Potential for CCS in Kazakhstan

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Kazakhstan is a huge country covering a territory, which totals 2 717 300 square kilometres. Kazakhstan borders with the Russian Federation in the north and west, Turkmenistan, Kyrgyz Republic and Uzbekistan - in the south and China - in the south-east. The borders also go along the Caspian seashore in the south-west. The total population residing in the country is about 15 million people. That makes it the largest country in Central Asia and one of the most sparsely populated in the world with density of 5.5 people per square kilometre. 56.4 % of population lives in urban areas.

Kazakhstan inherited a significant part of infrastructure from the Soviet times and has a relatively well-educated population. Kazakhstan is one of the ten largest countries of the world with excess energy and mineral resources (2 806 registered deposits have been identified). Kazakhstan is one of ten countries with the largest resources of uranium, coal, manganese, tungsten, molybdenum, gold, phosphorites and iron including the largest resources of uranium and lead in the world, the second largest resources of zinc and chromate ores, the fourth largest resources of copper, and the seventh of gold. Kazakhstan is the second largest producer of oil and coal among CIS countries.

Real GDP grew more then 9 percent last years. The growth of GDP can be explained by firstly, favourable situation in the world market: in particular, high prices of the main exports from Kazakhstan: oil, ferrous and non-ferrous metals. Secondly, there have been quite high industrial growth rates, especially in construction. These high rates are also typical of transport and communications, and other service sectors.

According to the results of greenhouse gases inventory in Kazakhstan, the total emissions of gases with direct greenhouse effect in 2005 amounted to 240.7 mln. t of ?O_2-equivalent, including 187.7 mln. t of the emissions resulting from all energy activity, 16.1 mln. t from industrial processes, 20.2 mln. t from agriculture and 16.6 mln. t from wastes. The absorption of CO_2 by forests in 2005 amounted to 5.9 mln. t. Thus, net emissions taking into account the absorption (sequestration) of CO_2 by forests amounted to 234.8 mln. t of ?O_2-equivalent (Table 1).

Total specific GHG emissions amounted to more than 15.2 t per capita in 2005, and about 12.3 t of it fall to CO_2 only.

Total emissions of ? ?$_2$ come to 186.3 mln. t; the increase, as compared to 2000, is 49 mln. t or 35 % that is 78 % of 1990 level (238.3 mln. t). This is the general trend for CIS countries.

91.4 % of total ? ?$_2$ emissions account for energy sector activity. Substantial part of energy sector activity is the country's electric power industry (Table 2).

Kazakhstan has a substantial electric power industry – the third largest one in the Former Soviet Union after Russia and Ukraine - with installed capacity of around 18 500 MW – 88 % account for thermal power plants and the balance - for hydroelectric plants (Table 3).

Main characteristics of power sector of Kazakhstan:

- high concentration of electricity generation (7 400 MW of thermal capacity at three sites only: Ekibastuz-1 (8 X 500 MW)/Ekibastuz-2 (2 X 500 MW) and Aksu (8 X 300 MW);
- location of large plants mostly close to fuel deposits;

Table 1. Total emissions of gases with direct greenhouse effect, mln. t ? ? $_2$-equiv.

IPCC sources categories	1990	1992	1994	2000	2005
CO_2	**238.3**	**261.2**	**243.7**	**137.3**	**186.3**
Energy activity	220.1	246.3	236.5	126.6	170.2
Fuel combustion	*216.8*	*243.0*	*233.9*	*120.3*	*163.7*
Volatile emissions	*3.3*	*3.3*	*2.6*	*6.3*	*6.5*
Industrial processes	18.3	14.9	7.2	10.7	16.1
Land tenure change and forestry	-8.1	-7.1	-4.8	-7.1	-5.9
? H_4	**64.0**	**57.8**	**46.3**	**33.9**	**42.7**
Energy activity	39.0	32.8	23.9	13.1	17.0
Fuel combustion	*1.6*	*1.9*	*1.2*	*0.4*	*0.6*
Volatile emissions	*37.4*	*31.0*	*22.7*	*12.7*	*16.4*
Industrial processes	0.05	0.04	0.02	0.03	0.03
Agriculture	16.9	16.5	13.6	7.4	9.5
Wastes	8.0	8.5	8.7	13.4	16.2
N_2O	**27.0**	**25.1**	**17.6**	**9.0**	**11.7**
Energy activity	0.8	0.9	0.9	0.4	0.5
Fuel combustion	*0.8*	*0.9*	*0.9*	***0.4***	***0.5***
Agriculture	25.8	23.8	16.2	8.3	10.7
Wastes	0.4	0.4	0.5	13.4	16.2
Total emission	**329.3**	**344.1**	**307.6**	**180.2**	**240.7**
Net-emissions (sources and effluent)	**321.2**	**336.9**	**302.7**	**173.1**	**234.8**

