ECODEFENSE!

RUSSIAN COAL INDUSTRY:
ENVIRONMENTAL AND PUBLIC HEALTH IMPACTS AND REGIONAL DEVELOPMENT PROSPECTS

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Note to reader: This is a preliminary version of Ecodefense!'s report on the Russian coal industry, pending the addition of an appendix, which will contain a list of accidents in the Russian coal mining industry in the past two years; translation into English of the titles of Russian-language sources (all references are currently provided in footnotes throughout the text); and a general edit. Some additional information may also be incorporated into the official edition, which will be forthcoming later in 2013.

1. Russian coal: The industry's structure in Russia's regions and its role in the country's economy

Russia has the world's second largest reserves of coal. Coal is produced in 25 constituent territories of the Russian federation. The individual shares of the major coal mining areas in national coal production are as follows: Kuznetsk basin: 52%; Kansk-Achinsk basin: 12%; Pechora basin: 5%; East Donets basin: 3%; and South Yakutsk basin: 3%.[1]

Kuzbass (Kemerovo Region) is the most important coal supplier, and rising production volumes in the past ten years in Russia have been due first and foremost to the introduction of new production capacities at Kuzbass.[2]The surface mines of the Kansk-Achinsk basin (Krasnoyarsk Region) rank second in significance.

Russia's coal industry today is represented by over 240 coal mining operations, including 96 underground mines and around 150 surface mines, together accounting for total production capacities in excess of 360 million tons of coal per year.

Coal in Russia is currently mined primarily by open-pit mining (65%), since this extraction method provides for a relatively high output and low production cost.

Today, the coal mining industry of Russia is represented entirely by privately owned companies. Practically all mines where coking coal is extracted, furthermore, form part of metallurgical holdings. Some sixteen holding companies, including five coal and metals mining companies – EVRAZ, Severstal Resources (Severstal), Mechel Mining (Mechel), Ural Mining and Metallurgical Company, and Industrial Metallurgical Holding Management Company – constitute the industry's largest, together responsible for around 78% of total coal production in the country.[3]

Two major areas of coal use are the metals industry and electricity generation. It is used for electricity and heating purposes in the housing and utilities sector, at large power plants, boiler houses and by households to supply heat to residential buildings, single family houses, and similar.

Electricity generation has a diverse structure across Russian regions depending on the prevailing type of fuel used. Where Russia's European part and the Urals mostly rely on gas in their heating needs, and the share of coal is insignificant (less than 10%), in Siberia and the Far East, every second kilowatt-hour of electricity is produced from coal. Electricity use has increased in Russia at a rate of 20% in the past ten years, a growth accounted for primarily by power generation at gas-fired power plants.[4]

2. Coal's impact on the environment and health

Air, water, and soil pollution

The coal industry is a compound source of negative impacts affecting the natural environment. Coal mining operations result in air and water pollution and land disturbance (particularly, topsoil), as well as generation of large amounts of waste.

Each year, 360 million of cubic meters of air is blown into Russian mines and over 200 million tons of water is pumped out; at open cast mines, between 300 million and 350 million tons of rock is moved into waste rock dumps.[5] In 2009, the specific emission

[1] Горкина Т. И. Угольная промышленность мира. Региональные аспекты развития.
[2] Энергетика и промышленность России 07 (195) апрель 2012 г.
[3] Структура угольной отрасли. Министерство энергетики РФ. http://minenergo.gov.ru.
[4] Энергетика и промышленность России 11 (199) июнь 2012 года.
[5] Сенкус В. В., Майер В. Ф.Экологические проблемы горнодобывающих предприятий в Кузбассе.

intensity rate at enterprises engaged in mining fuel and energy resources was around 5 kilograms per ton of coal produced.[6]

Kemerovo Region, where populations of eight cities are predominantly employed by the coal mining industry, has been the focus of the most detailed studies of the state of the environment in Russia's coal producing regions. The report *On the State of the Environment in Kemerovo Region in 2011* estimates the average concentrations of certain harmful pollutants in the region's atmosphere at levels exceeding by 2 or 3 times the maximum allowable limits established in the Russian Federation. In a number of cases, these concentrations exceed permissible limits by as much as 18 times. In Kemerovo Region alone, the annual total emission rate for atmospheric pollutants is estimated at over 1.5 million tons, and wastewater pollutant discharges are estimated at over 0.5 million cubic meters a year.

