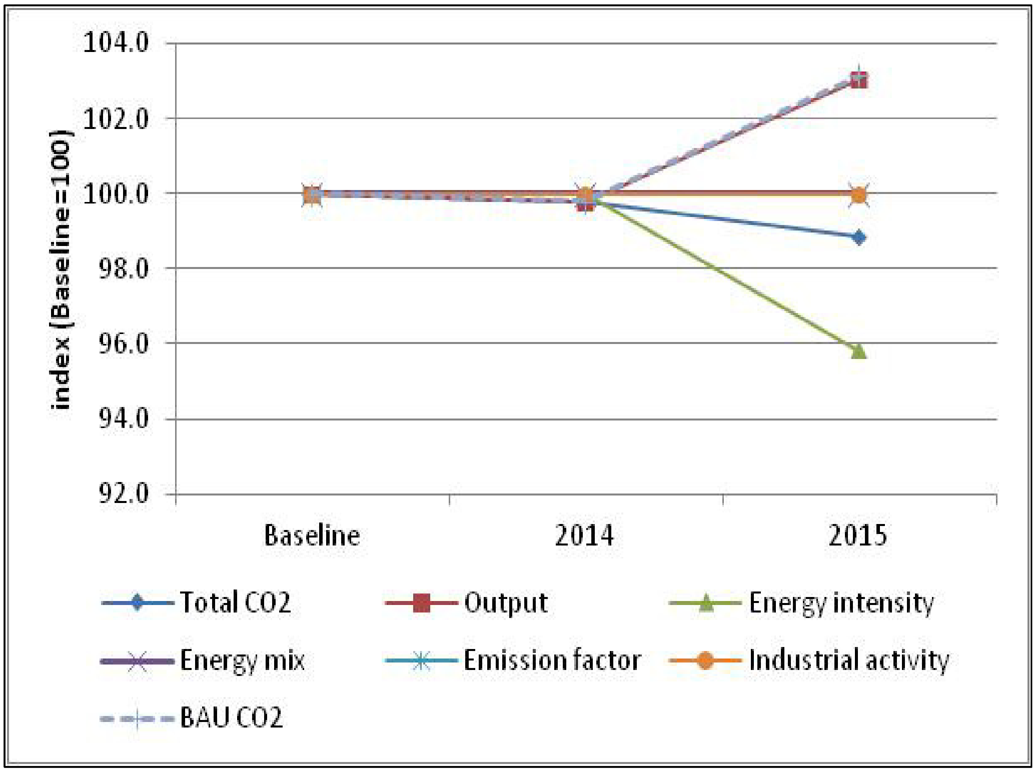
Figures 7.3 The results of decomposition analysis for coal industry

The industry's output is primarily affected by world oil prices. Oil production is expected to reach almost 82 Mt by 2015, while refining will reach 14.3 Mtoe by the same period. Oil and gas production and refining is expected to increase by almost 6% annually by 2015. The required energy intensity reduction would be around 15%.



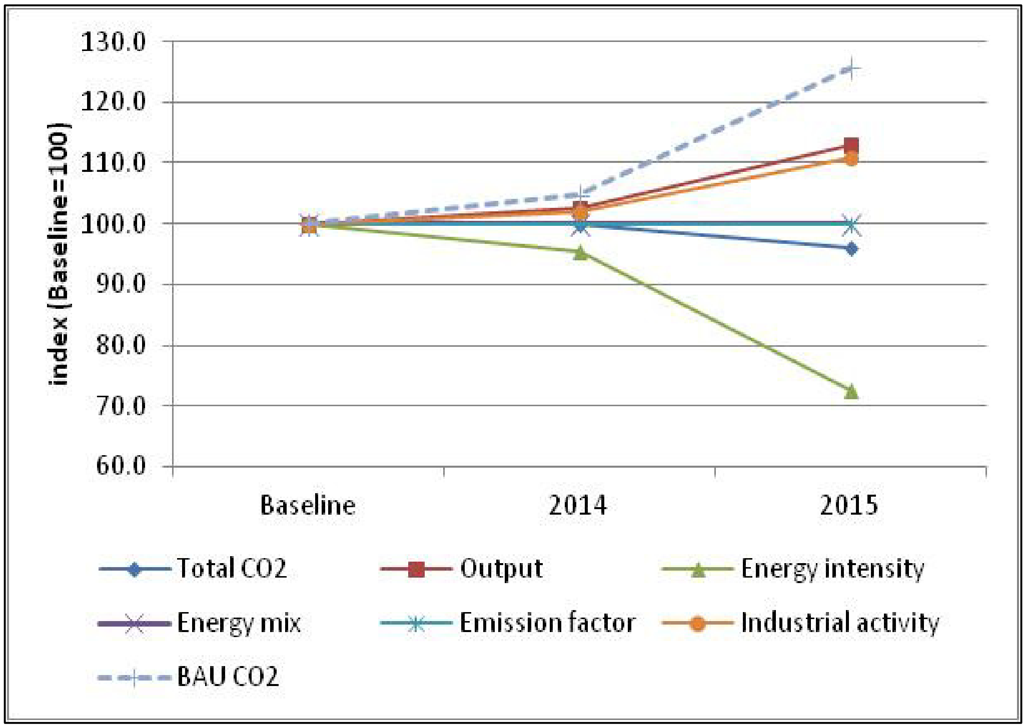
Figures 7.4 The results of decomposition analysis for oil and gas industry

The government of Kazakhstan plans to increase access of population to gas from current 42% by 56% by 2030 [265]. This would require expansion of the existing transport and distribution infrastructure. BAU CO_2 emissions caused by oil and gas transportation and distribution due to expected output increase by average 1.5% annually would increase by 3.1 % by 2015. The required energy intensity reduction would be around 4% by 2015.



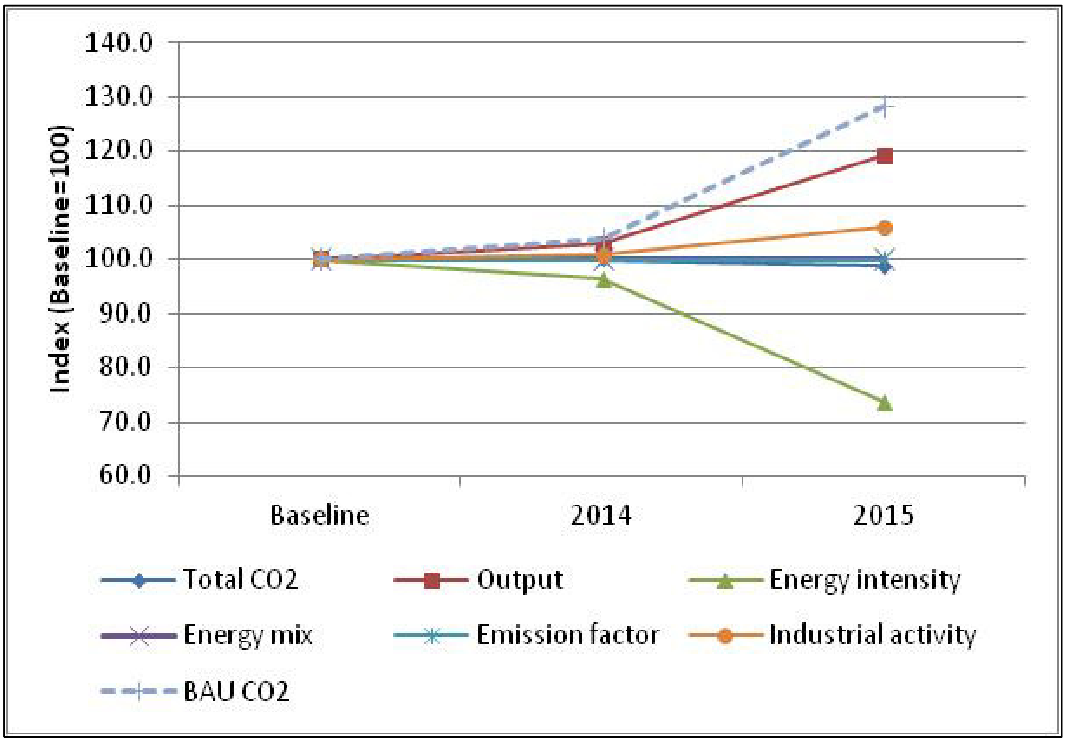
Figures 7.5 The results of decomposition analysis for oil and gas transport and distribution

The industrial output of iron and steel industry is expected to increase by 2.8% and 14.9% in 2014 and 2015 respectively. That would cause almost 25% increase in CO_2 emissions by 2015. The required energy intensity improvement in order to meet the ETS target would be around 27%.