Table 2. Historical electricity balance of Kazakhstan, billion kWh

	1990	1998	2000	2003	2006
Total electricity consumption	104.72	53.40	54.38	61.98	71.77
Electricity generation	87.38	49.59	51.42	63.65	71.55
Deficit (-), surplus (+)	-17.34	-3.81	- 2.96	+1.63	-0.22

Table 3. Structure of Installed Capacity of Power Plants, by energy type in 2003

Type of Power Plants	Capacity, MW	%
Coal Thermal Power Plants	12 440	67.4
Gas and Oil Thermal Power Plants	3 774	20.4
Hydro Power Plants	2 247	12.2
Total	18 461	100

- high share of co-generation of electricity and heat for industrial and community use (38 (CHP) - 32 of which are in urban or suburban locations (38% of the total capacity);
- insufficient share of hydropower plants (8 hydroelectric plants) – only 12 % is the share of hydropower, whilst hydro potential is estimated as 27 bln. kWh per year;
- developed network of 220 kV, 500 kV and 1150 kV transmission lines;
- unified vertical system of operative supervisory management.

Thermal power plants in Kazakhstan can be categorized, both by the type of fuel used and by the type of generated product, into condensing power plants that generate electricity only and co-generation power plants that generate electricity and heat. The installed capacity of condensing power plants of Kazakhstan totals to 9.3 GW, of which 7.1 GW are coal based; and 6.9 GW are generated by co-generation power plants, 77 % of which are coal-fired. Co-generation power plants in Kazakhstan meet about 40 % of domestic heat demand and 48 % of electricity demand.

Table 4. Electricity Generation Structure, billion kWh

Types of Power Plants	1990	1995	1998	2000	2003
Electricity generation, total:	87.38	66.98	49.59	51.42	63.65
Including:					
Coal Power Plants	62.33	47.37	33.6	37.26	46.99
Gas and Oil Power Plants	17.7	10.8	7.99	6.65	8.05
Hydro Power Plants	7.35	8.31	7.7	7.51	8.61
Nuclear Power Plants	0.5	0.5	0.3	0.0	0.0

In 2003 thermal power plants consumed:

- 68 % of the total consumption of fossil fuel (15.7 mln. t oe)
- 42 % of the total consumption of gas (2.62 mln. t oe)
- 8 % of the total consumption of oil (0.73 mln. t oe)

The total power generated in 2003 was equal to 63.65 bln. kWh, with 87.1 % produced by thermal power plants (coal-fired PP – 73.8 %, gas and oil fired PP – 12.7 %) and 12.4 % produced by hydro power plants.

Till 2015 up to 30 % of installed capacities of coal-fired power plants in Kazakhstan need rehabilitation. In addition, it is planned to extend the existing coal-fired power plants and construct the new ones (2500 – 3000 MW) by 2015. Need for power plants construction will only increase in the next decades. As is known, it is coal-fired power plants that are considered the first to implement carbon capture and storage (CCS) technology.

Coal-fired power plants constitute a considerable part of the country's energy sector owing to a great deal of coal reserves and developed coal industry.

The coal-mining industry of Kazakhstan comprises 24 coalmines and 11 coal pits with the total planned production capacity of 162 mln. t. Major coal deposits are located in the central part of

Kazakhstan, which provides geographical advantages for transporting coal over the territory of the Republic. Major power plants are located near the deposits, facilitating fuel supply.

