J Arid Land 7(5): 706–715
doi: 10.1007/s40333-015-0132-y
jal.xjegi.com; www.springer.com/40333

The relationship between energy consumption and economic growth and the development strategy of a low-carbon economy in Kazakhstan

XIONG Chuanhe[1,2], YANG Degang[1*], HUO Jinwei[1], ZHAO Yannan[1,2]

[1] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China;
[2] University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Fossil energy is the material basis of human survival, economic development and social progress. The relationship between energy consumption and economic growth is becoming increasingly close. However, energy consumption is the major source of greenhouse gases, which can significantly affect the balance of the global ecosystem. It has become the common goal of countries worldwide to address climate change, reduce carbon dioxide emissions, and implement sustainable development strategies. In this study, we applied an approximate relationship analysis, a decoupling relationship analysis, and a trend analysis to explore the relationship between energy consumption and economic growth using data from Kazakhstan for the period of 1993–2010. The results demonstrated: (1) the total energy consumption and GDP in Kazakhstan showed a "U"-type curve from 1993 to 2010. This curve was observed because 1993–1999 was a period during which Kazakhstan transitioned from a republic to an independent country and experienced a difficult transition from a planned to a market economy. Then, the economic system became more stable and the industrial production increased rapidly because of the effective financial, monetary and industrial policy support from 2000 to 2010. (2) The relationships between energy consumption and carbon emissions, economic growth and energy exports were linked; the carbon emissions were mainly derived from energy consumption, and the dependence of economic growth on energy exports gradually increased from 1993 to 2010. Before 2000, the relationship between energy consumption and economic growth was in a recessional decoupling state because of the economic recession. After 2000, this relationship was in strong and weak decoupling states because the international crude oil prices rose and energy exports increased greatly year by year. (3) It is forecasted that Kazakhstan cannot achieve its goal of energy consumption by 2020. Therefore, a low-carbon economy is the best strategic choice to address climate change from a global perspective in Kazakhstan. Thus, we proposed strategies including the improvement of the energy consumption structure, the development of new energy and renewable energy, the use of cleaner production technologies, the adjustment and optimization of the industrial structure, and the expansion of forest areas.

Keywords: energy consumption; economic growth; the decoupling relationship analysis; low-carbon economy; Kazakhstan

Citation: XIONG Chuanhe, YANG Degang, HUO Jinwei, ZHAO Yannan. 2015. The relationship between energy consumption and economic growth and the development strategy of a low-carbon economy in Kazakhstan. Journal of Arid Land, 7(5): 706–715. doi: 10.1007/s40333-015-0132-y

The large-scale use of fossil energy has become the symbol of modern industrial civilization. However, energy consumption is the major source of greenhouse gas emissions, which can significantly affect the balance of the global ecosystem. Moreover, modifying economic growth dependent on energy consumption has become a popular topic throughout the world (Wang, 2009, 2010; Cheng et al., 2014). In their study on the industrial development of Greece, Samouilids and Mitropoulos (1984) described the economic growth and the potential decoupling of energy and considered that Greece could relief energy

*Corresponding author: YANG Degang (E-mail: dgyang@ms.xjb.ac.cn)
Received 2014-10-29; revised 2015-02-09; accepted 2015-03-11

dependence and change energy limitations through technological progress and industrial structural adjustment. The OECD (2002) has stated that in addition to the effect of economic growth on the environment, there are other factors to be considered: policy, industrial structure, technological progress and many other external effects. Indeed, to explain economic growth and the decoupling of carbon emissions, many factors shall be considered, such as energy consumption structure, industrial structure and policy effects. According to the course of economic development and a large number of facts and data validation in developed countries, the increase in economy growth and energy consumption are synchronized at the early stage of economic growth; however, economic growth has tended to demonstrate "decoupling" and then "hooking" patterns of energy consumption in recent years. It is important to implement a circular economy in the future (Duan and Deng, 2004). Coordinating the relationship between energy consumption and economic growth is an important task for the healthy development of the economy.

Kazakhstan has become one of the fastest growing economies in the world since its independence. Research about Kazakhstan has mainly concentrated on potential energy reserves and mining (Yang, 2008), energy geopolitics (Sun, 2008; Li et al., 2009), and energy multilateral cooperation (Mi, 2010; Sun, 2011), with a particular focus on energy production and export but less attention on the relationship between energy consumption and economic growth and the development of a low-carbon economy. As the world's largest inland country, Kazakhstan has experienced a rapid growth in energy consumption demand, which will be accompanied by a series of problems in terms of resources and environment (Sun, 1999; Zhao, 2003; Gu, 2005). Resources and environmental constraints on economic growth will also increase continuously; moreover, this growing demand will have far-reaching effects on the fragile ecological environment in this arid region. Therefore, it is particularly necessary to explore the relationship between energy consumption and economic growth and to develop a low-carbon national economy. This paper applied decoupling theory to analyze the relationship between energy consumption and economic growth, to demonstrate the connection between energy consumption and carbon emissions, economic growth and energy export in Kazakhstan from 1993 to 2010, and to forecast total energy consumption by 2020. A development strategy for a low-carbon economy was proposed to provide basic theoretical support to enable good social and economic development and efficient use of energy in Kazakhstan, as well as to provide a reference for the establishment of related policies in the energy field in the rest of Central Asia.