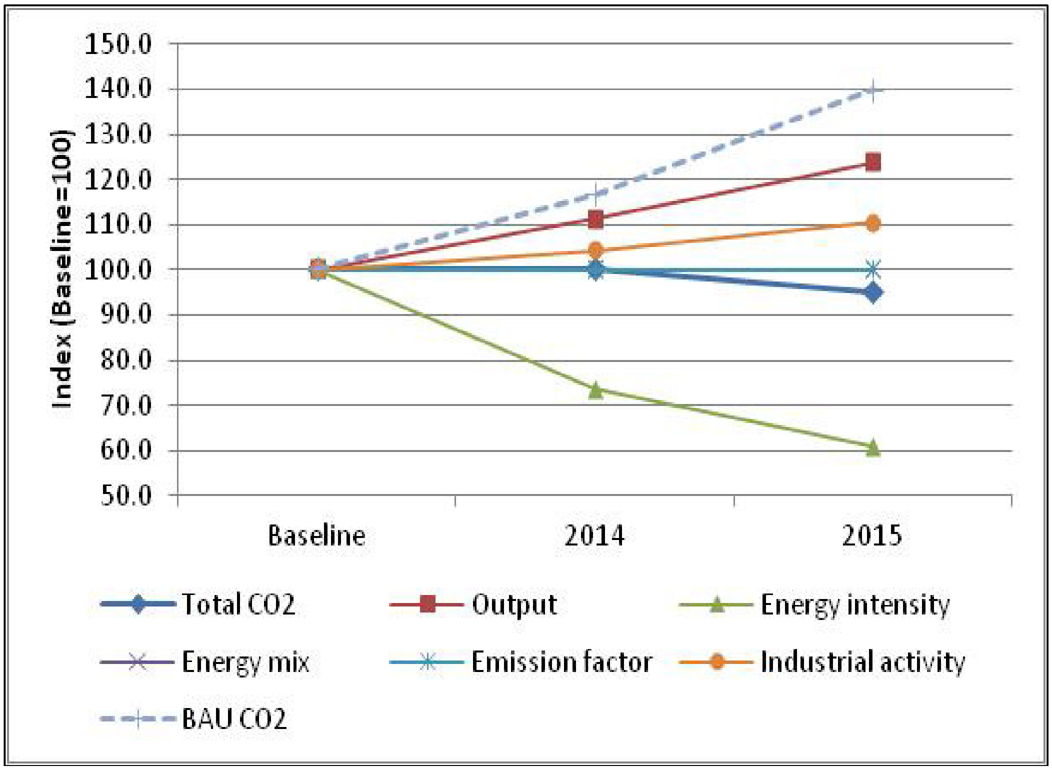
Figures 7.6 The results of decomposition analysis for iron and steel industry

The production of non-ferrous metals is expected to increase by 3.1% and 22.2% in 2014 and 2015 respectively. As a result, the resulted BAU CO_2 emissions from the industry would increase by 28.1% by 2015 in relation to a baseline year. Therefore, the required energy intensity improvements would reach almost 24% by 2015.



Figures 7.7 The results of decomposition analysis for non-ferrous industry

The chemical industry is expected to achieve the highest growth amongst the other industries. It is planned that the industry would increase by almost 30% through 2015. Therefore, the required energy intensity reduction would be almost 35% by 2015.



Figures 7.8 The results of decomposition analysis for chemical industry

Total energy saving potential achieved by energy intensity reduction is going to reach 53.25 PJ in relation to baseline year and 150.79 PJ in relation to BAU scenario as seen in Table 2. The highest energy savings could be achieved by iron and steel and non-ferrous industries, while the chemical and oil and gas transportation and distribution industries have the lowest energy saving potentials.

Gomez et al have estimated the potential energy savings for different industries in Kazakhstan if best available technologies or energy efficiency standards were adopted [266]. The energy savings as a result of ETS targets for power, iron and steel, non-ferrous metals and chemical would constitute 1.7%, 16%, 11% and 28% respectively, implying the different level of penetration of the best available technologies as displayed in Table 7.2. Hence, the energy efficiency improvement investments would be different for the industries, assuming no CO_2 permits purchase.

Table 7.2 Energy saving potential by industrial energy intensity reduction, %

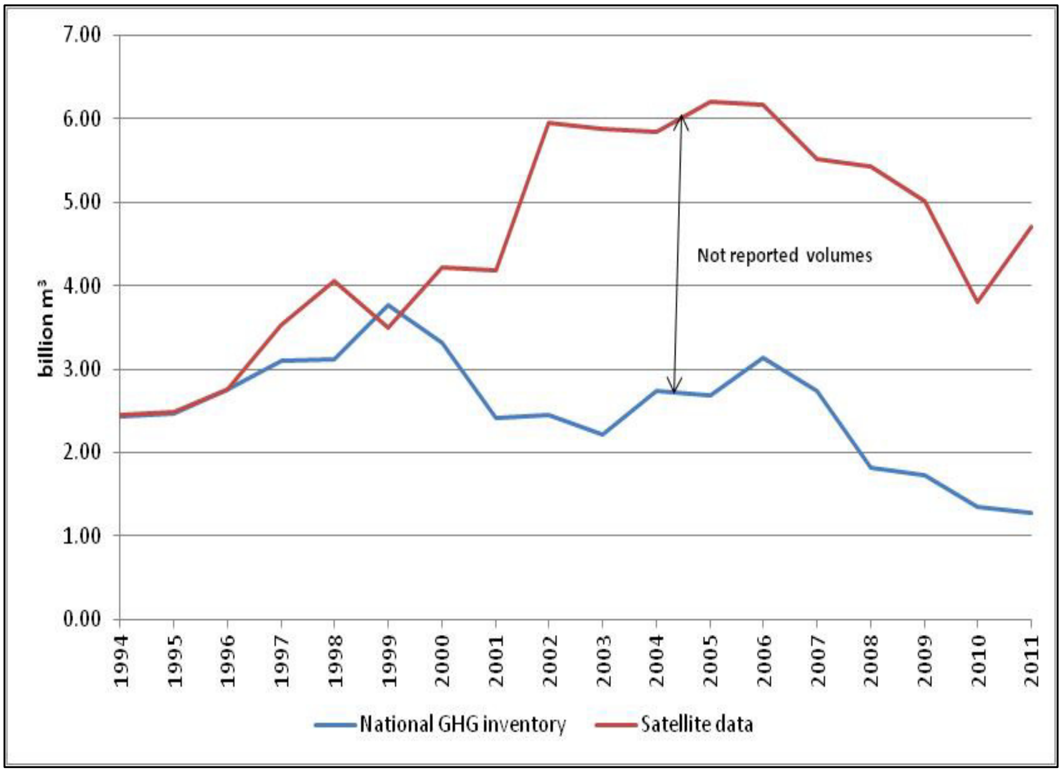
Industry	**In relation to baseline year**			**In relation to BAU scenario**		
	2014	**2015**	**Total**	**2014**	**2015**	**Total**
Power	0.00*	16.20	**16.20**	0.00*	36.03	**36.03**
Coal	0.00*	0.00*	**0.00**	0.00*	0.00*	**0.00**
Oil and gas production	1.52	5.83	**7.35**	4.49	15.11	**19.60**
Oil and gas transport and distribution	0.00*	0.33	**0.33**	0.00*	1.24	**1.24**
Iron and steel	2.14	15.80	**17.94**	5.10	36.91	**42.01**
Non-ferrous metals	0.95	8.06	**9.01**	4.46	37.82	**42.28**
Chemical	0.54	1.89	**2.42**	2.05	7.57	**9.62**
Total	**5.15**	**48.10**	**53.25**	**16.11**	**134.69**	**150.79**

Note. Energy savings due to reduced industrial outlook are not included

This is a first attempt to estimate the effects of emerging ETS on industrial energy intensities. The resulting energy intensity reductions would also differ significantly due to differences in the industrial output outlooks.

Although the main reason for implementation of ETS in Kazakhstan is to promote industrial innovation and energy efficient technologies, it is likely that the targets would be achieved without such measures. Kazakhstan's economy is affected by the Dutch disease, and the performance of non-oil sectors are tied to oil and gas sector. Hence, falling oil prices would cause decline in oil and gas output, causing the decline in the non-oil industries as well. This in return will cause the CO_2 reduction without any attempts to promote innovative and energy efficient development.

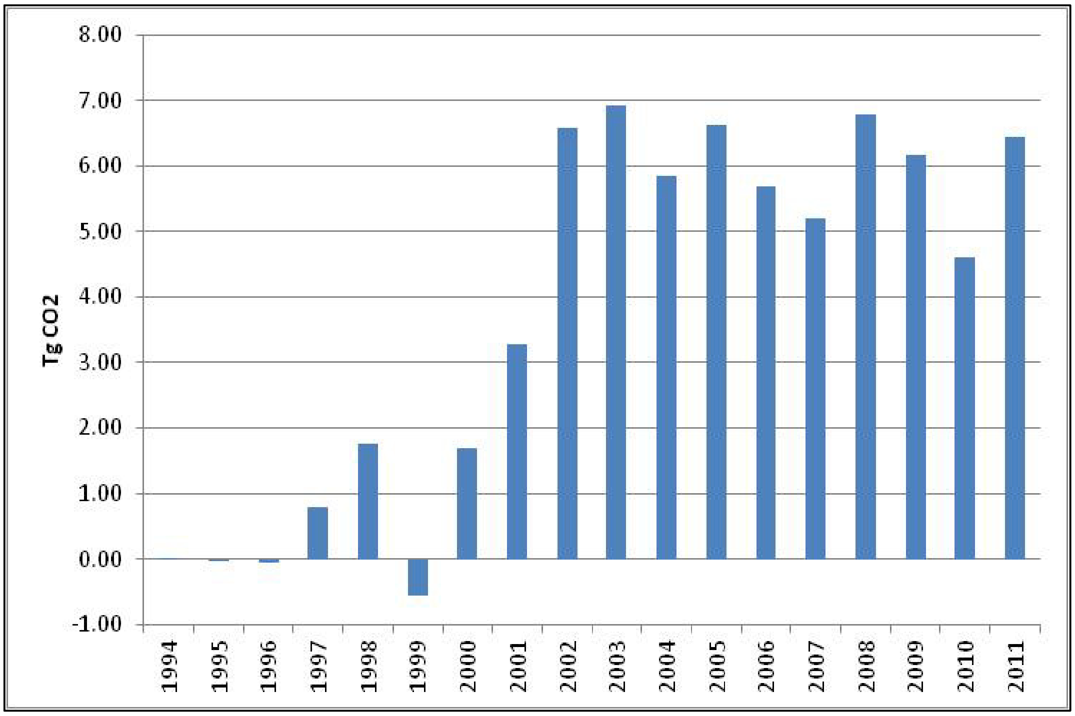
Widespread corruption tends to prevent positive effects of policies aimed to improve environmental sustainability [267]. Very often companies, primarily oil and gas, in Kazakhstan tend to neglect environmental regulations [268-270]. It is likely that the government considers companies that provide resource rents to be "too big to fail" and they may benefit from relaxed environmental standards applied to them. The typical example would be under-reporting of flare gas volumes by oil and gas companies [271]. Figure 7.9 displays the volumes of flare gas underreported by oil and gas companies based on satellite data in Kazakhstan from 1994 till 2011.