Over 3 % of the world's industrial reserves of coal, about 170 bln. t, are located in Kazakhstan. Coal balance reserves of Kazakhstan are estimated at 38-39 bln. t, which is 23 % of total geological reserves. Kazakhstan coals can be subdivided by energy value into hard coal and lignite. Over 60 % of coal reserves are presented by hard coals.

The Karaganda, Ekibastuz and Kuuchekinsk Coal Fields are the major deposits in the country. Coke is processed at the Karaganda coalfields only. It should be noted that coals are excavated here by the underground method (deep mining) and used mostly in metallurgy. Coals from other fields are excavated by the surface method (open pit mining) and are used for energy production.

There are plans to develop the application of energy-efficient technologies both by electricity consumers and electricity generators, to involve renewable energy sources and nuclear power in the energy balance and to extend the use of "clean" coal technologies at power plants in Kazakhstan.

The important strategic direction of the energy sector development is also to modernize the existing heating systems with the combined generation of electricity and heat, as the effective power-saving technology makes it possible to significantly lower the consumption of fuel and reduce the greenhouse gases emissions.

Modernization of the existing power plants, holding to the concept of combined heat and power generation at CHP makes it possible to keep the CO_2 emission at the following level (the data is given for the forecast of electricity generation in the country, to which the Energy Balance of Republic of Kazakhstan is oriented up to 2030, taking into consideration plans of nuclear energy development).

Table 5. CO_2 emission of power plants with the account for the increased fuel efficiency at thermal power plants (TPP), while holding to the concept of combined heat and power generation at CHP

Million tons

	1990	2000	2005	2010	2015	2020
Generation of power, billion kWh						
Low	87.38	51.42	67.57	87.1	106.1	121
High	87.38	51.42	67.57	96.9	119.2	135
CO_2 emission, million tons						
Low	111.6	55.3	78.0	102.1	124.6	144.3
High	111.6	55.3	78.0	115.4	141.4	163.1

6600 MW of capacity are subject to modernization during the period till 2015, including 2300 MW at CHP.

One of the priorities in development of electricity sector and settlement of environmental problems in Kazakhstan is the use of renewable energy resources. The potential of renewable energy resources (hydro-energy, wind and solar energy) is significant in Kazakhstan.

The possible construction of the Kerbulakskaya (50 MW, 300 mln. kWh), Mainakskaya (300 MW, 970 mln. kWh) and Bulakskaya (89 MW, 400 million kWh) Hydro Power Plants (HPP) would enable the emission reduction.

Table 6. CO_2 emission of power plants with the account for the increased fuel efficiency at TPP while holding to the concept of combined heat and power at CHP and putting into operation of Kerbulakskaya, Mainakskaya and Bulakskaya HPP

Million t

	1990	2000	2005	2010	2015	2020
Generation of power, billion kWh						
Low	87.38	51.42	67.57	87.1	106.1	121
High	87.38	51.42	67.57	96.9	119.2	135
CO_2 emission, million t						
Low	111.6	55.3	78.0	100.8	121.9	141.1
High	111.6	55.3	78.0	113.4	138.3	159.5

Use of the oil gas at some deposits, construction of the wind power plants, construction of small HPP would allow to predict emission of CO_2 in the total amount of approximately 1.24 million t per year.

Thus, the total potential for reduction of CO_2 emissions resulting from generation of power during the considered period of time can be estimated as the 25 mln. t per year up to 2020.

The big potential for reduction of CO_2 emissions lies in the consumption of power (as estimated by specialists, it is 10-15% of the total) which can be involved through increase in the effectiveness of industrial and municipal use of energy by means of energy saving and environmentally friendly technologies.

Thus, even considering the planned measures, the significant increase of CO_2 emissions can be expected in Kazakhstan (1.5 times the level of 1990 by the year 2020) due to power industry in particular. In this situation the potential for CCS technologies application is quiet high especially taking into account the plans for construction of coal-fired power plants.