1 Materials and methods

1.1 Data

GDP data for Kazakhstan from 1993 to 2010 were obtained from the World Bank (World Bank, 2014a), and energy data were obtained from the Statistical Yearbook of Kazakhstan (Ministry of National Economy of the Republic of Kazakhstan, 2012), the International Energy Agency (International Energy Agency, 2014) and the World Bank (World Bank, 2014b).

1.2 Methods

Decoupling theory was proposed by scholars to resolve issues regarding the dependence of economic growth on material consumption (Pang et al., 2014). The World Bank's decoupling concept (delinking) includes both dematerialization and depollution and refers to the process of gradually reducing the effects of economic activities on the environment (de Bruyn and Opschoor, 1997). However, the decoupling concept of the Organization for Economic Cooperation and Development (OECD) is being more widely cited. The OECD states that decoupling involves breaking the link between the environmental "bads" and economic "goods" (OECD, 2003a), or the link between environmental pressure and economic performance (Enevoldsen et al., 2007; Lu et al., 2007). In the 1990s, the OECD first applied the decoupling theory to agricultural policy research; now, it is applied in various fields. The main applications involve the relationship between the decoupling of economic growth and pollution emissions, material flow, waste and energy (Hüttler et al., 1999; OECD, 2003a; Wang, 2009; Wang et al., 2009; Yu, 2009), the decoupling relationship between the output or economic growth of certain sectors (energy, transportation, agriculture,

manufacturing, etc.) and the corresponding environmental impact (OECD, 2003b; Zhao et al., 2006; Yu, 2008), decoupling analysis regarding land resources (Chen and Du, 2006; Cao et al., 2007; Du and Chen, 2007; Guo and Yan, 2007; Li et al., 2008; Song et al., 2009; Yang et al., 2009); the comparative study for the decoupling conditions of different regions (Vehmas et al., 2003), decoupling policy (Zhang, 2000; Femia et al., 2001), and the application of decoupling theory and other relevant methods (Wang, 2006; Zhu and Qiu, 2007).

Decoupling measurement methods include the comprehensive analysis, the decoupling index, the elastic analysis, and the descriptive statistics analysis (Zhong, 2010). This paper used the decoupling index and elastic analysis methods.

1.2.1 The decoupling index method

The formulae describing the decoupling index between energy consumption and economic growth are:

$$\mathrm{DIn} = \frac{\mathrm{EIn}}{\mathrm{GIn}}. \quad (1)$$

$$\mathrm{EIn} = \frac{\mathrm{En}}{\mathrm{Eo}}. \quad (2)$$

$$\mathrm{GIn} = \frac{\mathrm{GDPn}}{\mathrm{GDPo}}. \quad (3)$$

Where DIn is the decoupling index between energy consumption and economic growth at time *n*; EIn is the energy consumption index at time *n*; GIn is the growth index at time *n*; Eo is the total energy consumption at the base time and En is the total energy consumption at time *n*; GDPo is the GDP at the base time; and GDPn is the GDP at time *n*. In this paper, the base time is the year of 1993. When DI≥1, the energy consumption growth rate and economic growth rate are synchronous, or the energy consumption growth rate is higher than the rate of economic growth; this relationship indicates that there is no occurrence of decoupling, which is denoted as the absolute hook. When 0<DI<1, the energy consumption growth rate is lower than the rate of economic growth, which is denoted as relative decoupling (OECD, 2002; Wang, 2010).

1.2.2 The elastic analysis method

The elastic analysis method is mainly used to measure the degree of elastic decoupling. This decoupling method was proposed for the decoupling analysis of traffic and GDP (Tapio, 2005; Wang, 2009). The formula describing the decoupling elasticity index of energy consumption and economic growth is:

$$\mathrm{eg} = \Delta\mathrm{E}/\Delta\mathrm{GDP} = \frac{\mathrm{En}}{(\mathrm{Eo}-1)} \Big/ \frac{\mathrm{GDPn}}{(\mathrm{GDPo}-1)}. \quad (4)$$

Where eg is the decoupling elasticity index; ΔE indicates the change in energy consumption from the base time to time *n*; ΔGDP indicates the difference in GDP from the base time to time *n*; Eo is the total energy consumption at the base time; En is the total energy consumption at time *n*; GDPo is the GDP at the base time; and GDPn is the GDP at time *n*. In this paper, the base time is the year of 1993. There are six types of decoupling elasticity indices: strong decoupling, when the economy rises and energy consumption decreases; strong negative decoupling, when the economy declines and energy consumption increases; weak decoupling, when the economy rises and energy consumption increases, but the energy consumption growth rate is lower than the rate of economic growth; expansive negative decoupling, when the economy rises, the energy consumption increases and the energy consumption growth rate is higher than the rate of economic growth; weak negative decoupling, when the economy declines, the energy consumption decreases and the energy consumption growth rate is higher than the rate of economic growth; and recessionary decoupling, when the economy declines and the energy consumption decreases, but the energy consumption growth rate is lower than the rate of economic growth (Fig. 1) (Zhong, 2010; Wu et al., 2011).

