CHEMICAL ENGINEERING TRANSACTIONS

VOL. 76, 2019

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Petar S. Varbanov, Timothy G. Walmsley, Jiří J. Klemeš, Panos Seferlis

ISBN 978-88-95608-73-0; **ISSN** 2283-9216

DOI: 10.3303/CET1976177

Assessment of Greenhouse Gas Emissions from Various Energy Sources

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GHG emissions caused by energy generation and consumption is both a global as well as localised issue. Especially for Kazakhstan, which is one of the most significant coal reserves and mining countries. Kazakhstan is the 9th biggest country worldwide and the biggest country in Middle Asian (MA), is a gateway to the west for China. It has been playing a significant role in the "Belt & Road" strategy. It is essential to specify GHG emissions in Kazakhstan, especially that from energy consumption, which has not been studied deeply so far. To fill that gap, this study analysed the GHG emissions from the main types of energy in Kazakhstan from 2006 to 2016, based on the GHG emissions assessment methods defined by The Intergovernmental Panel on Climate Change (IPCC). The GHG emissions characters of Kazakhstan and the whole world were also compared. Results showed that: 1) the energy consumption structures of Kazakhstan and the whole world are visibly different. Coal accounted for a significant proportion in Kazakhstan; 2) the consumption changes of different types of energy ranged widely; 3) the change trends of GHG emissions from Kazakhstan and whole world are similar, first upward then downward; 4) the GHG emission sources structure of Kazakhstan is visibly different to that of the whole world, coal accounted for more than 58 % of whole GHG emissions in Kazakhstan. This study can contribute to understanding energy consumption and GHG emissions in Kazakhstan.

1. Introduction

Reducing greenhouse gases (GHG) emissions (mainly CO_2, CH_4 and N_2O), have been crucial for supporting the sustainable development of for the world. Energy generation and consumption related human activities, in the context of rapid urbanisation and industrialisation worldwide, especially in developing countries, have been playing a pivotal role in GHG emissions. EPA (US EPA, 2016) reported that most GHG emissions (about 75 %) worldwide come from energy production and consumption related human activities, which have been the main driving forces of the global climate change. The energy needed for manufacturing, processing, transporting, materials mining, maintenance, cleaning, construction and dealing with it at the end of the life, all these processes relate to GHG emissions (Wang et al., 2019). From the perspective of life cycle GHG emissions, the electricity generation from different kinds of energies related methods result in GHG emissions. Studies focusing on low GHG emissions have been attracting increasing attention of the international scientific community.
The "One Belt & One Road Initiative" (OBOR) or the "Belt & Road Initiative" (BRI) (Huang, 2016), as shown Figure 1a, is China's greatest international economic ambition, aiming at stimulating economic development in a vast region covering sub-regions in Asia, Europe and Africa, which accounts for more than 64 % of world population and more than 30 % of world GDP (Huang, 2016). According to the study conducted by Duan et al. (2018), the proven reserves of natural gas, oil, and coal in the nations under the BRI make up 79.9 %, 58.8 %, and 54.0 % of the world's total. All BRI participants have a common interest in using this initiative to develop

Paper Received: 15/04/2019; Revised: 22/05/2019; Accepted: 30/05/2019
Please cite this article as: Wang X.-C., Klemes J.J., Dong X., Sadenova M.A., Varbanov P.S., Zhakupova G., 2019, Assessment of Greenhouse Gas Emissions from Various Energy Sources, Chemical Engineering Transactions, 76, 1057-1062 DOI:10.3303/CET1976177