It is evident that CCS technologies may also find its place in the overall pattern of the country's energy sector. All the more, it will be due to the fact that Kazakhstan is rich not only in coal resources, but also in oil and gas with great deal of deposits, and continuous build-up of production and import of energy resources goes on.

About 0.5 % of world's mineral energy resources are located in Kazakhstan; that is equal to 90 bln. t of oil equivalent (toe). This amount includes 70 % of coal, 22 % of oil and oil condensate and 8 % of gas. Prospective oil- and gas-bearing areas comprise 62 % of the entire country's territory, and only roughly half of them have been explored. 197 oil and gas deposits have been discovered with explored resources of hydrocarbons amounting to more than 2 bln. t of oil, 0.7 bln. t of oil gas and some 2 000 bln. m^3 of natural gas. Forecasted extractable resources of the Kazakhstan continental part are estimated at 10 bln. t of oil and oil gas, and more than 7 000 bln. m^3 of natural gas. The Kazakhstan's sector of the Caspian Sea is extremely promising with estimated resources of about 13 bln. t of oil equivalents.

Table 7. Energy Balance

	1990	1995	1998	1999	2000	2001	2002	2003
Production								
Coal, million tons	131.5	83.4	69.77	58.26	77.4	79.08	73.73	84.9
Oil, million tons	25.82	20.64	25.78	30.18	35.32	40.09	47.27	51.45
Natural gas, billion m^3	7.7	5.92	7.95	7.2	9.09	8.28	6.02	7.56
Consumption								
Coal, million tons	89.7	65.1	47.45	43.14	52.92	50.64	51.52	57.02
Oil, million tons	18.95	16.64	9.1	7.51	7.15	8.60	9.55	8.66
Natural gas, billion m^3	14.45	11.3	8.7	6.15	7.83	5.87	7.21	7.79
Export								
Coal, million tons	32	23.0	23.55	16.26	25.71	27.51	22.73	27.03
Oil, million tons	21	11	16.39	23.57	29.35	32.40	34.09	44.27
Natural gas, billion m^3	4.7	0.62	2.3	3.83	5.22	5.54	10.44	11.01
Import								
Coal, million tons	10.2	1.0	1.23	1.14	0.69	0.21	0.20	0.36
Oil, million tons	14	7	0.29	0.9	1.0	2.34	2.63	2.48
Natural gas, billion m^3	11.45	6	3.05	2.78	4.22	4.28	8.17	8.7

The analysis of the data presented (Table 7) proves that the production of primary energy resources decreased within the 1990-1998 reporting period due to political and economic transformations in the country. In 1998, coal production decreased by 47% as compared to 1990. However, oil and gas production, having recovered from a sharp fall, show a growth tendency: in 1998 oil production reached 99.8 % of the level of 1990 and natural gas production had increased by 3.2 %. Since 2000 stable growth in production and consumption of coal, oil and gas is observed. From 2000 to 2005 oil and oil condensate production increased from 35.32 mln. t to 61.5 mln. t.

Thus, there is a number of potential geological formations in the country that can be used to store captured CO_2 in future, including:

- depleted and disused oil and gas fields;
- deep saline aquifers;
- deep unmineable coal seams.

The legislation of Kazakhstan related to attraction of investments and new technologies to the country has been developed in recent years (more than 50 billion dollars of direct foreign investments have been attracted during the last 10 years. Kazakhstan is a leader among CIS countries with regard to this index per capita). Provision is made for further development of legal framework of the country in this direction; the country's industrial development program has been approved and now is effective. It enables Kazakhstan to keep and further develop the available research base and increase the number of scientific manpower. It shall be noted here that the Environmental Code was adopted last year, and Kazakhstan is an active participant in the activity related to UN FCCC.

The energy policy of the Republic of Kazakhstan within a long-term outlook pursues four main goals:

- to ensure reliable power sources required for sustainable economic growth;

- to meet the demand of the population for energy services at acceptable prices;
- to develop reliable energy saving systems that would guarantee energy security;
- to preserve a sound environment and prevent uncontrolled climatic changes.

It is feasible for Kazakhstan to succeed in these main goals, since it has considerable fuel and energy resources combined with a developed energy infrastructure.