Source: Author's calculations based on GHG Inventory [105] and GGFR [272]

Figures 7.9 Flare gas volumes reported in the National GHG Inventory compared to satellite data

The reported volumes of flared associated petroleum gas are almost 4 times lower than satellite data. Total underreported CO_2 emissions for the period consisted almost 68 Tg of CO_2 as seen in Figure 7.10. When the government of Kazakhstan started using satellite data to monitor illegal flaring, the case of illegal venting off of the gas was reported [272]. It is likely that it was not the single case. Furthermore, it is possible that other industries use corruption schemes and underreport their emissions to overcome environmental regulations. Hence, it is unlikely that without improving institutional qualities in the country the policies aimed to promote environmental sustainability will succeed.



Source: Author's calculations based on GHG Inventory [105] and GGFR [272]

Figures 7.10 Underreported volumes of CO_2 emissions

It is likely that the current framework of quota allocations under the ETS in Kazakhstan will be abandoned. The government is planning to transition to benchmark approach similar to the EU ETS by 2016 [273]. It would be effective if the benchmark CO_2 emissions are estimated using the Life Cycle Assessment. It could lead to CO_2 emissions reduction throughout the production chain and the innovative technologies would spill-over to other industries.

7.2 Summary

This chapter outlines the principles of Green Growth in Kazakhstan and assesses the effect of Kazakh Emissions Trading Scheme (ETS) on industrial energy intensities. The Concept of Transition to Green Economy aims to achieve an economic growth with a sustainable use of natural resources. The cap-and-trade ETS reflects the government's commitments to promote sustainable development and reduce the environmental impact of Kazakhstan's economy. The ETS covers enterprises with the annual CO_2 emissions exceeding 20,000 tons/year from oil and gas sector, mining, metallurgy, the chemical industry and the power sector. Allocated CO_2 emissions quotas are at a range of 0% from the baseline in 2014 and 1.5% in 2015.

Logarithmic Mean Divisia Index method is used to decompose CO_2 emissions of the industries (power, coal, oil and gas production and refining, oil and gas transport and distribution, iron and steel industry, non-ferrous metals and chemical industry). CO_2 emissions of the industries are decomposed to five explanatory factors: activity, energy intensity, fuel mix, emission factor and the volume of non-energy activities. It is assumed that emission factor and fuel mix do not change due the short time frame under investigation. Business-as-Usual (BAU) scenario is constructed based on industry-specific outlook and required energy intensities are estimated.

The results indicate different level of energy intensity improvements for industries. The energy savings for power, iron and steel, non-ferrous metals and chemical would constitute 1.7%, 16%, 11% and 28% respectively, implying the different level of penetration of the best available technologies. Coal is the only industry expected to decline its output throughout 2014-2015 period, resulting in CO_2 emissions below its permit. Total energy savings from energy intensity reduction is going to reach 53.25 PJ in relation to baseline year and 150.79 PJ in relation to BAU scenario.

However, it is possible CO_2 emissions reductions could be achieved without any technical innovation and energy efficiency improvement due to probable industrial output decline due to low oil prices as a result of the Dutch disease in Kazakhstan. Furthermore, it is possible that wide-spread corruption and lack of integrity of enterprises could result in significant underreporting of CO_2 emissions, which in result inhibit the ETS aims.

Chapter 8

Conclusions and Policy Implications

To the best knowledge of the author, this is the first attempt to perform a comprehensive multi-level analysis on issues related to economy, energy and the environment in Kazakhstan. As a result of country's development approach of "economy first, politics second", Kazakh economy is among the most energy and carbon intense in the world. Hence, it is important to understand historic transformation to oil dependence of the country and implications on energy and the environment. The economic development of Kazakhstan is focused on expansion of energy intense industries with higher environmental impact. This creates a serious contradictions between energy, environmental and economic development strategies of the country.

Energy security analysis of Central Asian republics indicated the presence of different agenda for each country of the region. Kyrgyz Republic and Tajikistan are energy deprived countries, while Kazakhstan and Turkmenistan have become the major hydrocarbons exporters, affecting their economies. It is likely that Uzbekistan has been transforming from energy exporting country to energy importing nation. Security of energy demand has become important to ensure the inflow of oil revenues to the Kazakh economy.

Oil dependence has impacted economy, energy system and the environment of Kazakhstan. The results of modeling relationship between CO_2 emissions, energy use and economic output revealed that there is no presence of the EKC in Kazakhstan. It is likely that CO_2 emissions are only caused by energy use. This indicates that energy conservation policies can reduce emissions without negative impact on economic output of Kazakhstan. Furthermore, policies to promote energy efficiency and energy saving will have positive effect on emissions reduction.

The mechanisms of the Dutch disease indicate that the industrial development of Kazakhstan is vulnerable to the volatility of world oil market. Moreover, oil dependency has a negative effect on agriculture. The development of the export-oriented industries led to degradation of other non-focus industries and consecutive import growth. The plummeting prices of commodities have negative effect on both financial and economic stability of Kazakhstan. Hence, there is an urgent need to reduce the effects of the phenomenon. The results of the analysis indicate that the focus of diversification strategies of Kazakh government should shift from industrial diversification towards agriculture.

Furthermore, decomposition analysis of CO_2 emissions from industry sector indicated the significant differences on the volume and the driving factors affecting the emissions. The energy system is largely dependent on fossil fuel. While crude oil export is a source of oil revenues, coal is the main fuel of the Kazakh industry. Power industry has the biggest negative environmental impact among the industries.

Power sector may have the largest environmental improving effect due to its structure. The results of LCA of power sector with regional breakdown shows the existence of significant variations in environmental impact of power generation between the regions. It was identified that regions with large coal consumption in power production have large GHG and acidifying gases life cycle intensity. There are considerable regional variations in environmental impact of power generation due to the contrast in the structure of power sector between the regions. Therefore, renewable energy deployment in different regions would have different emissions reduction potential. Furthermore, coal industry has negative effect on the respiratory health in Kazakhstan.

Assessment of renewable energy potential in Kazakhstan indicated that resources of wind energy are significantly larger than other renewable energy sources. The wind characteristics of the sites are suitable for an introduction of industrial-scale wind farms. The environmental improving effect analysis of wind power showed that significant emissions reduction could be achieved by the technology. Over 80 billion KZT of the total external cost reduction by wind power development could be achieved. Kordai was identified as the most suitable site based on the multi-criteria assessment.

Green growth strategy is likely to fail without diversification of the region towards less energy and carbon intense industries. Analysis of Kazakh ETS indicates the significant differences among the industries on required industrial energy intensity reductions. The Dutch disease may assist in achieving reduction targets without any technological innovations to industrial process. Moreover, weak institutions and importance of tradable industries for the economy of Kazakhstan may lead to relaxed environmental regulations.

Further research has to include analysis of relationship between institutional qualities and resource dependence of Kazakh economy. Furthermore, there is a need for estimation of country-specific external cost factors of airborne pollutants from thermal power plants in Kazakhstan. Future studies should include analysis of a relationship between coal consumption and respiratory health on a regional level, given the size of the country and diversity of fuel mix. National level studies provide a broader picture of the issue, however, much of the regional variations remain hidden. Hence, the future studies should include panel data analysis of relationships between fossil fuels combustion and respiratory diseases for all 14 regions of Kazakhstan.

8.1 Policy Recommendations

Given the structure of the study, the policy recommendations are also multi-stage. Energy sector needs to shift from being a factor of economic growth of Kazakhstan towards the country's economic development. This requires enforcement of the existing strategies aiming at promotion of energy efficiency and renewable energy. Wind power in Kazakhstan contributes to economic development by directly improving the environmental situation and reducing the external costs of energy production. Furthermore, development of wind energy could positively affect education and research. However, development of large scale renewable energy projects could negatively affect coal, oil and gas industry, which has a significant importance for economic growth of Kazakhstan.

Currently, energy users do not pay for the external costs of power generation in Kazakhstan, and power utilities are satisfied with the status quo. Moreover, the existing penal system for environmental polluters seems to be inadequate to reduce the air pollution. In this regard, the most effective way to address the energy production issues could be the transfer of the external costs of the power production from the users to producers. On top of that, the cost of renewable energy should be estimated using the country-specific damage costs of global warming and acidification.

The existing studies define two distinct methods to reduce the effects of the Dutch disease in the short run: by slowing the appreciation of the domestic currency appreciation and by diversifying the adversely affected non-commodity sectors [274-276]. The first method proposes sterilization of the capital inflows by saving revenues in special funds and reinvesting them slowly. It may help to reduce inflationary pressures, achieve stable revenue stream and creates savings for future generations. Sovereign Wealth Fund is used by the government of Kazakhstan for this purpose.

The second method involves government protectionism of non-commodity sectors by increasing subsidies and import tariffs. The aim is to create favorable conditions for sectors to become more competitive and achieve economic diversification. This will make the economy more robust to external commodity price shocks. However, this measure may lead to appreciation of domestic currency by artificially reducing demand for foreign currency by the sector, worsening the effects of the phenomenon.