2 Results and discussion

2.1 Approximate relationship analysis

Kazakhstan's total energy consumption and GDP decreased first and then increased from 1993 to 2010, showing a "U"-type curve (Fig. 2). However, Kazakhstan's GDP decreased sharply first and then increased slowly between 1993 and 1999. This trend was observed because from 1993 to 1999 when Kazakhstan transitioned from a republic to an independent country, the production departments and the domestic economy experienced a significant recession, and the economy

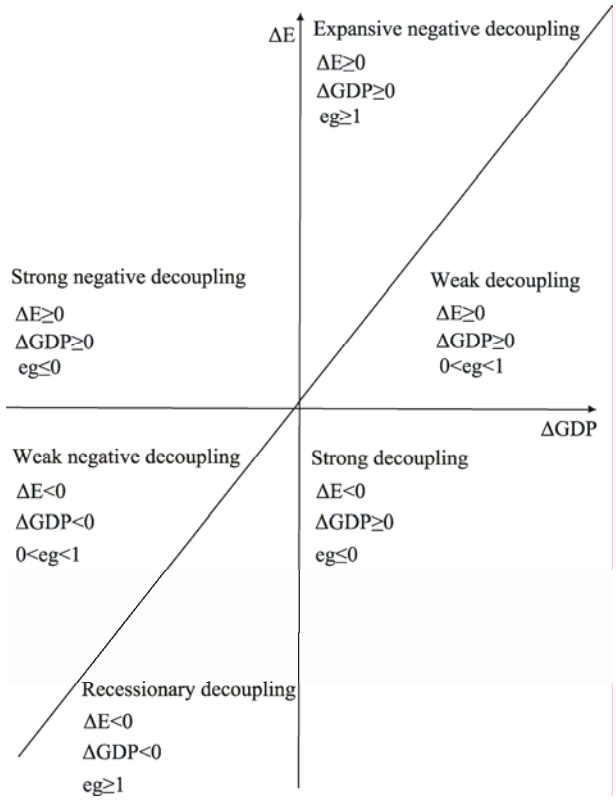

Fig. 1 Decoupling degree model of energy consumption (E) and economic growth (GDP). eg, decoupling elasticity index.

underwent a difficult changeover from a planned economy to a market economy. Between 2000 and 2010 when Kazakhstan experienced the initial pain of reform, the economic system was more stable, and the total value of industrial production increased rapidly with effective financial, monetary and industrial policy support. The reasons why the energy consumption inflection point was delayed to the GDP inflection point include: Kazakhstan's net energy exports have soared since 1999; the oil and gas industry output value accounts for more than 10% of the GDP in Kazakhstan; and the development of the energy industry drives the development of other industrial sectors.

2.2 Decoupling relationship analysis

Using Eqs. 1–4, we obtained the dynamic relationship between energy consumption and economic growth in Kazakhstan based on a data consolidation calculation (Table 1; Figs. 3 and 4). According to the results of the decoupling analysis, Kazakhstan's social development can be divided into three stages: the first stage (1993–2000), the second stage (2001–2006) and the third stage (2007–2010).

For the first stage (Table 1), the energy consumption index decreased rapidly from 1993 to 2000. The GDP growth index decreased sharply first and then increased slowly from 1993 to 2000, with the lowest point occurring in 1995. The decoupling index decreased rapidly between 1993 and 2000, with 1994 being in the relative hook state. The decoupling index remained between 0.60 and 1.00 for the rest of this period (the relative decoupling stage). Based on the elastic index, $\Delta E<0$, $\Delta GDP<0$ and $0<eg<1$ in 1994, indicating weak negative decoupling, and $\Delta E<0$, $\Delta GDP<0$ and $eg>1$ from 1995 to 2000, indicating recessional decoupling. This first stage represented Kazakhstan's period of transition from a republic to an independent country, during which the production departments and the domestic economy experienced a significant recession.