The main objectives of the governmental policy in the energy sector are:

- to ensure fuel and electricity independence of Kazakhstan;
- to create fuel and electricity markets in Kazakhstan;
- to work out legislation that will encourage development of the energy sector;
- to implement energy saving policy;
- to improve the ecological situation in Kazakhstan;
- to involve renewable sources of energy into the energy balance of the Republic.

The new structural policy in the area of energy sector development within the next 15-30 years provides for:

- growth in oil production, more efficient use of oil, increased domestic consumption and export of oil;
- more efficient utilisation of natural gas, increased domestic consumption of natural gas;
- priority of fine processing and complex utilisation of hydrocarbon raw materials;
- as ecologically acceptable technologies will be introduced, improvement of quality of coal products through increased volumes of high calorific coals, and stabilization and further building up of coal production rates;
- intensified development of local energy resources (hydro energy, minor deposits of hydrocarbons, etc.), greater use of non-conventional and, first of all, renewable resources (wind and solar energy, mine methane, biogas, etc.)

The new technical policy in the area of energy sector development is oriented towards:

- a fundamental increase in economics and energy efficiency at all stages of production, conversion, distribution and use of energy resources;
- ecological and emergency security of energy sources and reliable energy supplies to consumers;
- use and development of new quality technologies and techniques to ensure sustainable energy sector development, including environmentally friendly coal-fired power plants, as well as efficient technologies for the use of new energy sources, production and processing of hydrocarbon raw materials, etc.

Future application of CCS technologies does not conflict with energy policy of the country but has a possibility to fit suitably into it in the long view.

Application of CCS technologies is possible because of the following reasons:

- availability and further development of coal-fired power plants;
- significant number of oil and gas deposits – both continental and offshore ones;
- possibility of other geological formations for CO2 storage;
- high level of population education and availability of highly qualified specialists in power, oil and gas industry, geology.

Kazakhstan electricity sector will need to move towards a low-carbon portfolio of plant by the middle of the century. CCS, alongside with improved energy efficiency, nuclear power, “clean” coal technologies and renewables, may be an element in achieving this.

A key prerequisite for developing CCS is to reduce the efficiency penalty arising from the capture process. A number of technologies, e.g. ultra-supercritical, PFBC and IGCC, need further development in parallel if CCS is to become economically viable, and it is crucial that these technologies are not held up by waiting for zero-emission technologies. CCS will be part of the solution but must compete on a level playing field with other technologies.

Extensive R&D efforts must be undertaken to improve the range of capture technologies (precombustion, oxyfuel and post-combustion) with special emphasis on reducing the efficiency penalty and reaching the highest possible capture rate, and also to demonstrate the long-term viability of storage.

The institutions and national governments should as a priority ensure that an enabling regulatory framework is put in place as soon as necessary.

CCS technologies, when commercially viable, should be deployed rapidly by using market-based instruments, with a view to moving towards a largely carbonneutral production fleet. Moreover, what is commercially feasible for one company in one country, may not be the same for companies elsewhere, given that storage capacities will not be uniformly available.

All these issues may be reviewed by the specialists inside of a special Center, and establishment of such Center in Kazakhstan could be quite timely. The special center could start work for a successful deployment of CCS technologies to:

- examine possible measures to stimulate the construction and operation of sustainable fossil fuels technologies in commercial power generation in the Kazakhstan;
- determine availability of storage capacity in Kazakhstan;
- develop an enabling framework for CCS in the Kazakhstan, regulatory questions surrounding CO2 transport and storage;
- provide a clear perspective when coal- and gas-fired plants will need to install CO2 capture and storage;
- promote public acceptance of storage.

Thus, in Kazakhstan as in some CIS countries there are conditions favourable for implementation of CCS technologies, with its application extended to the developed countries and increase of commercial attractiveness. No doubt that international cooperation is required to distribute the information on CO_2 capture and storage research, development and demonstration, stimulate discussions of technical, economic and regulatory aspects of CCS technology. It will contribute to extension of CCS technology application possibilities around the world.