Another environmental problem associated with the coal mining industry is methane emissions**.** Between 1.5 billion and 2 billion cubic meters of methane is released into the atmosphere from underground and open cast coal mines.[7] Methane, a gas capable of igniting even in wet condition, is one of the principal greenhouse gases affecting the world's climate and contributing to global warming.

Atmospheric pollution

In the past decade, dust and gas emissions from the coal mining industry have more than doubled, reaching 549,000 tons over a level of 233,000 tons ten years ago. Rock weathering provides a pathway into the atmosphere for a broad range of pollutants; with air transport over significant distances, the resulting atmospheric pollution becomes transboundary.

According to information provided by the Environmental Protection Inspection of Neryungri – a town in Yakutia located near the Neryungri open pit coal mine – "at coal quarries, blast fracturing of barren rock and coal seams is accompanied by the release of a dust and gas cloud reaching 15 million to 20 million cubic meters in size and with dust concentrations of 0.135 to 0.217 kilograms per cubic meter. This dust and gas cloud rises to an altitude of 1,500 to 1,700 meters and within four to six hours results in the dispersal of up to 500 tons of dust."

Air basin pollution during coal mining and processing is due to drilling and blasting operations, exhaust fumes from the internal combustion engines of vehicles used for coal excavation, emissions from boiler plants, and fires caused by spontaneous ignition of coal. With open pit mining, solid particles – inorganic dust with silicon dioxide content, coal ash, and black carbon (soot) – are the main pollutants.[8]

The impact of the coal mining industry is not limited to the territory where the coal producing enterprises are located, but the environment of the nearby populated areas is affected as well. Coal mining cities traditionally suffer from high concentrations of suspended particulate matter in the air. Increased content of lead, cadmium, mercury, and arsenic is found in locally produced foods.[9]

Cities with the worst record in Russia for solids emissions to the atmosphere are coal mining cities (Vorkuta: 33,700 tons per year) and cities reliant on coal for energy production (Suvorov, Tula Region, Cherepetskaya GRES[10]: 33,500 tons per year); Vorkuta and four cities of Kemerovo Region – Novokuznetsk, Mezhdurechensk, Leninsk-Kuznetsky, and Prokopyevsk – as well as Ukhta and Inta in the Komi Republic, lead the country in emissions of hydrocarbons and volatile organic compounds.

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[6] Государственный доклад «О состоянии и охране окружающей среды Кемеровской области в 2010 году».
[7] Сенкус В.В., Майер В.Ф.Экологические проблемы горнодобывающих предприятий в Кузбассе.
[8] Государственный доклад «О состоянии и охране окружающей среды Кемеровской области в 2010 году»
[9] Доклад о развитии человеческого потенциала в Российской Федерации.
[10] For Russian "state district power station" – a high-capacity electricity producing thermal power plant. – Translator.

Novokuznetsk, Kemerovo Region, has one of the highest air pollution levels in the country. Source: Ecodefense!

According to information provided by the Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet) in Yakutia, residents of the coal mining city of Neryungri suffer from the worst air pollution levels in the republic. The main components of the smog that periodically shrouds the city of Neryungri, in Rosgidromet's data, are formaldehyde (8.3 times the allowable limit), benzo[*a*]pyrene (2 times the allowable limit), and nitrogen dioxide (2 times the allowable limit). Air pollution levels in Neryungri put it on the list of Russia's worst polluted cities.

Water pollution

Coal mining operations result in a considerable impact on local water resources as they disrupt the area's hydrological regime – via flooding or, more frequently, desiccation of lands – and pollute groundwater and runoff. Coal mining alters the location and movement of underground and surface water levels, impairs the water quality of shallow aquifers, affects the soil moisture regime, depletes underground water resources, increases mechanical soil compaction, and changes the natural river flow regimes.

Soil desiccation as a result of water drainage at the mine sites, combined with subsequent discharges of underground mine water, disrupts the ecological equilibrium of plant and animal life. When coal mining operations shut down at a mine, old opencast workings become a source of pollution of drinking water supplies.

Tailings dumps contain large quantities of acid, which may infiltrate waterways and aquifers, becoming another source of pollution contaminating drinking water supplies. Cones of depression in Kemerovo Region alone total an area of 2,000 square kilometers.[11]

According to the report *On the State of the Environment in Kemerovo Region in 2011*, water quality in the rivers flowing through the region's industrial areas is assessed as "polluted" and "very polluted." In certain cases, experts record "extremely high pollution" levels in the region's rivers.