There is a no general agreement among the scientists on the effective policies to minimize the effects of the Dutch disease. However, the majority of existing studies recommend investing in education and infrastructure projects to mitigate the impacts of phenomenon in the long run. It is important to develop effective combination of short- and long-term policies addressing the Dutch disease based on country-specific analysis.

Agricultural reforms were the basis of sustainable economic development in Japan, South Korea and Taiwan in the mid-twentieth century [277]. The role of agriculture in Kazakhstan remains insignificant (less than 10% of GDP) and lacks government's attention. There is a need to restructure agriculture towards labor intensive and small scale development.

The abovementioned policy recommendations contradict the rent-seeking attitude and widespread corruption inflicted by extractive economic and weak political institutions. Corruption has become a normal way of life as it penetrated in all aspects of daily life in Kazakhstan from oil contracts till schools, kindergarten [278-279]. The level of corruption endangers the legitimacy of the government and may affect the political stability of the country [280]. Hence, the ability of Kazakh government to improve the existing institutional qualities is questionable.

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Acknowledgements

It would not have been possible to write this master's thesis without the help and support of the kind people around me, to only some of whom it is possible to give particular mention here.

Above all, I would like to thank my wife Kuanysh for personal support and great patience and my daughters Sayuri and Lala for inspiring me at all times. Most especially to my parents Kairgali and Gulzada, sister Kuralai, brother-in-law Michael, nephew Adam Jan and niece Amina, words alone cannot express what I owe them for their encouragement and whose patient love enabled me to complete this research.

This thesis would not have been possible without the help, support and patience of my supervisors, Prof. Keiichi Okajima and Prof. Yohji Uchiyama, not to mention his advice and unsurpassed knowledge of energy-related risk engineering.

I would like to express my sincere gratitude to the Department of Risk Engineering of the University of Tsukuba for their support and assistance. I am grateful to Tomoko Nishizaki-san for making my stay comfortable at New Energy System Laboratory. I would like to thank all my fellow members of the laboratory for promoting a stimulating and welcoming academic and social environment.

I would like to thank Prof. Hady George Kahy from Temple University Japan Campus on his advice on economic aspects of the research. I would also like to thank Mr. Pierre Boileau Energy Data Centre of International Energy Agency for providing energy data of Central Asian republics.

I would like to mention that the section of this work related to wind power assessment is part of a research project "Co-benefit Study on Development of GHG Mitigation Technologies toward Asian Low-Carbon Society" supported by the Environment Research and Technology Development Fund (E-1001) of the Ministry of the Environment of Japan.

Last, but by no means least, I thank my friend in Kazakhstan, Japan and elsewhere for their support and encouragement throughout, some of whom have already been named.

Appendices

Appendix I

Coal import origins to energy importing countries of Central Asia, in percentage of total fuel import

	KG			TJ			UZ		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
CA	96.4	100	100	47.4	74.2	100	53.2	51.9	99.8
RUS	3.6	0.0	0.0	35.4	13.7	0.0	3.7	2.2	0.1
CHN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FSU	0.0	0.0	0.0	17.2	12.1	0.0	43.1	45.0	0.0
Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: CA – Central Asia; RUS – Russia; CHN – China; FSU – Former Soviet Union republics, excluding Estonia, Latvia and Lithuania; EU – European Union, including candidate states.

Oil and gas import origins to energy importing countries of Central Asia, in percentage of total fuel import

	Oil						Gas					
	KG			TJ			KG			TJ		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
CA	12.2	3.7	2.0	1.7	5.1	9.4	98.8	97.9	97.5	81.7	99.9	100.0
RUS	75.6	73.3	93.4	97.0	88.2	58.5	1.2	2.1	2.5	18.3	0.1	0.0
CHN	0.1	0.8	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
FSU	9.5	13.5	0.0	0.1	2.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Asia	0.1	0.2	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EU	2.5	8.4	4.3	0.8	3.5	5.1	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.1	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0

Crude oil export destinations from energy exporting of Central Asia, in percentage of total fuel export

	KZ				TM				UZ	
	1995	2000	2005	2012	1995	2000	2005	2012	1995	2000
CA	0.0	0.0	0.6	0.7	0.0	0.0	0.0	0.0	87.3	100
RUS	0.0	11.5	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
CHN	0.0	2.0	3.2	18.8	0.0	0.0	0.0	0.0	0.0	0.0
FSU	0.0	4.4	0.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Asia	0.0	0.5	9.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0
EU	100	40.3	71.5	69.5	100	100	100	100	12.7	0.0
Other	0.0	41.3	11.9	6.3	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Uzbekistan has been a net crude oil importer since 2001.

Gas export destinations from energy exporting of Central Asia, in percentage of total fuel export

	KZ			TM			UZ		
	1995	2005	2012	2000	2005	2012	2000	2005	2012
CA	0.0	2.9	5.3	3.8	1.3	2.1	25.6	31.5	79.3
RUS	0.0	9.5	5.6	0.0	0.0	0.0	0.0	0.0	0.0
CHN	0.0	0.4	0.1	0.0	0.0	97.9	0.0	0.0	20.7
FSU	0.0	20.1	31.8	96.2	79.7	0.0	74.2	39.2	0.0
Asia	0.0	1.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0
EU	100	65.5	55.8	0.0	19.0	0.0	0.2	29.3	0.0
Other	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Kazakhstan was a net gas importer from 1996 till 2000, no gas export from Turkmenistan in 1995 and Uzbekistan was a net gas importer from 1995 till 1998.

Appendix II

Results of Johansen's co-integration test of model (3.2-I)

Variables: LCO and LE					
Eigenvalue	**Trace Statistic**	**5% critical value**	**Max. Eigen Statistic**	**5% critical value**	**Number of co-integration**
0.469	15.016	15.494	13.303	14.265	None
0.078	1.714	3.841	1.714	3.841	At most 1

Note: The optimal lag lengths are selected using AIC.

Breusch-Godfrey Serial Correlation LM test of VECM model (3.5-3.8)

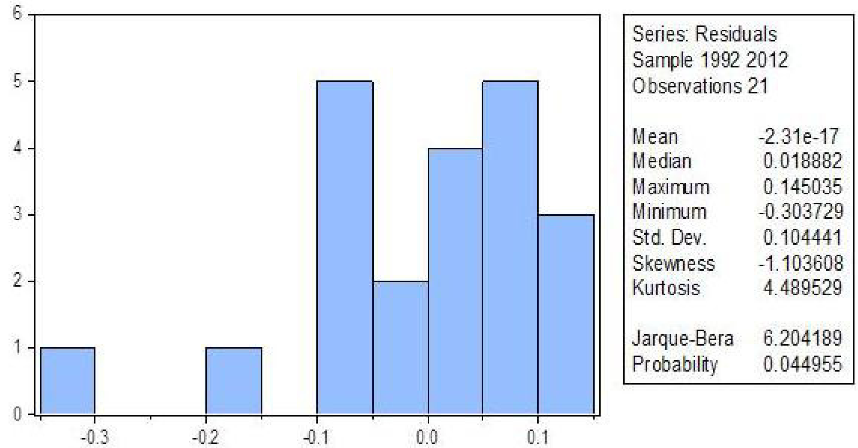
F-statistic	0.36701	Prob. F(2,14)	0.6993
Obs*R-squared	1.04617	Prob. Chi-Square(2)	0.5927

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Sample: 1992 2012
Included observations: 21

Variable	Coefficie	Std. Error	t-Statistic	Prob.
C(1)	0.0705	0.5647	0.1248	0.9025
C(2)	0.1231	0.8115	0.1517	0.8816
C(3)	0.0660	0.3993	0.1654	0.8710
C(4)	-0.1539	0.5677	-0.2710	0.7903
C(5)	0.0065	0.0329	0.1969	0.8468
RESID(-1)	-0.3047	0.5646	-0.5397	0.5979
RESID(-2)	-0.1225	0.4169	-0.2939	0.7731

R-squared	0.0498	Mean dependent var	-2.31E-17
Adjusted R-squared	-0.3574	S.D. dependent var	0.104441
S.E. of regression	0.1217	Akaike info criterion	-1.113617
Sum squared resid	0.2073	Schwarz criterion	-0.765443
Log likelihood	18.6930	Hannan-Quinn criter.	-1.038054
F-statistic	0.1223	Durbin-Watson stat	2.000742
Prob(F-statistic)	0.9917		

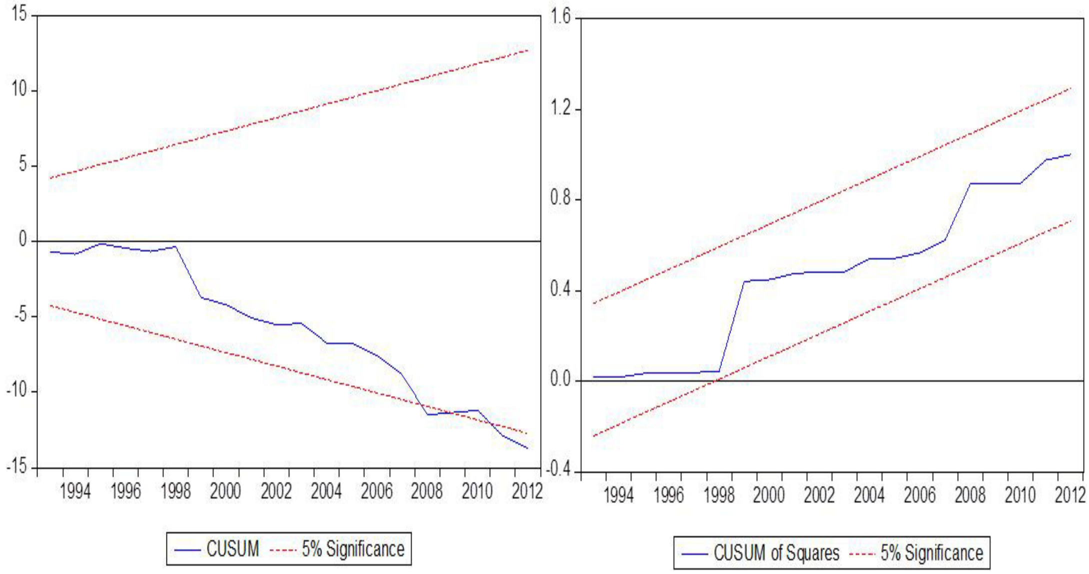
Residuals normality test of VECM model (3.5-3.8)