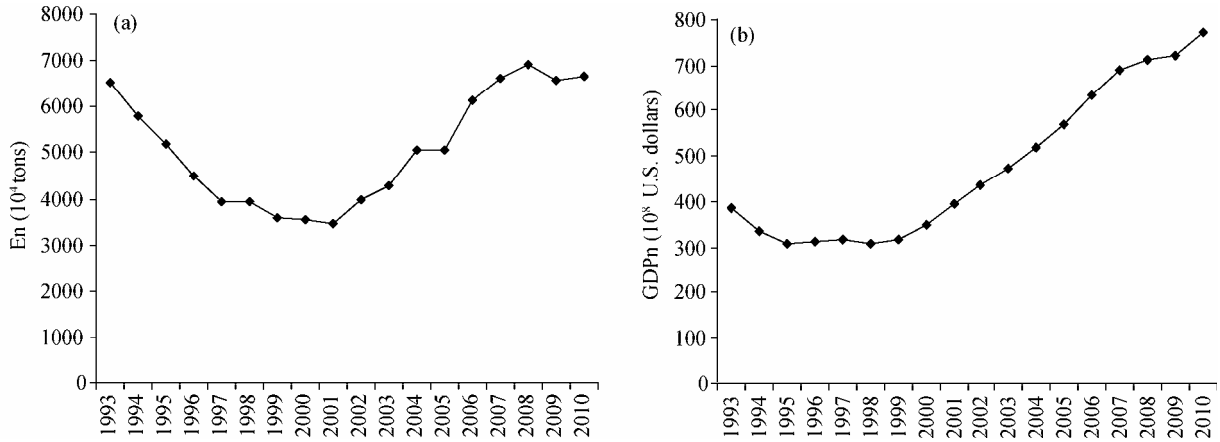

Fig. 2 Change in energy consumption (a) and GDP (b) in Kazakhstan from 1993 to 2010

Table 1 Results of the decoupling analysis concerning energy consumption and economic growth

Year	En (10^4 tons)	GDPn (10^8 U.S. dollars)	EIn	GIn	DIn	ΔE	ΔGDP	eg	Decoupling state
1993	6,527.45	384.50	1.00	1.00	1.00	0.00	0.00		
1994	5,789.88	336.05	0.89	0.87	1.01	–737.57	–48.45	0.90	Weak negative decoupling
1995	5,197.83	308.50	0.80	0.80	0.99	–1,329.62	–76.00	1.03	Recessionary decoupling
1996	4,517.77	310.04	0.70	0.81	0.86	–2,009.67	–74.46	1.59	Recessionary decoupling
1997	3,929.36	315.31	0.60	0.82	0.73	–2,598.08	–69.19	2.21	Recessionary decoupling
1998	3,920.51	309.32	0.60	0.80	0.75	–2,606.93	–75.18	2.04	Recessionary decoupling
1999	3,581.54	317.67	0.55	0.83	0.66	–2,945.90	–66.83	2.60	Recessionary decoupling
2000	3,558.18	348.80	0.55	0.90	0.60	–2,969.26	–35.70	4.90	Recessionary decoupling
2001	3,445.85	395.89	0.52	1.03	0.51	–3,081.59	11.39	–15.94	Strong decoupling
2002	3,962.00	434.69	0.60	1.13	0.54	–2,565.44	50.19	–3.01	Strong decoupling
2003	4,293.63	475.12	0.66	1.24	0.53	–2,233.82	90.61	–1.45	Strong decoupling
2004	5,047.56	520.73	0.78	1.35	0.57	–1,479.88	136.23	–0.64	Strong decoupling
2005	5,073.94	571.24	0.78	1.49	0.52	–1,453.51	186.74	–0.46	Strong decoupling
2006	6,139.73	632.36	0.94	1.64	0.57	–387.72	247.86	–0.09	Strong decoupling
2007	6,609.93	688.64	1.01	1.80	0.57	82.49	304.14	0.02	Weak decoupling
2008	6,924.40	711.36	1.06	1.85	0.57	396.95	326.86	0.07	Weak decoupling
2009	6,583.50	719.90	1.01	1.87	0.54	56.06	335.40	0.01	Weak decoupling
2010	6,642.87	772.45	1.02	2.01	0.51	115.42	387.95	0.02	Weak decoupling

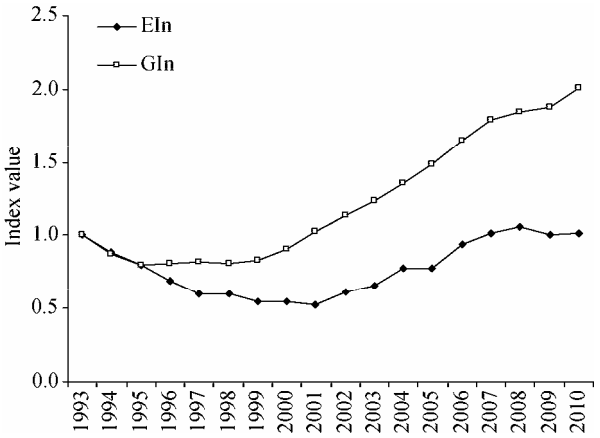

Fig. 3 Relationship between GDP growth (GIn) and energy consumption (EIn) in Kazakhstan

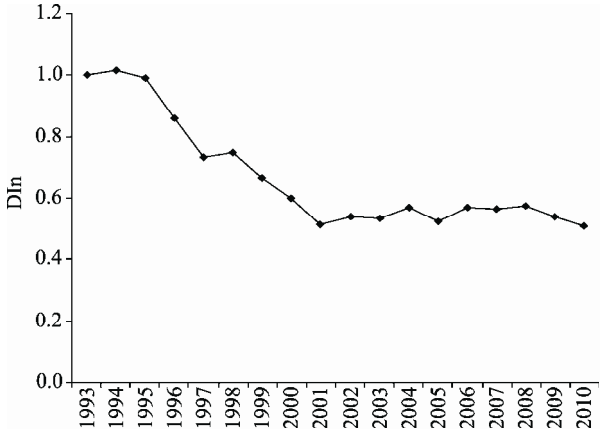

Fig. 4 Decoupling index (DIn) of economic growth and energy consumption in Kazakhstan

For the second stage (Table 1), the energy consumption index rose slowly from 2001 to 2006 and the GDP growth index increased rapidly during this period. The decoupling index fluctuated during the same period and this period was in the relative decoupling stage. Based on the elastic index, $\Delta E<0$, $\Delta GDP>0$ and $eg<0$ between 2001 and 2006, indicating a strong decoupling state. Kazakhstan's net energy exports soared during this stage, and the output value of the oil and gas industry accounted for more than 10% of the GDP in Kazakhstan, but the development of the energy industry did not drive the development of other industrial sectors, which explains the strong decoupling between energy consumption and GDP growth.