[11] Сенкус В.В., Майер В.Ф.Экологические проблемы горнодобывающих предприятий в Кузбассе.

Land disturbance

In the past ten years, the total area of lands disturbed as a result of coal mining operations reached 6 hectares per each 1 ton of coal produced.[12]In Kemerovo Region, according to the regional Department for Natural Resources and Environment, the percentage of disturbed lands is ten times the national average.

Displacement of massive amounts of rock (over 8 billion cubic meters in Kuzbass) to the surface leads to land subsidence and elimination of the established ecological communities.

The processes involved in the removal, storage, and redistribution of soils as a result of coal mining operations destroy the local ecosystems.

Soil disturbance and the various impacts associated with mining contribute to land erosion. Soil removal from the area alters or destroys many natural soil characteristics and makes it impossible to use this land for agriculture. Soil structure may be disturbed by pulverization[13] or use of various blasting methods.

The removal of vegetative cover and activities associated with the construction of haul roads, and hauling and stockpiling of topsoil, increase the quantity of dust around mining operations. Dust degrades air quality in the immediate area, may have an adverse impact on vegetative and animal life, and may constitute health and safety hazards for mine workers and nearby residents.[14][15]

Land subsidence may also occur due to underground tunnel collapses. With subsurface mining, massive amounts of waste rock hauled to the surface form enormous spoil tips.

Reclamation of lands after coal mining operations is a difficult process and, depending on the climate conditions in the area, creating new ecosystems may not be possible for a period of at least 60 to 90 years. If the area is characterized by an adverse climate – with the average annual precipitation of less than 250 millimeters, for instance – reclamation efforts will yield no results: The disturbed lands have effectively been turned into an arid, barren wasteland.

Generation of waste

The coal industry is a source of great amounts of waste. In Kemerovo Region, coal mining is responsible for over half of all wastes (55%).[16] The area subject to reclamation in the region totals 4,938.5 hectares; no more than about 160 hectares of land has been rehabilitated since the restructuring of the Kuzbass coal industry[17].

Massive piles of displaced geological material are formed during mining operations as a result of relocation and storage of waste. The associated adverse impacts include transformation of landscapes, impaired air quality, depletion of lands suitable for agriculture, contamination of soils, soil erosion, changes in the area's hydrological and hydrogeological properties, and

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[12] Сенкус В.В., Майер В.Ф.Экологические проблемы горнодобывающих предприятий в Кузбассе.

[13] Squillace, Mark. The Strip Mining Handbook: A Coalfield Citizens' Guide To Using The Law To Fight Back Against The Ravages Of Strip Mining And Underground Mining, Washington, D.C.: Environmental Policy Institute, Friends of the Earth, 1990 (retrieved via Wikipedia's article on the Environmental impact of the coal industry, April 2013).

[14] Squillace, Mark. The Strip Mining Handbook: A Coalfield Citizens' Guide To Using The Law To Fight Back Against The Ravages Of Strip Mining And Underground Mining, Washington, D.C.: Environmental Policy Institute, Friends of the Earth, 1990 (retrieved for this translation via Wikipedia's article on the Environmental impact of the coal industry, April 2013).

[15] United States Department of the Interior. Coal: Construction and Mining Impacts, Washington, D.C.: Office of Indian Energy and Economic Development, Tribal Energy and Environmental Information Clearinghouse (TEEIC). Retrieved March 9, 2012 (retrieved for this translation via Wikipedia's article on the Environmental impact of the coal industry, April 2013).

[16] Официальный сайт г.Новокузнецка http://www.admnkz.ru/actionDocument.do?id=51920.

[17] Государственный доклад "О состоянии и охране окружающей среды Кемеровской области в 2010 году".

development of social, ecological, and economic problems that may have a disastrous effect on the region.

Environmental and health impacts of coal-fired power plants

Use of coal as fuel for generation of electricity and heat is another source of severe ecological problems. Coal is burned both at large electricity generating plants or combined heat and power stations that serve large communities of consumers and at smaller plants that are often located within residential neighborhoods.