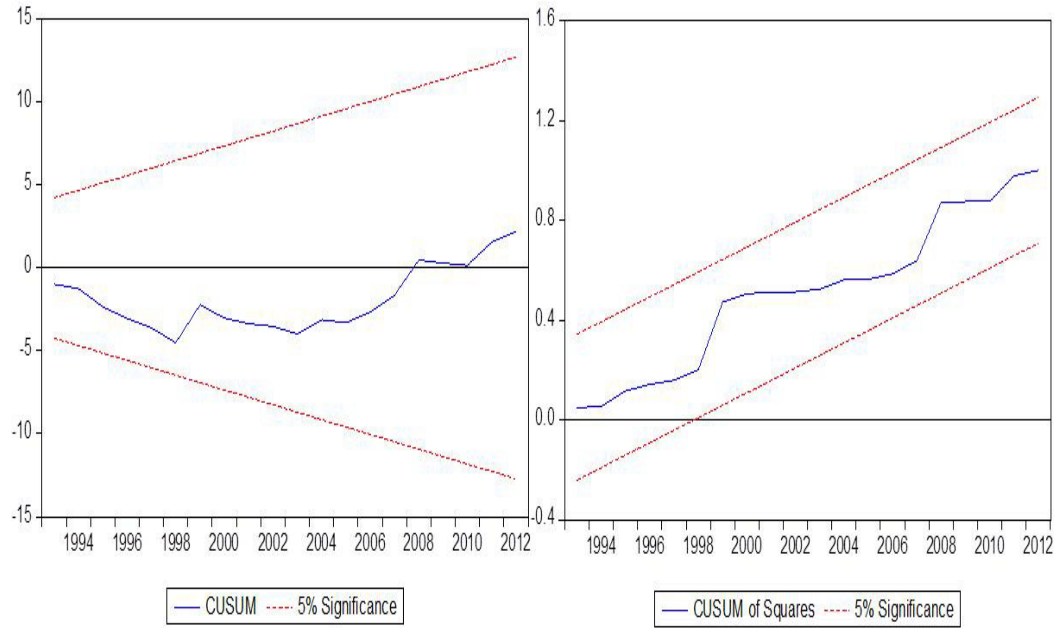
Breusch-Pagan-Godfrey test for heteroskedasticity of VECM model (3.5-3.8)

F-statistic	0.9453	Prob. F(6,14)		0.4943
Obs*R-squared	6.0546	Prob. Chi-Square(6)		0.4171
Scaled explained SS	6.1323	Prob. Chi-Square(6)		0.4085
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Sample: 1992 2012				
Included observations: 21				
Variable	Coefficie	Std. Error	t-Statistic	Prob.
C	0.0500	0.1662	0.3007	0.7681
LCO(-1)	0.0577	0.0555	1.0396	0.3161
LE(-1)	-0.0898	0.1015	-0.8853	0.3910
LGDP(-1)	-0.2462	0.1370	-1.7970	0.0939
LCO(-2)	0.0198	0.0662	0.2997	0.7688
LE(-2)	-0.0787	0.0676	-1.1636	0.2640
LGDP(-2)	0.3099	0.1686	1.8379	0.0874
R-squared	0.2883	Mean dependent var		0.0104
Adjusted R-squared	-0.0167	S.D. dependent var		0.0199
S.E. of regression	0.0201	Akaike info criterion		-4.7199
Sum squared resid	0.0056	Schwarz criterion		-4.3718
Log likelihood	56.5592	Hannan-Quinn criter.		-4.6444
F-statistic	0.9453	Durbin-Watson stat		2.2920
Prob(F-statistic)	0.4943			

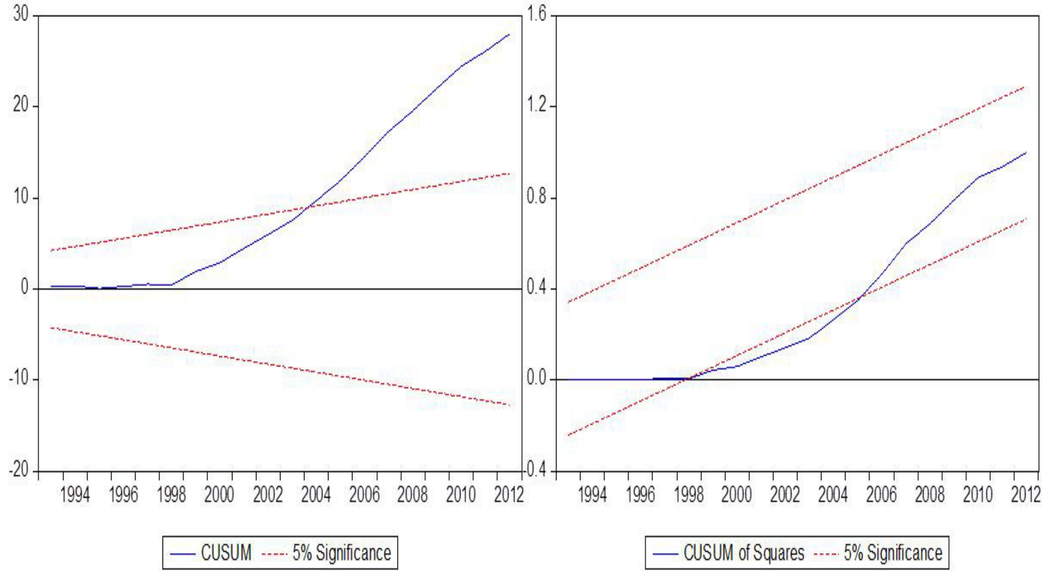
Plot of the CUSUM and CUSUMSQ for variable LCO of VECM model (3.5-3.8)



Plot of the CUSUM and CUSUMSQ for variable LE of VECM model (3.5-3.8)



Plot of the CUSUM and CUSUMSQ for variable LGDP of VECM model (3.5-3.8)

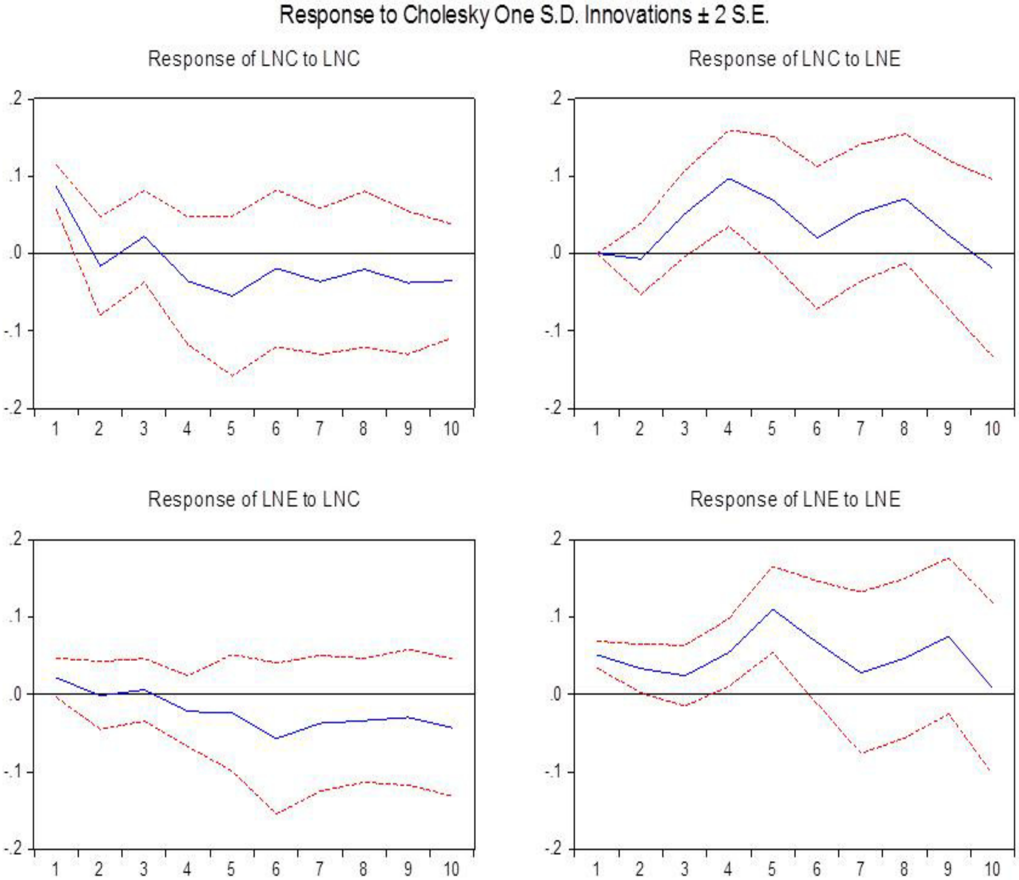


System residual Pormanteau test for autocorrelations of VAR models (3.9-3.10)