For the third stage (Table 1), the energy consumption index increased rapidly and then tended to be stable between 2007 and 2010, and the GDP growth index continued to increase during this period. The decoupling index decreased slowly during this period, and this period was in the relative decoupling stage. Based on the elastic index, $\Delta E>0$, $\Delta GDP>0$ and $0<eg<1$ between 2007 and 2010, corresponding to the

weak decoupling state. Kazakhstan's domestic economy continues to grow steadily and the energy consumption rate is gradually decreasing.

During the period of 1993–2010, the decoupling index between energy consumption and economic growth decreased first and then tended to be stable, which indicates a relative decoupling stage (Fig. 4). According to the elastic index, the relationship between energy consumption and economic growth was in a weak negative decoupling state in 1994, a recessional decoupling state between 1995 and 2000, a strong decoupling state between 2001 and 2006, and a weak decoupling state between 2007 and 2010 (Table 1). Meanwhile, the relationships between energy consumption and carbon emissions, economic growth and energy exports were in the linked state, which shows that carbon emissions were derived mainly from energy consumption, and the dependence of economic growth on energy exports gradually increased between 1993 and 2010 (Table 2). The decoupling state from 1993 to 2010 indicates that energy exports had little effect on the energy consumption (Table 2). Before 2000, the presence of a recessional decoupling state was because of the economic recession. After 2000, the reasons why the relationship was in the strong and weak decoupling states include: the rise of the international crude oil prices, the increase of energy exports year by year, the improvement of energy efficiency, and the rapid increase in the total value of industrial production (Wang et al., 2013). However, the increase in the total energy consumption still did not slow down.

Table 2 Results of the decoupling analysis concerning energy consumption, carbon emissions, energy exports and economic growth

Year	Decoupling index between energy consumption and economic growth	Decoupling index between energy consumption and carbon emissions	Decoupling index between energy exports and economic growth	Decoupling index between energy consumption and energy exports
1993	1.00	1.00	1.00	1.00
1994	1.01	1.20	1.13	0.90
1995	0.99	1.23	1.09	0.91
1996	0.86	1.10	1.71	0.50
1997	0.73	1.13	2.40	0.31
1998	0.75	1.16	2.38	0.31
1999	0.66	0.92	2.74	0.24
2000	0.60	0.87	3.54	0.17
2001	0.51	0.84	3.60	0.14
2002	0.54	0.95	3.41	0.16
2003	0.53	1.07	3.57	0.15
2004	0.57	1.04	3.53	0.16
2005	0.52	1.01	3.41	0.15
2006	0.57	1.13	3.01	0.19
2007	0.57	1.21	2.74	0.21
2008	0.57	1.22	3.00	0.19
2009	0.54	1.32	3.24	0.17
2010	0.51	1.25	3.09	0.16

2.3 Trend analysis of energy consumption

In the present study, we predicted the total annual energy consumption in Kazakhstan between 2011 and 2020 in different situations via historical analysis and forecasting. The formula describing the pre-measurement energy consumption is:

$$\mathrm{GIn} = \frac{\mathrm{GDP}_{2010} \times (1+\mathrm{V})^{\mathrm{n}}}{\mathrm{GDPo}}. \quad (5)$$

$$\mathrm{En} = \mathrm{DIn} \times \mathrm{GIn} \times \mathrm{Eo}. \quad (6)$$

Where En is the pre-measurement of the energy consumption at time *n* and V is the rate of economic growth.

Based on historical data, we used the annual economic growth rate of 8.28%, averaged over nearly 10 years, as the pre-economic growth rate between 2011 and 2020. Moreover, we used the mean value (0.54) of the decoupling index and the lowest level (0.51) of the

decoupling index over the past 10 years, as the two types of scenario predictions for the period of 2011–2020.

According to the Kazakhstan 2020 national strategic development plan (Yi, 2010), Kazakhstan's energy consumption will be $10{,}070.49\times10^4$ tons of oil equivalent by 2015 and $11{,}733.01\times10^4$ tons of oil equivalent by 2020 when the annual economic growth rate is 8.28% (Yi, 2010). Table 3 shows that Kazakhstan can achieve its goal of energy consumption by 2015 and not by 2020. Therefore, only when the decoupling index between economic growth and energy consumption is less than 0.51 and the government formulates/enforces industrial, energy and other policies can Kazakhstan be expected to achieve the stage goal of the 2020 national strategic development plan.