In the USSR, the ecological footprint of coal-fired power generation did not receive particular attention. The emissions plume from the Ekibastuz-based GRES-1 in Kazakhstan – the largest coal-fired thermal power plant in the Soviet Union – stretched for several hundred kilometers. The problem of tooth wear in cattle grazing in the vicinity of the station – an issue attributed to constant ash deposition – was discussed at a government meeting, which seriously considered denture treatment for cows, to be paid for with funds provided by the Ministry of Energy.[18]

Over 140 thermal power plants in Russia run on coal[19]; the number of boiler houses using coal as fuel is unknown, but may be assumed to add up to tens of thousands. Paying due attention to the ecological consequences of burning coal for power generation is important because in plans developed through 2020, it is thermal power stations that are projected to remain the country's primary energy producing sources, and the proportion of coal-fired plants in the national fuel mix may increase from 25% to 36-37%, with the share of natural gas decreasing from 70% to 58%. If this happens and government programs are implemented according to plan, then CO_2 emissions may in ten years rise by 1 million tons.

Coal-fired power generating units operating in Russia are equipped with technologies that do not allow for efficient capture, transportation, storage, and management of coal ash and boiler slag. They are also characterized by relatively high levels of atmospheric pollution. Emissions of fine suspended particles and sulfur dioxide by many coal-fired generating units in Russia are about 10 times higher than at coal-fired power stations in the European Union.[20] Fine particulate matter is especially hazardous for human health, and the additional mortality associated with the impacts of atmospheric pollution is primarily attributed to the health effects of fine particles in the air.

According to B.T. Velichkovsky, member of the Russian Academy of Medical Sciences and researcher in dust-induced lung pathology, inhalation of dust particles causes what is termed a "breathing blast": Upon entering the human body, fine particles cause excessive production of increased levels of highly chemically reactive free radicals, which triggers the development of chronic respiratory disease, especially in children, and the development of pulmonary hypertension and pulmonary heart disease in the elderly population, accounting for up to 80% of all deaths from bronchopulmonary pathologies. [21]

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[18] "Приватизация энергобаланса страны" «Эксперт» №7 (548) 19 фев 2007.

[19] Структура угольной отрасли. Министерство энергетики РФ. http://minenergo.gov.ru.

[20] Доклад о развитии человеческого потенциала в Российской Федерации 2009. Энергетика и устойчивое развитие, http://www.undp.ru/documents/NHDR_2009_Russian.pdf, National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf citing Крылов Д.А., Крылов Е.Д., Путинцева В.П. Оценки выбросов в атмосферу SO2 и NOx, твердых частиц и тяжелых металлов при работе ТЭС, использующих кузнецкий и канско-ачинский уголь // Бюллетень по атомной энергии. – 2005. - №4. – с. 32-36. (D.A.Krylov, E.D.Krylov, V.P.Putintseva, Estimates of ambient air emissions of SO2, NOx, solids and heavy metals from operation of coal-powered heat & power plants using coal from the Kuznetsk and Kansko-Achinsk basins // Nuclear Power Bulletin, 2005 No.4, pp. 32-36).

[21] Доклад о развитии человеческого потенциала в Российской Федерации 2009. Энергетика и устойчивое развитие, http://www.undp.ru/documents/NHDR_2009_Russian.pdf, National Human Development Report in the

Siting new coal-fired cogeneration plants near populated areas sparks public protests – such as the project of a new combined heat and power plant proposed for Zheleznogorsk, in Krasnoyarsk Region. In Russia's Northwest, during a public hearing in Svetly, Kaliningrad Region, local residents spoke against the proposed construction of a cogeneration plant that was to run on coal supplied from Kuzbass.[22]

Table 1 shows that the economic impact of health effects resulting from harmful emissions of coal-based power may be quite substantial.

Table 1. Economic parameters of risk assessment.[23]

Health risk	Impact unit	Cost per impact, in roubles
Reduction of life expectancy	1 man-year	600,000
Chronic bronchitis	1 disease	1,500,000
Days lost due to illness	1 day	1,000

Environmental risks associated with coal combustion are higher for Siberia and the Russian Far East – areas with a harsh continental climate and a low capacity of the atmosphere for self-purification. According to the 2009 *National Human Development Report in the Russian Federation*, in these climate conditions, even small-scale emissions can cause air pollutants to accumulate and reach high concentrations. In Abakan, Barnaul, Blagoveshchensk, Gorno-Altaisk, Krasnoyarsk, Kyzyl, Chita, and Ulan-Ude, up to 70% of all heat generating facilities use solid fuel, and emissions by power-generating units account for 50% to 60% of all air pollution from stationary sources. The average concentration of solid particles in the air of cities in the eastern part of Russia is 30% higher than in European Russia (143 micrograms per cubic meter and 110 micrograms per cubic meter, respectively).[24] The permissible limit established in Russia stands at a value of 150 micrograms per cubic meter.[25]