Null Hypothesis: no residual autocorrelations up to lag h
Sample: 1995 2012
Included observations: 18

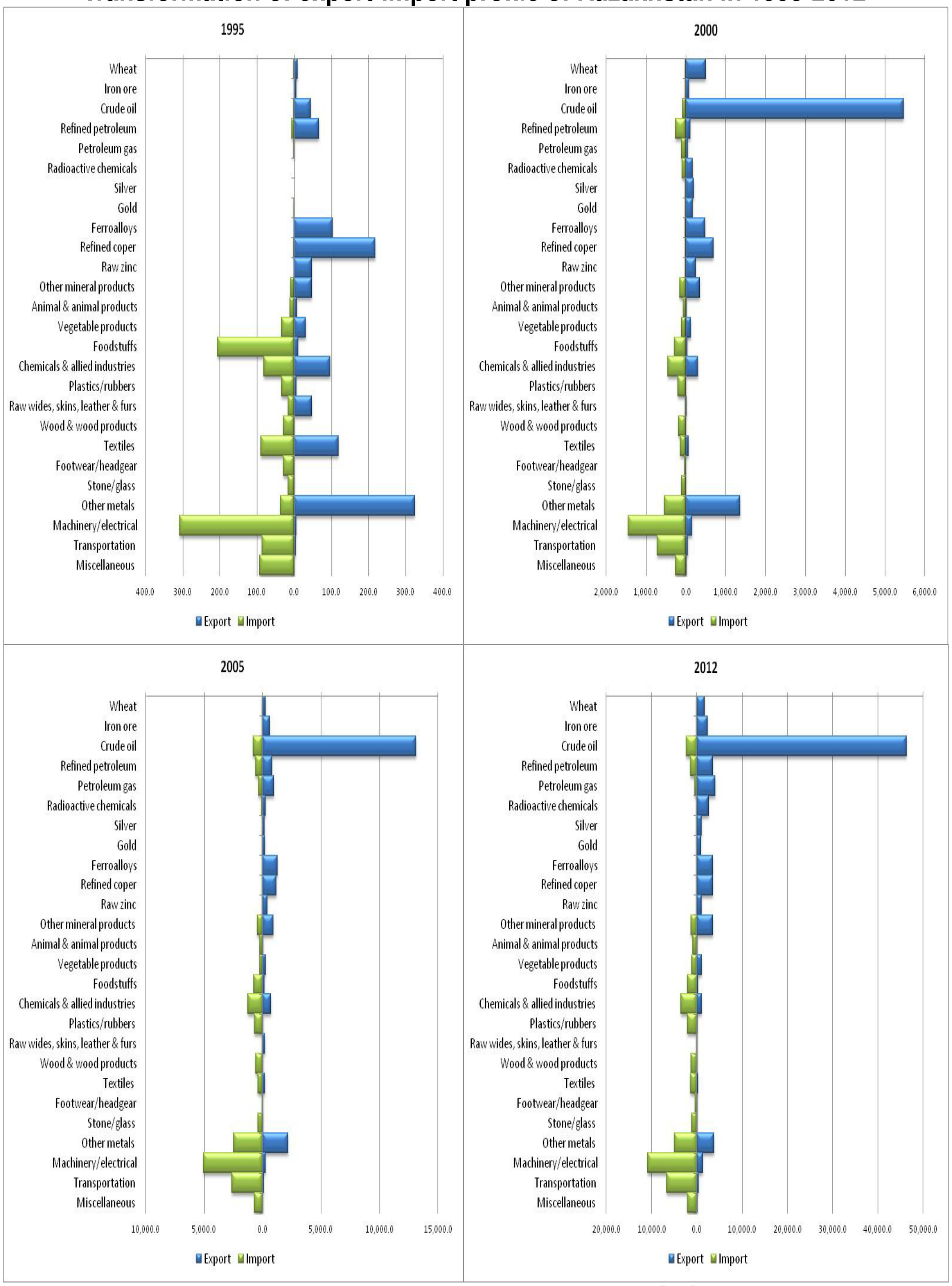
Lags	Q-Stat	Prob.	Adj Q-St	Prob.	df
1	1.5967	0.8094	1.6906	0.7924	4
2	6.3309	0.6102	7.0166	0.5348	8
3	10.9812	0.5305	12.5969	0.3990	12
4	13.4950	0.6363	15.8290	0.4650	16
5	14.1786	0.8213	16.7754	0.6675	20
6	16.3627	0.8745	20.0517	0.6938	24
7	16.5675	0.9566	20.3868	0.8500	28
8	18.6897	0.9705	24.2067	0.8368	32
9	22.3473	0.9635	31.5219	0.6815	36
10	23.9636	0.9790	35.1585	0.6877	40
11	25.4599	0.9886	39.0063	0.6851	44
12	28.9340	0.9867	49.4286	0.4159	48

Impulse response to Cholesky 1% shock of VAR models (3.9-3.10)



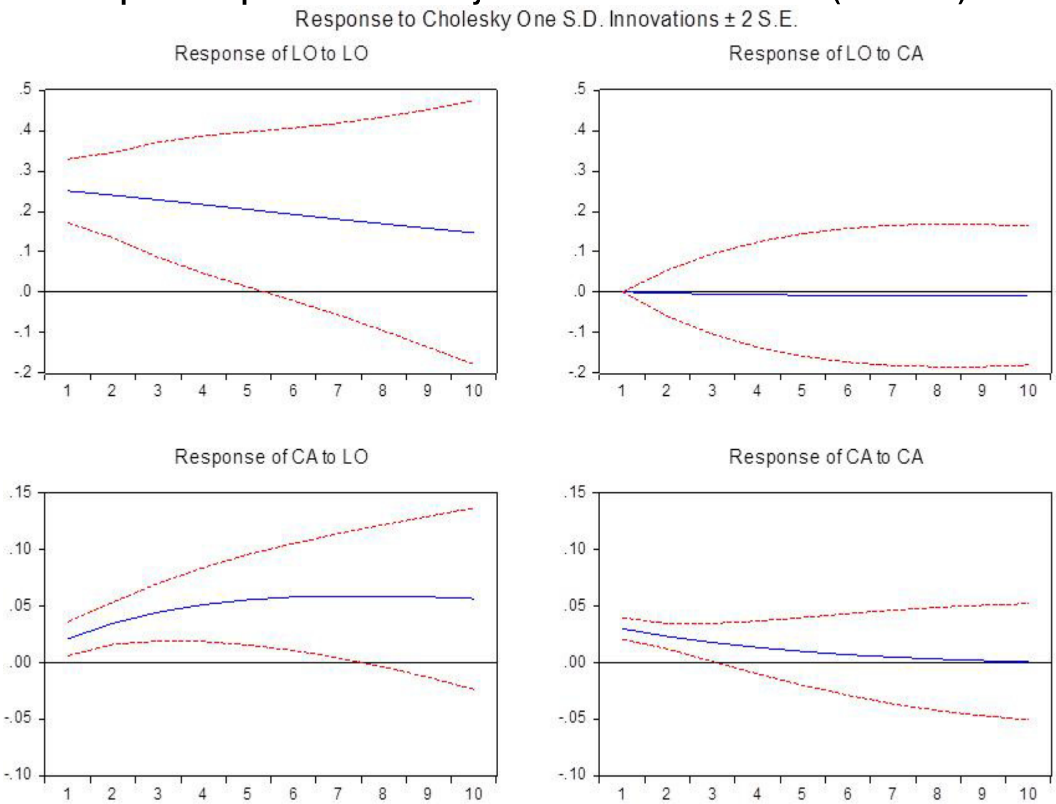
Appendix III

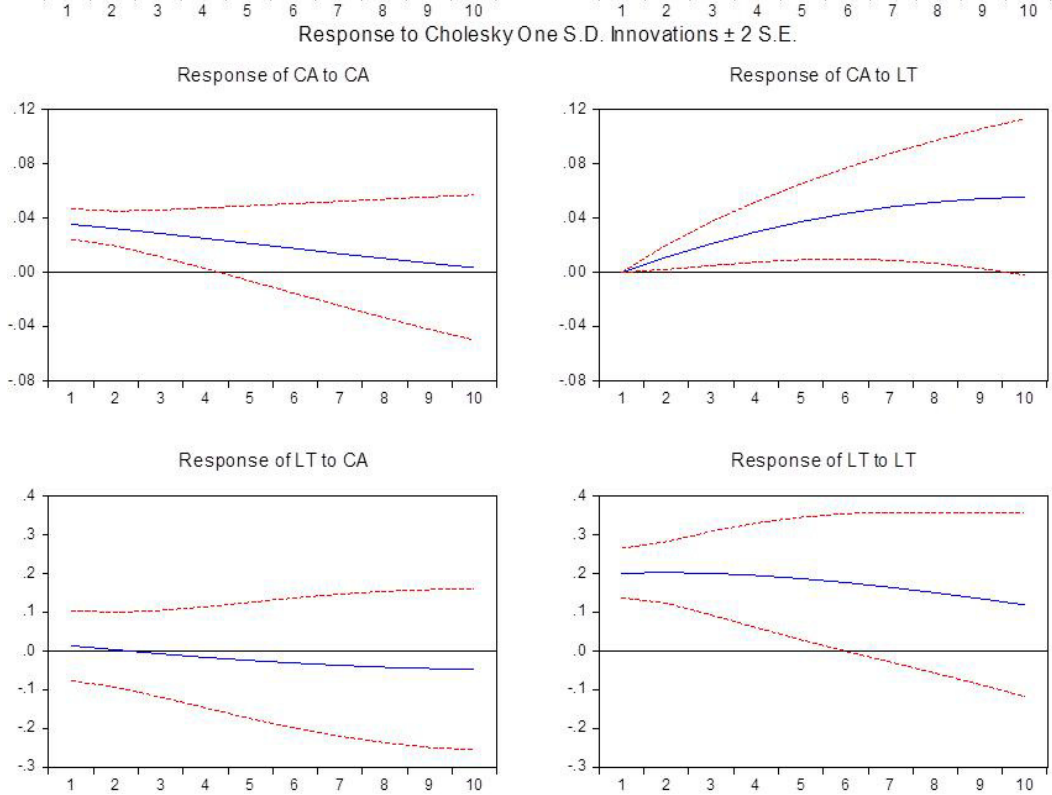
Transformation of export-import profile of Kazakhstan in 1995-2012