their domestic economies. A plentiful amount of energy resource reserves have also provided the foundation and possibility for the initiation of cooperation between those nations(Duan et al., 2018).
Kazakhstan, the 9th biggest country worldwide and the biggest country in Middle Asian (MA), is a gateway to the west for China. It plays a crucial role in the BRI, especially for the SREB. As the most impressive reformer in the MA region, Kazakhstan is set to benefit enormously from China's Belt and Road initiative as an equal partner. However, it has been facing a series of environmental and economic related challenges, like fossil energy dominance, renewable energy shortage, unbalanced economic development, etc. According to the study conducted by Russell et al. (2018), the Republic of Kazakhstan has experienced many years of environmental degradation, mostly because of the poor management of its significant natural resources. The energy generation and consumption of Kazakhstan have significantly increased emissions, especially CO_2 emissions; however, without in-depth analysis (Akbota and Baek, 2018). Kerimray et al. (2018) investigated the energy transition to a coal-free residential sector in Kazakhstan, exploring the optimised strategy for coal utilisation. Kerimray et al. (2018) also analysed that there are mostly different in energy utilisation data and the consequent CO_2 emissions in Kazakhstan. Their study provided the first comprehensive review of energy consumption trends in Kazakhstan, improving energy strategies and setting appropriate sectoral energy intensity reduction plans are significant for achieving GHG emissions decrease and efficiency improvements in the economy.
However, not a large quantity of related research has been done focusing on Kazakhstan; many fields were not attended fully. Those studies mentioned above mainly focus on one kind of energy or analysing the strategies from the politic and economic perspective. The in-depth exploring of GHG emission sources structure requires to be more studied. To fill this gap, the objective of this study is to analyse the energy-related GHG emissions of Kazakhstan, with extension to the consumption change of different type of energy as well as the GHG emissions comparison between Kazakhstan and worldwide. So far, there is no study investigated this topic. This study can be a stepping stone to understand the status of Kazakhstan, supporting and directing future studies.

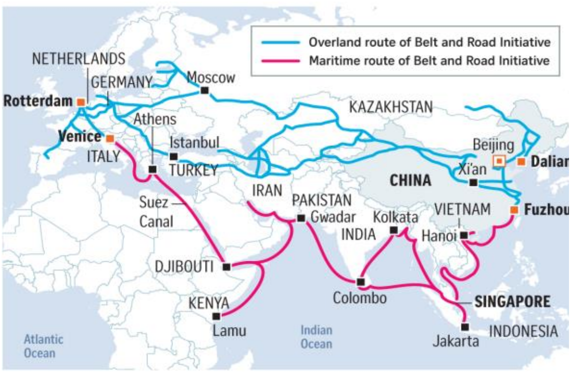

Figure 1a: "Belt & Road" map (China-Belt-and-Road-Initiative-map-ST-photo, 2018)

Figure 1b: Map of Kazakhstan (Hamidov et al., 2016)

2. Materials and methods

2.1 Study area

As shown in Figure 1b, Kazakhstan locates in MA and is the biggest country in the MA region, which is surrounded by China, Russian Federation, Turkmenistan, Uzbekistan and Kyrgyzstan.

2.2 Data sources

Information sources used in this study include: 1) the consumption amount of different types energy in Kazakhstan, which was obtained from the Energy Information Administration (www.eia.gov); 2) GHG emission factors of CO_2, CH_4 and N_2O, which was retrieved from IPCC (IPCC, 2006).
In this study, not all but the main types of energy are considered, they are coal (anthracite, metallurgical coal, bituminous, subbituminous, lignite, metallurgical coke), petroleum (motor gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, liquefied petroleum gases, others) and natural gas. These kinds of fossil energy are the main source of GHG emissions, especially the CO_2, CH_4 and N_2O. Other types of energy, like electricity, wind energy, are not involved in this study. The energy consumption detail of Kazakhstan and worldwide from 2006 to 2016 is showed in Table 1. Table 2 illustrates the emissions factors and calorific values of different types of energy considered in this study.

Table 1: Consumption of different types of energy in Kazakhstan and worldwide in different years.

Energy types, *i* (Unit)		Consumption amount, A_{ENG}					
		2006		2011		2016	
		KAZ*	World	KAZ	World	KAZ	World
Coal (kt)	Anthracite	50	389,016	1.1	538,068	0.2	519,046
	Metallurgical coal	6,349	780,234	9,416	1,017,439	11,778	1,041,412
	Bituminous	52,454	3,207,434	68,499	3,884,184	57,672	3,683,329
	Subbituminous	4,250	1,084,884	5,485	1,236,968	4,978	1,326,323
	Lignite	5,532	1,016,564	5,248	1,128,445	4,165	1,061,915
	Metallurgical coke	3,482	504,120	3,674	608,195	3,691	654,922
Petroleum (kt)	Motor gasoline	2,753	706,071	3,623	776,661	4,462	850,392
	Jet fuel	271	158,978	324	170,051	369	187,258
	Kerosene	187	39,249	157	27,164	46	15,089
	Distillate fuel oil	2,787	755,699	4,183	867,945	5,789	877,949
	Residual fuel oil	2,751	383,705	1,621	346,077	1,374	256,542
	LPG*	229	145,233	438	168,940	568	194,675
	Others	1,077	549,248	2,329	619,051	2,557	612,314
Natural gas (10^{12} m^3)		11	2,907	13	3,371	14	3,621

*KZA: Kazakhstan; LPG: Liquefied Petroleum Gases

Table 2: GHG emission factors and calorific value of different types of energy (kg GHG/TJ on a Net Calorific Basis) (IPCC, 2006).