Occupational hazards of the coal industry

Coal mining is an industry with the most dangerous working conditions in terms of the risks to the workers' health and life. According to data from the Russian Ministry for Civil

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Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf, citing Величковский Б.Т. Патогенетическое значение пиковых подъемов среднесуточных концентраций взвешенных частиц в атмосферном воздухе населенных мест. Гигиена и санитария, 2002. - №6. - С. - 14-16 (B.T.Velichkovskiy, Pathogenic impact of peak increases of mean daily concentrations of particulate matter in populated areas. Hygiene and Sanitation, 2002, No.6, pp. 14-16).

[22] Горкина Т. И. Угольная промышленность мира. Региональные аспекты развития

[23] National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf, citing Экономические параметры оценки риска для расчета ущерба, обусловленного воздействием на здоровье населения разных факторов вреда / И.Л.Абалкина, В.Ф.Демин, С.И.Иванов и др. // Проблемы анализа риска. – 2005. – Т.2. - №2. – с.132-138. (I.L.Abalkina, V.F.Demin, S.I.Ivanov et al., Economic parameters of risk assessment for calculating damage to public health due to various hazards // Risk assessment challenges, 2005, Vol.2, No.2, pp 132-138).

[24] National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf.

[25] Б.А. Ревич, "К оценке влияния деятельности ТЭК на качество окружающей среды и здоровье населения" журнал "Проблемы прогнозирования", 2010, №4.

Defense, Emergencies, and Elimination of Consequences of Natural Disasters, an average of between 40 and 50 accidents involving human casualties take place at Russian mines each year.[26] Russia has never since 1998 been able to achieve the Soviet-era one-human-life-per-one-million tons-of-coal-mined safety standard.[27] As of 2002, according to information made available that year, the coal mining industry yearly claimed between 180 and 280 lives.[28]

Statistical data demonstrate that in the past decade these rates have not changed.[29]

Occupational illnesses

Classified as one of the most hazardous industries, the coal industry is responsible for causing 84% of all occupational illnesses in Russia.[30] Records show that the main increase in occupational illnesses in Russia in 1996 to 2003 was accounted for by the health impacts of the coal industry: between 29.4 and 91.7 cases per every 10,000 employees, with the average range across Russia estimated at 1.77 to 2.24 cases.

A coal mine in the village of Sheregesh, Kemerovo Region. The coal mining industry remains one of the most dangerous in terms of occupational hazards. Source: Ecodefense!

In Kemerovo Region, where two thirds of all Russian coal operations are concentrated, occupational morbidity in workers employed in the coal industry was 113.3 cases, a sharp increase over the average regional rate of 18.4 cases per every 10,000 of all employed[31] – and 9 times higher than on average in Russia.[32] Occupational morbidity in workers of the coal

[26] http://top.rbc.ru/incidents/19/03/2007/97298.shtml
[27] "О мерах по комплексному развитию угольной отрасли Российской Федерации и его законодательному обеспечению". "Горная Промышленность" №6 (94) 2010
[28] Национальный план действий по гигиене окружающей среды Российской Федерации. Федеральный центр гигиены и эпидемиологии. Москва. 2002.
[29] See also the appendix to this report with a list of accidents at Russian coal mines for the period between 2011 and 2013.
[30] "Дороже денег". Деловой Кузбасс 11.02.2013
[31] ФГСЭН. Москва, 2004
[32] Государственный доклад «О санитарно-эпидемиологической обстановке в Кемеровской области в 2011 году»

industry of Kuzbass is the main cause of newly diagnosed disability and re-certified disability due to occupational disease. A comparative assessment of occupational morbidity rates in Russia showed that before 1997, Kemerovo Region had the second highest occupational morbidity rate in the country, next to the Komi Republic. Since 1997, however, and to the present day, the region has continued to hold a firm lead in occupational disease statistics.[33]

Studies in industrial hygiene show that workers of the coal mining industry of Kuzbass, both those employed at open cast and subsurface mines, are exposed to a complex of adverse workplace factors, including hand-arm and whole-body vibration, noise, dust, and physical overexertion.[34] Respiratory diseases rank as the most frequent among the industry's occupational diseases, with those of the peripheral nervous system and vibration sickness (condition developed due to exposure to the sustained effect of local and general vibration) in second and third place, respectively, followed by disorders of the musculoskeletal system.