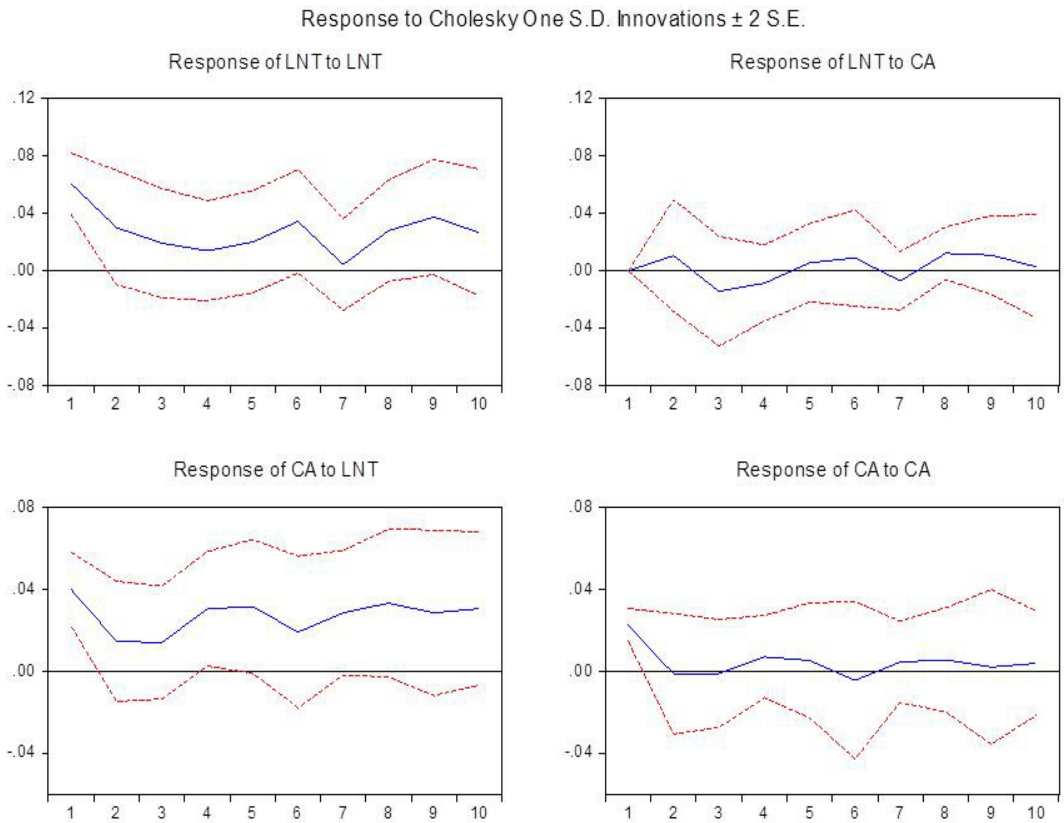


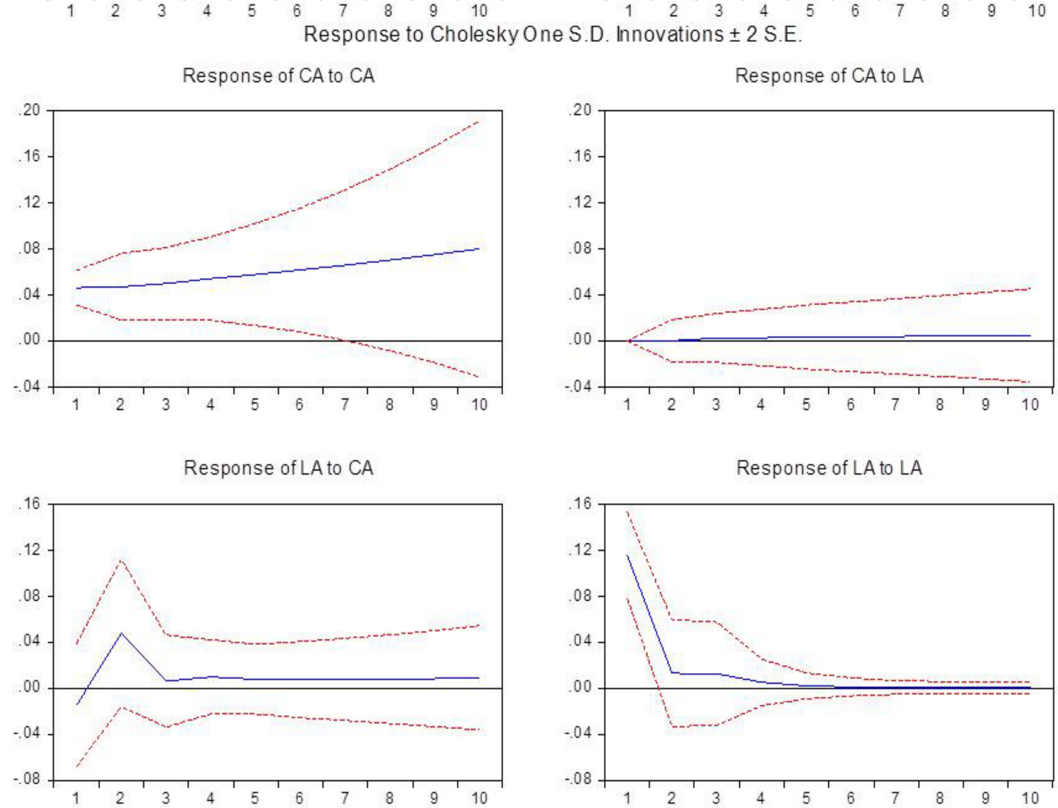
Source: Author's calculations based on Hausman et al. (2011) [53] and Simoes and Hidalgo (2011) [54]

Impulse response to Cholesky 1% shock of VAR models (3.12-3.13)






Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of LNT to LNT
Response of LNT to CA
Response of CA to LNT
Response of CA to CA


Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of CA to CA
Response of CA to LA
Response of LA to CA
Response of LA to LA

Appendix IV

Net calorific value and carbon emission factors of fuels in Kazakhstan

IPCC Fuels	**Kazakhstan Fuels**		
IPCC fuel category	Kazakh fuel category	Net Calorific Value, GJ/t	Carbon Emission Factor, tC/TJ
Crude oil	Crude oil	40.12[CS]	20.31[CS]
	Gas condensate		
Gasoline	Aviation gasoline	44.21[CS]	19.13[CS]
	Vehicle gasoline		
	Gasoline-like jet fuel		
Jet kerosene	Kerosene-like jet fuel	43.32[CS]	19.78[CS]
Other kerosene	Kerosene for lighting and other purposes	44.75[D]	19.6[D]
Gas and diesel oil	Diesel fuel	43.02[CS]	19.98[CS]
	Domestic furnace fuel	42.54[CS]	20.29[CS]
	Motor fuel for slow diesel vehicles	42.34[CS]	20.22[CS]
Residual fuel oil	Heating oil (mazut)	41.15[CS]	20.84[CS]
	Navy mazut (oil)		
LPG	Liquefied propane and butane	47.31[D]	17.20[D]
	Liquefied carbohydrate gases		
Shale oil	Oil and shale bitumen	40.19[D]	22.00[D]
Lubricants	Spent lubricants	40.19[D]	20.00[D]
Petroleum coke	Petroleum and shale coke	31.00[D]	27.50[D]
Other types of fuel	Other types of fuel	29.309[D]	20.00[D]
Coking coal	Karagandy coking coal	24.01[CS]	24.89[CS]
Sub-bituminous coal	Hard coal	17.62[PS]	25.58[PS]
	Ekibastuz coal	16.24*	25.54*
	Borlinsk coal	16.13**	23.66**
Lignite	Lignite (brown coal)	15.73[PS]	25.15[PS]
Coke	Hard-coal coke and half coke	25.12[D]	29.50[D]
Coke oven gas	Coke oven gas	16.73[PS]	13.00[D]
Blast furnace gas	Blast furnace gas	4.19[PS]	66.00[D]
Natural gas	Natural gas	34.78[CS]	15.04[CS]
Biomass	Heating wood	10.22[CS]	29.48[CS]

D–IPCC default; *Sources: National Inventory Report to UNFCCC [105]*
CS-country specific data; *Gassan-zade, 2004 [147]*
PS-plant specific data;
**Average data of Ekibastuz (whole basin), group I and group II [Gassan-zade, 2004]*
***Acquired from literature [Gassan-zade, 2004]*

CH_4 and N_2O emission factors for different fuel categories

Source	CH_4 emission factor, kg/TJ			N_2O emission factor, kg/TJ		
	Coal	Gas	Oil and oil products	Coal	Gas	Oil and oil products
Combustion	1	1	3	1.4	0.1	0.6

Source: National Inventory Report to UNFCCC [105]

NO_x and SO_2 emission factors from combustion of different fuel categories

Fuel category	NO_x emission factor, kg/tce	SO_2 emission factor, kg/tce
Coal	5.55	16.74
Fuel oil	2.46	8.20
Natural gas	1.75	1.02
Condensate	2.99	0.00
Refinery gas	2.13	0.002