Energy types, *i*		Emission Factors, *F* (kg/TJ)			Calorific Values, *J* (TJ/Gg)
		CO_2	CH_4	N_2O	
Coal	Anthracite	98,300	10	1.5	26.7
	Metallurgical coal	94,600	10	1.5	25.8
	Bituminous	94,600	10	1.5	25.8
	Subbituminous	96,100	10	1.5	18.9
	Lignite	101,000	10	1.5	11.9
	Metallurgical coke	107,000	10	1.5	28.2
Petroleum	Motor gasoline	69,300	10	0.6	44.3
	Jet fuel	70,750*	10	0.6	44.2
	Kerosene	71,900	10	0.6	43.8
	Distillate fuel oil	73,300	10	0.6	38.1
	Residual fuel oil	77,400	10	0.6	40.4
	LPG	63,100	5	0.1	47.3
	Others	73,300	10	0.6	45.5
Natural gas		64,200	10	0.6	48.0

* Average of jet gasoline and jet kerosene.

2.3 Methods

According to the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), contributors to carbon emissions can be classified into four sectors: 1) Energy consumption; 2) Industrial processes and product use; 3) Agriculture, forestry and other land use; 4) Waste. In this study, the energy consumption related to GHG emissions had been analysed. The detailed calculation process is shown below.
The GHG estimation from energy consumption was calculated based on Eq(1):

$$E_{GHG,i} = C_{ENG,i} \times (F_{CO_2,i} + F_{CH_2,i} + F_{N_2O,i}) \quad (1)$$

where $E_{GHG,i}$ is the amount of GHG emitted by energy type i, $C_{ENG,i}$ is the consumption amount of energy type i expressed in TJ units, $F_{CO_2,i}$, $F_{CH_2,i}$ and $F_{N_2O,i}$ are the GHG emission factors of CO_2, CH_4 and N_2O from energy i, respectively, which were all quoted from the IPCC (2006).

$$C_{ENG,i} = A_{ENG,i} \times J_i \quad (2)$$

where $A_{ENG,i}$ is the consumption amount of energy type i expressed in mass or volume units, J_i is the net calorific value of energy i provided by the IPCC (2006).

3. Results and discussion

This section shows the result details of energy consumptions and related GHG emissions of Kazakhstan and worldwide. The discussion is also provided.

3.1 Energy consumption structure

As shown in Table 3, there is an apparent difference between the energy consumption structure of Kazakhstan and that of the whole world. Coal is the main energy utilised in this country, and its calorie is much more than that from petroleum and natural gas. This is consistent with the resource reserves of Kazakhstan. Kazakhstan is one of the biggest coal mining countries. Its coal reserves comprise c. 37×10^{12} t (4 % of the world estimated reserves) and the sector is said to have enough reserves to last over 100 y (Karatayev and Clarke, 2016). The coal-fired plants in Kazakhstan account for 75 % of total power generation (Karatayev and Clarke, 2016). 32 % of Kazakhstan's population nationwide, including 70 % of rural households, used coal as the primary source for space heating energy (Howie and Atakhanova, 2017). All of these phenomena have been leading to concerns over GHG emissions and impacts on human health and the environment. The Government of Kazakhstan plans to increase coal production from 120 Mt in 2010 to almost 200 Mt by 2030 (Coal Age, 2019). That coal is used in coal-fired boilers for drying coal, heating mine facilities and providing air ventilation, as well as the production of coke for industrial use and in thermal plants for heat and power (Karatayev and Clarke, 2016).