Table 3 Forecast of energy consumption in Kazakhstan between 2011 and 2020

Year	GDPn (10^8 U.S. dollars)	When DIn=0.54, En (10^4 tons)	When DIn=0.51, En (10^4 tons)
2011	836.38	7,192.58	7,712.87
2012	905.59	7,787.78	8,351.13
2013	980.53	8,432.24	9,042.20
2014	1,061.67	9,130.03	9,790.47
2015	1,149.52	9,885.56	10,600.65
2016	1,244.65	10,703.61	11,477.88
2017	1,347.65	11,589.36	12,427.71
2018	1,459.17	12,548.41	13,456.13
2019	1,579.92	13,586.82	14,569.66
2020	1,710.66	14,711.16	15,775.33

2.4 Development strategy of a low-carbon economy in Kazakhstan

Through the foregoing approximate relationship analysis and decoupling relationship analysis, we know that Kazakhstan's GDP and energy consumption have increased rapidly in the 21st century, but Kazakhstan is a country with high energy consumption, low energy efficiency and a medium level of per capita income. At the same time, based on energy consumption trend analysis, we know that Kazakhstan cannot achieve its energy consumption goal by 2020. It has become the common goal of countries worldwide to address climate change, reduce carbon dioxide emissions, and implement sustainable development stratagems. Therefore, a low-carbon economy is the best strategic choice for Kazakhstan to ensure that its quest for rapid economic growth and transformation is not achieved at the expense of environmental quality. Therefore, we propose the following strategies:

(1) Improving energy consumption structure and developing new energy and renewable energy. The coal-dominated energy consumption pattern has not changed since 1993. Carbon emissions from coal, oil, natural gas consumption have accounted for 63.02%, 19.76% and 17.21% of the total average discharge, respectively, over the past 20 years in Kazakhstan (Wang et al., 2013). From the perspective of carbon emissions and pollutants, the emissions of CO_2 and air pollutant quantity are the largest when one unit of energy is produced by coal combustion; while natural gas produces the lowest emissions of CO_2 and air pollutants. The amount of CO_2 emitted by oil combustion is 38%–43% more than that emitted by natural gas when one unit of energy is produced, and the amount of CO_2 emitted by coal combustion is 72%–95% more than that emitted by natural gas when one unit of energy is produced (Zhang and Wen, 2001). From the perspective of climate protection and atmospheric pollution control, natural gas is the most attractive fossil fuel. In addition to the control of CO_2 emissions by fossil fuels, we also recommend investment in and policy incentives for the development of alternative (clean) energy resources such as solar, wind and biofuels (biogas) to meet the growing energy demands in Kazakhstan while ensuring environmental sustainability.

(2) Using cleaner production technologies and improving energy utilization efficiency. Carbon emissions from coal consumption have accounted for 63.02% of the total average discharge over the past 20 years in Kazakhstan. The utilization of clean coal technology in the future will play a very important role. Energy efficient technologies not only lower energy use, reduce carbon emissions and improve cost effectiveness, but can also play a greater role through technology transfer.

(3) Adjusting and optimizing the industrial structure and promoting the transition to a low-carbon economy. Kazakhstan's heavy industry is relatively developed, but the light industry is relatively backward. Therefore, strategies should aim to: eliminate the backward industries of high energy consumption

and high pollution; promote the optimization and upgrading of traditional industries; encourage the development of new energy technologies and low-carbon technological industries; and actively develop low-carbon transportation and construction industries that adapt to a low-carbon economy.

(4) Strengthening the propaganda work of climate change through publicity, correctly guiding residential consumption behavior and forming an appropriate atmosphere to save energy, improve energy utilization efficiency and reduce greenhouse gas emissions.

(5) Prioritizing forest protection, expanding the forest area and improving the capacity of carbon sinks. Forests are highly important in acting as absorption "sinks" of CO_2. Kazakhstan has 2.17×10^7 km^2 of forest area and should enact laws and regulations to stop deforestation, initiate natural forest protection projects, accelerate key forestry ecological engineering works, increase reforestation efforts and establish a forestry fund system. In addition, Kazakhstan should advocate for comprehensive utilization and decreased use of timber and encourage the development and use of wood substitutes.

3 Conclusions and policy recommendations

The present study explored the relationship between energy consumption and economic growth using data from Kazakhstan over the period of 1993–2010. The results show that a low-carbon economy is the best strategic choice to address global climate change in Kazakhstan.

Kazakhstan's total energy consumption and GDP first decreased and then increased from 1993 to 2010, showing a "U"-type curve. This type of curve was observed because 1993–1999 was a period during which Kazakhstan transitioned from a republic to an independent country and the economy underwent a difficult transition from a planned economy to a market economy. From 2000 to 2010 when Kazakhstan experienced the initial pain of reform, the economic system was more stable and the total value of industrial production increased rapidly under effective financial, monetary and industrial policy support.