Estimation of average values of data from National Inventory Report to UNFCCC [105] for different capacity power plants

Implied emission factors of activities in pre-combustion phase

Activity	Amount of fuel	Implied emission factor CH_4, kg/unit
Underground coal mining, t	11,370,000.00	22.88
Surface coal mining, t	75,250,000.00	8.30
Oil production, kt	61,918.20	106.32
Oil transportation, kt	11,124.00	29.89
Oil refining/storage, kt	10,843.10	35.31
Natural gas transmission, 10^6 m^3	130,182.40	503.72
Natural gas distribution, 10^6 m^3	5961.36	21,007.12
Flaring, tce	107,346,606.50*	0.02**

Activity	Implied emission factor, kg/unit			
	CO_2	CH_4	N_2O	NO_x
Petroleum refining, t	657.36**	0.05**	0.01**	5.71**

Source: National Inventory Report to UNFCCC [105]

**Data acquired from the Committee of Statistics of the Republic of Kazakhstan [6]*

*** Estimated using data from National Inventory Report to UNFCCC [105] and the Committee of Statistics of the Republic of Kazakhstan [6]. Implied emission factor of CO_2 for the process is 47.22 kg/tce.*

External cost factors of airborne pollutants from thermal power plants in China

Pollutant	CO_2	SO_2	NO_x
External cost factors (USD/t)	50	3680.42	2438.25

Source: Zhang et al. [162]

External cost factors of airborne pollutants from thermal power plants in Kazakhstan

Pollutant	CO_2	SO_2	NO_x
External cost factors (USD/t)	86.40	6359.85	4213.35

Source: Author's calculations

**GNI per capita, PPP (FY2012): China – 10920 USD, Kazakhstan – 18870 USD. KZT to USD exchange rate is 186.*

Appendix V

Annual wind power output estimation for 300 MW wind farms

Arkalyk

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	8.6	2.54	9.5	60,776.7	27.2	0.92
February	8.4	1.32	10.2	69,716.6	34.6	0.74
March	6.1	1.42	7.3	55,036.1	24.7	0.70
April	6.5	2.04	7.3	40,565.2	18.8	0.80
May	6.9	2.05	8.6	57,526.4	25.8	0.85
June	6.6	2.60	7.2	29,168.8	13.5	0.86
July	5.3	2.41	5.9	19,629.0	8.8	0.76
August	5.7	2.91	6.2	15,671.0	7.0	0.83
September	5.9	2.61	6.5	22,286.9	10.3	0.82
October	5.2	3.64	5.6	6,188.2	2.8	0.83
November	6.5	2.26	7.2	36,522.0	16.9	0.82
December	9.5	2.11	9.8	71,626.0	32.1	0.89

Astana

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	10.9	3.62	11.7	78,890.7	35.3	0.99
February	8.8	1.76	11.2	71,322.0	35.4	0.85
March	8.1	1.95	9.3	67,625.4	30.3	0.86
April	7.6	2.05	8.7	56,834.6	26.3	0.86
May	9.0	2.22	10.1	74,039.8	33.2	0.91
June	6.9	2.15	7.8	44,237.9	20.5	0.84
July	5.7	2.16	6.4	28,524.0	12.8	0.76
August	5.4	2.39	6.1	21,267.0	9.5	0.77
September	5.9	2.46	6.6	24,261.3	11.2	0.81
October	6.0	2.11	6.8	34,529.1	15.5	0.78
November	6.9	2.85	7.6	28,511.6	13.2	0.90
December	10.7	4.43	11.4	63,469.0	28.4	0.99

Fort Shevchenko

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	9.5	2.24	10.7	82,007.2	36.7	0.92
February	8.6	2.18	9.8	59,103.6	29.3	0.90
March	7.5	2.42	8.4	49,014.0	22.0	0.89
April	7.5	2.55	8.3	43,739.8	20.2	0.90
May	8.8	2.05	9.8	73,240.9	32.8	0.88
June	7.4	3.72	8.0	21,245.7	9.8	0.95
July	6.7	3.81	7.2	14,286.0	6.4	0.94
August	7.6	3.45	8.2	28,414.8	12.7	0.95
September	9.5	2.59	10.5	75,248.8	34.8	0.94
October	8.2	2.35	9.2	61,591.3	27.6	0.90
November	8.7	2.72	9.7	60,858.6	28.2	0.94
December	8.5	2.25	9.6	67,968.1	30.5	0.90

Karabatan

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	8.3	2.92	9.1	48,304.1	21.6	0.94
February	8.2	1.84	9.8	62,675.8	31.1	0.86
March	7.7	2.92	8.5	40,125.7	18.0	0.93
April	7.4	1.81	8.8	62,783.9	29.1	0.83
May	8.6	1.93	9.5	71,244.3	31.9	0.86
June	8.0	2.55	9.1	52,796.9	24.4	0.92
July	7.3	2.71	8.2	40,236.1	18.0	0.91
August	6.9	2.53	7.8	38,520.3	17.3	0.88
September	7.6	2.11	8.9	59,986.1	27.8	0.87
October	7.1	2.92	7.6	29,056.6	13.0	0.90
November	7.5	2.67	8.5	43,834.5	20.3	0.91
December	7.6	2.40	8.8	53,726.9	24.1	0.90

Karkaraly

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	7.5	2.03	8.1	50,959.4	22.8	0.83
February	7.4	1.18	8.4	55,037.5	27.3	0.68
March	4.8	1.10	5.5	42,079.0	18.9	0.54
April	6.1	1.45	6.5	43,663.3	20.2	0.67
May	8.5	1.90	6.7	67,040.8	30.0	0.85
June	5.0	1.45	5.0	21,175.0	9.8	0.69
July	5.3	2.02	5.6	20,797.7	9.3	0.71
August	4.3	1.58	4.7	21,442.1	9.6	0.53
September	5.3	1.45	5.7	35,328.1	16.4	0.61
October	6.0	1.78	6.5	37,467.0	16.8	0.72
November	5.7	1.44	6.3	42,992.4	19.9	0.65
December	8.0	2.27	8.6	52,661.5	23.6	0.88

Kordai

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	7.3	1.59	7.9	59,163.3	26.5	0.76
February	5.9	1.29	6.3	38.714.8	19.2	0.62
March	5.9	1.28	6.5	49,686.5	22.3	0.63
April	6.2	2.05	6.5	31,740.8	14.7	0.75
May	5.7	1.72	6.3	37,822.6	16.9	0.70
June	6.0	1.99	6.4	31,396.6	14.5	0.74
July	4.2	2.04	4.4	12,019.3	5.4	0.54
August	6.5	2.04	6.8	36,929.5	16.5	0.77
September	6.0	1.29	6.2	46,969.6	21.7	0.62
October	5.8	1.29	5.9	43,845.3	19.6	0.60
November	6.4	1.76	6.8	42,789.4	19.8	0.73
December	5.0	1.56	5.3	30,015.3	13.4	0.60

Shelek

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	10.0	3.04	10.7	68,863.1	30.9	0.97
February	10.3	2.86	11.2	63,530.0	31.5	0.96
March	8.6	2.07	9.6	67,935.5	30.4	0.88
April	7.6	1.92	8.6	56,706.1	26.3	0.84
May	9.2	2.32	10.1	71,139.2	31.9	0.92
June	7.3	2.16	8.2	47,432.7	22.0	0.85
July	7.3	2.38	8.1	43,419.9	19.5	0.87
August	7.6	2.37	8.4	46,996.7	21.1	0.88
September	7.8	2.21	8.7	54,443.7	25.2	0.87
October	7.7	2.47	8.4	46,268.1	20.7	0.89
November	8.3	2.33	9.1	58,074.8	26.9	0.90
December	9.5	3.51	10.7	61,983.4	27.8	0.98

Yereymentau

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	13.4	4.98	14.0	115,315.3	51.7	1.00
February	11.9	2.22	13.1	90,175.9	44.7	0.93
March	7.2	1.53	8.3	63,984.8	28.7	0.76
April	8.2	2.52	8.9	51,984.1	24.1	0.91
May	9.8	2.79	10.6	73,410.0	32.9	0.96
June	7.5	2.59	8.2	41,314.8	19.1	0.90
July	6.0	2.86	6.5	19,055.0	8.5	0.84
August	5.9	2.67	6.4	20,298.5	9.1	0.82
September	7.3	2.41	8.1	44,395.1	20.6	0.87
October	8.3	2.36	9.1	59,935.8	26.4	0.90
November	11.3	1.86	11.5	91,665.5	42.4	0.88
December	13.6	6.51	14.0	112,942.0	50.6	1.00

Zhuzimdik

Month	Mean wind speed, m/s	k	c m/s	Net power output, MWh	Capacity factor, %	Availability
January	5.6	1.35	6.5	47,529.0	21.3	0.64
February	7.4	1.84	8.3	52,798.6	26.2	0.81
March	8.8	1.62	9.9	78,665.0	35.2	0.82
April	6.9	2.32	7.5	38,204.0	17.7	0.84
May	7.2	2.29	7.8	43,966.6	19.7	0.85
June	7.4	2.56	8.0	39,622.4	18.3	0.89
July	6.2	2.69	6.7	23,099.6	10.3	0.84
August	9.4	3.54	10.0	51,276.1	23.0	0.98
September	9.0	2.66	9.7	59,700.9	27.6	0.94
October	8.0	2.41	8.6	51,923.2	23.3	0.89
November	6.0	1.69	6.7	41,157.3	19.1	0.74
December	3.8	1.26	4.5	26,998.4	12.1	0.48