Table 1: Total calorie of different types of consumed energy (TJ)

Energy types	2006		2011		2016	
	KAZ	World	KAZ	World	KAZ	World
Coal	1,762,800	160,086,164	2,279,960	194,786,578	2,039,549	191,929,939
Petroleum	419,287	116,178,997	533,243	126,320,017	635,271	127,492,635
Natural gas	477	126080	563	146,205	607	157,047

3.2 Consumption change of different types of energy in Kazakhstan

As shown in Figure 2, the consumption amount changes in different types of energy range widely. Consumption of most kinds of energy increased. Set the 2006 amount as the basic value, the LPG (increase by 148.03 %) in the first place of the increase list. Distillate fuel oil (107.71 %), metallurgical coal (85.51 %) and motor gasoline (62.08 %) are those increased by more than 50 %. On the contrary, the anthracite (- 99.60 %) leads the reduction list and followed by kerosene (- 75.40 %), residual fuel oil (- 50.05 %) and lignite (- 24.71 %). During the past year, the government of Kazakhstan has paid much more attention to fossil fuel management and renewable energy generation and utilisation. Kazakhstan has considerable renewable energy potential, the development of which can provide significant environmental, economic and social benefits. The country's national low carbon energy strategy aims to bring the share of renewables in electricity production to 50% by 2050 (Karatayev et al., 2016). All of these kinds of measure have significantly contributed to the improvement of energy utilisation.

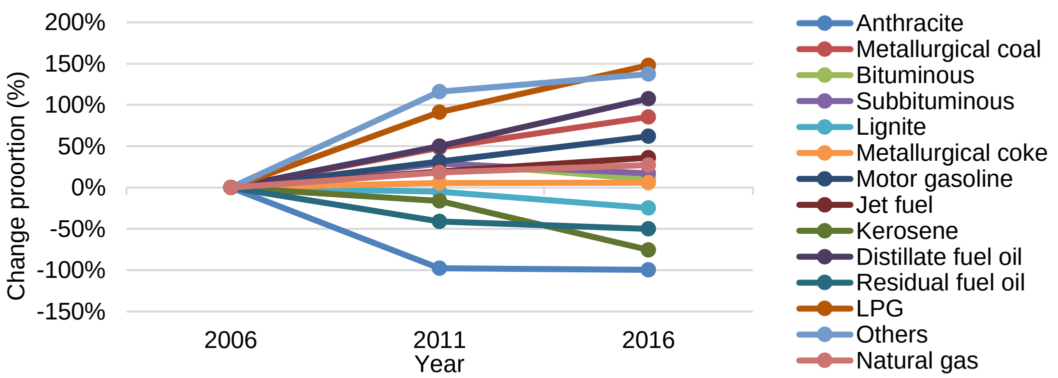

Figure 2: Energy consumption change of Kazakhstan

3.3 GHG emissions of Kazakhstan and worldwide

As shown in Figure 3 (a and b), the change trends of GHG emissions from Kazakhstan and the whole world are similar. There was a noticeable increase from 2006 to 2011 in both Kazakhstan and worldwide. Energy consumption has significantly increased during this period. On the country, from 2011 to 2016, there was a slight decrease. However, based on the study conducted by Wang et al. (2019), global GHG emissions have a slight upward trend. The sources of GHG are various, including energy consumption, industrial processes and product use, agriculture, forestry (and other land use), waste, etc. In this study, not all but the main types of energy are considered, which related GHG emissions showed a slight downward trend. It is a positive phenomenon because of the more reasonable energy strategies, innovation for renewables utilisation and biofuels, etc. (Varbanov et al., 2018). As shown in Table 3, the total calorie consumption of petroleum and natural gas increased from 2011 to 2016 in Kazakhstan and worldwide. However, that of coal reduced more. This is one of the main reasons that resulted in the slight decrease from 2011 to 2016 in Figure 3.

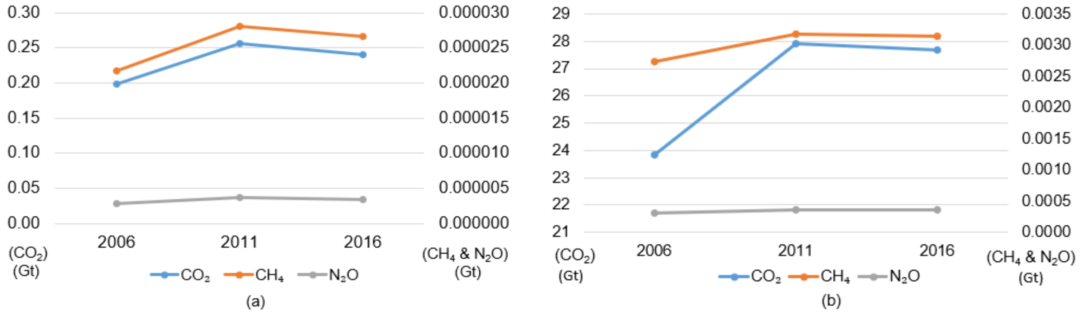

Figure 3: GHG emissions of Kazakhstan (a) and the whole world (b) (Gt)