The decoupling index between energy consumption and economic growth decreased first and then tended to be stable between 1993 and 2010, the relative decoupling stage. Based on the elastic index, the relationship between energy consumption and economic growth was in a weak negative decoupling state in 1994, a recessional decoupling state during 1995–2000, a strong decoupling state during 2001–2006, and a weak decoupling state during 2007–2010. Meanwhile, the relationships between energy consumption and carbon emissions, economic growth and energy exports were in the linked state, which demonstrate that carbon emissions were mainly derived from energy consumption, and the dependence of economic growth on energy exports gradually increased between 1993 and 2010. The relationship between energy consumption and energy exports was in the decoupling state in 1993–2010, which means that energy exports had little effect on energy consumption.

Forecasting results show that Kazakhstan can achieve its goal of energy consumption by 2015 and not by 2020. Only when the decoupling index between economic growth and energy consumption is less than 0.51 and the government formulates/enforces industrial, energy and other policies can Kazakhstan be expected to achieve the stage goal of the 2020 national strategic development plan.

By approximate relationship analysis, decoupling relationship analysis and trend analysis, we know that Kazakhstan's GDP and energy consumption have increased rapidly in the 21st century, but Kazakhstan is a country with high energy consumption, low energy efficiency and a medium level of per capita income. We thus proposed strategies including the improvement of the energy consumption structure, the development of new energy and renewable energy, the use of cleaner production technologies, the adjustment and optimization of the industrial structure, and the expansion of forest areas.

In conclusion, a low-carbon economy is the best strategic choice for addressing climate change in Kazakhstan. We recommended investment in and policy incentives for the development of alternative (clean) energy resources such as solar, wind and biofuels (biogas) to meet the growing energy demands in Kazakhstan while ensuring environmental sustainability. Second, we recommended introducing and emphasizing

coal gasification technologies to formulate a corresponding implementation strategy. Third, backward production capacity should be eliminated and excess capacity should be limited. Furthermore, public education programs on energy conservation and utilization efficiency that are currently underway in Kazakhstan should be intensified. Finally, environmental regulations must be strictly enforced. These will ensure that the country's quest for rapid economic growth and transformation is not achieved at the expense of environmental quality.

Acknowledgments

This work was supported by International Science & Technology Cooperation Program of China (2010DFA92720-07).

References

Cao Y G, Cheng Y, Yuan C, et al. 2007. Decoupling research between change of cultivated land quantity and change of GDP in representative areas. Resource Development & Market, 23(7): 586–589. (in Chinese)

Chen B M, Du H L. 2006. Analyzing decoupling relationship between arable land occupation and GDP growth. Resources Science, 28(5): 36–42. (in Chinese)

Cheng Y Q, Wang Z Y, Ye X Y, et al. 2014. Spatiotemporal dynamics of carbon intensity from energy consumption in China. Journal of Geographical Sciences, 24(4): 631–650.

de Bruyn S M, Opschoor J B. 1997. Developments in the throughput-income relationship: theoretical and empirical observations. Ecological Economics, 20(3): 255–268.

Du H L, Chen B M. 2007. Rationality of farmland occupation by constructions based on decoupling analysis method. Transactions of the Chinese Society of Agricultural Engineering, 23(4): 52–58. (in Chinese)

Duan N, Deng H. 2004. The rise of multi peak theory and circular economy. World Nonferrous Metals, 10: 7–9. (in Chinese)

Enevoldsen M K, Ryelund A V, Andersen M S. 2007. Decoupling of industrial energy consumption and CO_2-emissions in energy-intensive industries in Scandinavia. Energy Economics, 29(4): 665–692.

Femia A, Hinterberger F, Luks F. 2001. Ecological economic policy for sustainable development: potentials and domains of intervention for delinking approaches. Population & Environment, 23(2): 157–174.

Gu W. 2005. The ecological environment situation in Kazakhstan. Central Asian Information, 7: 36–39. (in Chinese)

Guo L, Yan J M. 2007. Study on the decoupling of cultivated land occupation by construction from economic growth in China. China Population Resources and Environment, 17(5): 48–53. (in Chinese)

Hüttler W, Schandl H, Weisz H. 1999. Are industrial economies on the path of dematerialization? Material flow accounts for Austria 1960–1996: indicators and international comparison. In: Ecologizing Societal Metabolism: Designing Scenarios for Sustainable Materials Management. Amsterdam, the Netherlands: Universitair Grafisch Bedrijf Leiden, 26–29.

International Energy Agency (IEA). 2014. World Energy Statistics. [2014-8-15]. http://www.iea.org/stats/index.asp.

Li H Q, Wang L M, Lang Y H. 2009. Evolution process and driving mechanism of energy geopolitical pattern—a study of Central Asia. World Regional Studies, 18(4): 56–65. (in Chinese)

Li X S, Qu F T, Guo Z X, et al. 2008. Decoupling between urban and rural construction land. China Population Resources and Environment, 18(5): 179–184. (in Chinese)

Lu I J, Lin S J, Lewis C. 2007. Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea. Energy Policy, 35(6): 3226–3235.

Mi K. 2010. Research on energy cooperative between Kazakhstan and China. MSc Thesis. Changchun: Jilin University. (in Chinese)

Ministry of National Economy of the Republic of Kazakhstan. 2012. Statistical Yearbook of Kazakhstan. [2014-8-15]. www.stat.gov.kz.

OECD. 2002. Indicators to measure decoupling of environmental pressures for economic growth. Paris: OECD, 211–222.

OECD. 2003a. Analysis of the links between transport and economic growth. Paris: OECD, 11.

OECD. 2003b. Environmental indicators: development, measurement and use. Paris: OECD, 13.

Pang J X, Chen X P, Wang H Y. 2014. Relationship of energy consumption with economic growth in Gansu province. Journal of Arid Land Resources and Environment, 28(2): 31–36. (in Chinese)

Samouilids J E, Mitropoulos C S. Energy and economic growth in industrializing countries: the case of Greece. Energy Economics, 6(3): 191–201.

Song W, Chen B M, Chen X W. 2009. Decoupling evaluation between cultivated land occupation and economic growth in Changshu City. Journal of Natural Resources, 24(9): 1532–1540. (in Chinese)

Sun W J. 2011. Game analysis on energy cooperation evolutionary of Central Asia. Development Research, 3: 133–136. (in Chinese)

Sun X. 2008. Study on energy geopolitics and multilateral energy cooperation in Central Asia. World Economy Study, 5: 37–43. (in Chinese)

Sun Z Z. 1999. The five Central Asian countries of new international pattern. East European & Central Asian Study, 4: 59–66. (in Chinese)

Tapio P. 2005. Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. Transport Policy, 12(2): 137–151.

Vehmas J, Kaivo-oja J, Luukkanen J. 2003. Global trends of linking environmental stress and economic growth. Tutu Publications 7/2003: 6–9.

Wang C J, Zhang X L, Du H R, et al. 2013. Variations and influence factors of carbon emission of primary energy consumption in Kazakhstan. Arid Land Geography, 36(4): 757–763. (in Chinese)

Wang C M. 2009. Analyzing decoupling of economic growth and energy consumption based on the sample of China. Journal of Shandong Institute of Business and Technology, 6: 1–3, 8. (in Chinese)

Wang C M. 2010. Decoupling analysis of china economic growth and energy consumption. China Population Resources and Environment,

20(3): 35–37. (in Chinese)

Wang H, Wang J Q, Zhao T. 2009. Decoupling and recoupling analysis of China's economic development and environments and energy consumption. Statistics and Decision, 17: 113–115. (in Chinese)

Wang H. 2010. Measurement of the relationship between China's economic growth and energy consumption by using delinking theory. Soft Science, 24(9): 23–27. (in Chinese)

Wang M X. 2006. The theory of decoupling applied to the model of recycling economy in Zhejiang province. Forestry Economics, (12): 40–43. (in Chinese)

Wang Q L. 2009. Decoupling analysis of China's economic development and energy consumption. Popular Business, 14: 60–61. (in Chinese)

World Bank. 2014a. World Development Indicators. [2014-8-15]. http://data.worldbank.org.cn/indicator/NY.GDP.MKTP.KD.

World Bank. 2014b. World Development Indicators. [2014-8-15]. http://data.worldbank.org.cn/indicator/EG.USE.COMM.KT.OE.

Wu H, Gu S Z, Zhou H, et al. 2011. Relationships between energy comsumption-carbon emissions and economic growth in Hebei province. Resources Science, 33(10): 1897–1905. (in Chinese)

Yang J M. 2008. The reserves, mining and attract of energy in Kazakhstan. Central Asian Information, 3: 12–14. (in Chinese)

Yang K, Chen B M, Song W. 2009. Decoupling analysis between arable land occupation and GDP growth in Hebei province. Resources Science, 31(11): 1940–1946. (in Chinese)

Yi L. 2010. The interpretation of Kazakhstan's 2020 national strategic development plan. New Silk Road Horizon, 2: 80. (in Chinese)

Yu F W. 2008. Analysis of the decoupling relationship between grain production and irrigation water of China. Chinese Rural Economy, 10: 34–44. (in Chinese)

Yu F W. 2009. Decoupling analysis of economic development and environments & resource. Journal of Inner Mongolia Finance and Economics College, 3: 29–34. (in Chinese)

Zhang K M, Wen Z G. 2001. China's point of view and countermeasures on global warming. China Soft Science, 7: 6–11. (in Chinese)

Zhang Z X. 2000. Decoupling China's carbon emissions increase from economic growth: an economic analysis and policy implications. World Development, 28(4): 739–752.

Zhao C Q. 2003. Guide to the World States: Kazakhstan. Beijing: Beijing Social Sciences Academic Press, 105–112. (in Chinese)

Zhao Y P, Sun Q H, Duan N. 2006. Responsive relationship between economic development and energy consumption in China—a practical research based on comparative de-link and re-link theory. Science Research Management, 27(3): 128–134. (in Chinese)

Zhong T Y, Huang X J, Han L, et al. 2010. Review on the Research of Decoupling Analysis in the Field of Environments and Resource. Journal of Nature Resource, 25(8): 1400–1412. (in Chinese)

Zhu D J, Qiu S F. 2007. Analytical tool for urban circular economy planning and itpreliminary application: a case of Shanghai. City Planning Review, 31(3): 64–69. (in Chinese)