3.4 GHG emissions sources structure

As shown in Figure 4, the GHG emission sources structure of Kazakhstan is visibly different from that of the whole world. Although the bituminous coal accounted for the most GHG emissions, the proportion of Kazakhstan (58.5 %) is much higher than that of the whole world (32.5 %). This is also consistent with the energy structure of Kazakhstan (Howie and Atakhanova, 2017); Coal is the main contributor to energy supply. The metallurgical coal (11.96 %), distillate fuel oil (6.72 %) and motor gasoline (5.70 %) are the followed main GHG emission contributors in Kazakhstan. Figure 5 shows the proportion of GHG emissions from Kazakhstan to worldwide, which showed the pattern that dropped first and then rose. This is consistent with Figure 3.

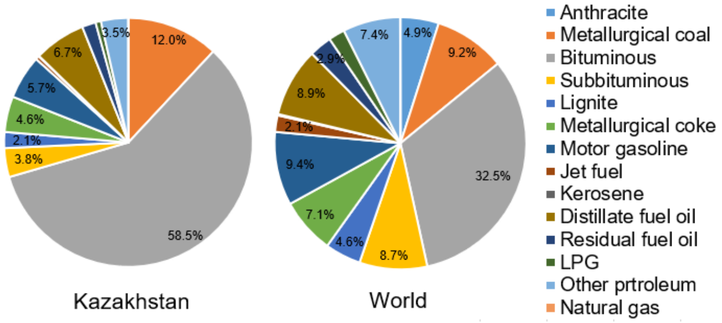

Figure 4: GHG emission sources in Kazakhstan and the worldwide

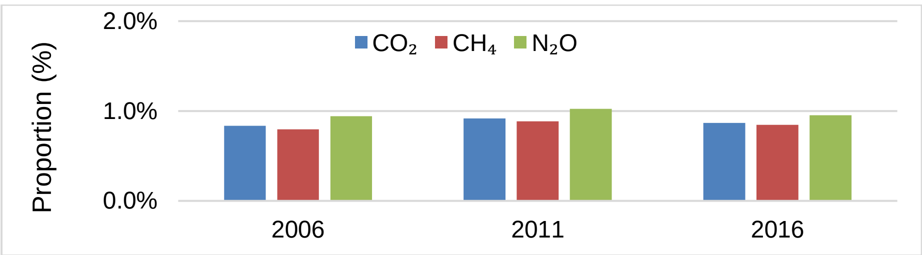

Figure 5: The proportion of GHG emissions from Kazakhstan to worldwide

4. Conclusion

This paper aims at analysing the GHG emissions from main types of energy in Kazakhstan from 2006 to 2016, using the GHG emissions assessment methods defined by IPCC. The GHG emissions characters of Kazakhstan and the worldwide were compared as well. The energy consumption structures of Kazakhstan and the whole world are different because of the difference in natural resources and mining structure. Coal accounted for a more significant proportion of Kazakhstan. The energy consumption changes also ranged widely in both Kazakhstan and the whole world because of the changes in energy strategies, etc. From 2006 to 2016, coal was the main contributor to GHG emissions, especially in Kazakhstan, accounting for more than 58 % of overall GHG emissions. However, there are also some potential limitations for this study; for example, it can only quantitatively analyse the energy consumption changes. The direct, indirect and total GHG emissions of different sectors also cannot be analysed by this approach. The study of driving forces from the perspective of technology, sectoral connection, economic structure and the economic scale was also not conducted. These aspects will be the main targets of future work.

Acknowledgements

This research has been supported by the project “Sustainable Process Integration Laboratory – SPIL”, project No. CZ.02.1.01/0.0/0.0/15_003/0000456 funded by EU “CZ Operational Programme Research, Development and Education”.

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