Public health impacts

Public health is the most sensitive indicator of the ecological state of coal mining regions. From this point of view, Kemerovo Region is the most well-studied among Russian regions (this, however, is not meant to attest to any systematic or comprehensive approach to evaluating industrial health risks in Russia, which still lacks an officially adopted roster of diseases linked to exposure to adverse environmental factors.

Morbidity patterns in the population of Kemerovo Region, where the coal industry remains the largest polluter, show that for patients seeking medical assistance, respiratory diseases are the most common complaints (23.5%), followed by disorders of the musculoskeletal system (10.4%), injuries and accidents (9.5%), and cardiovascular disease (8.5%).[35]

According to the 2009 *National Human Development Report in the Russian Federation*, public health problems in several Kuzbass cities reflect adverse industrial factors and air pollution, which accounts for 5.8% to 14.3% of newly diagnosed illnesses and 4% to 19%[36] of mortality. On the whole, says the report, Kemerovo Region saw a 19.4% rise in disease incidence and 19.7% increase in mortality in 1993 to 2006.

Health risks associated with adverse ecological impacts are considered to be the highest for pregnant women and children. In the past decade, morbidity rate among pregnant women in Kemerovo Region has increased almost by 5 times, with maternal mortality being twice as high as on average across Russia.

The incidence of preterm delivery and stillbirth in the city of Leninsk-Kuznetsky is higher than on average in the region; statistics also include cases of developmental abnormalities in newborns and a higher rate of infant morbidity.[37]

Infant mortality patterns show congenital abnormalities and respiratory disorders as the prevalent causes of death, which may also be indicative of harmful impacts of the coal industry.

In 2010, respiratory disorders dominated disease incidence patterns in children and adolescent patients. Kemerovo Region also saw an increase in malignancy incidence. Across the

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[33] Семенихин В.А. Профессиональная патология у шахтеров Кузбасса: особенности формирования и профилактика. 2006

[34] Семенихин В.А. Профессиональная патология у шахтеров Кузбасса: особенности формирования и профилактика. 2006

[35] Состояние здоровья населения Кемеровской области. Сайт департамента охраны здоровья населения Кемеровской области

[36] National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf, citing Зенков В.А. Гигиенические проблемы шахтерских городов Кузбасса: Автореф.дис.докт.мед.наук, 2000. - 42с. (V.A.Zenkov, Hygiene problems in Kuzbass mining towns, abstract of a thesis for a Doctor of Medicine degree, 2000, p.42).

[37] Ревич Б.А. «Горячие точки» химического загрязнения окружающей среды и здоровье населения России. - М.: Общественная Палата РФ, 2007.

region, the overall rate of newly diagnosed malignancies had increased by 9.7%. A carcinogenic risk assessment performed for the cities of Kemerovo, Novokuznetsk, and Prokopyevsk revealed that annual population cancer risk – or the increase in incidence of oncological disease over annual background rates – was 0.4 cases for Prokopyevsk; 1.6 cases for Novokuznetsk; and 2.3 cases for Kemerovo.[38] The calculated individual lifetime cancer risk for the populations of these cities was estimated at 3.1×10^{-4} for Kemerovo; 1.9×10^{-4} for Novokuznetsk, and 1.2×10^{-4} for Prokopyevsk. By medical standards, such risks to human health are unacceptable.

Abashevskaya Coal Mine, Kuzbass. Just like coal combustion at power plants, coal mining is a major source of a variety of ecological impacts that can severely affect the health and well-being of local populations. Source: Ecodefense!

Power generating capacities running on coal are likewise a source of serious hazard to public health. Populations of cities located near major coal-fired power plants are exposed to polluted air as well as contaminated drinking water. Such, for instance, is the ecological situation in Novocherkassk, Rostov Region, where increased concentrations of particulate matter and the carcinogenic benzo[a]pyrene have been registered in the air. Novocherkassk has been rated in a State Environmental Expert Evaluation report as an environmental problem zone. Mean annual concentrations of the main pollutants – formaldehyde, particulate matter, benzo[a]pyrene – exceeded Russian maximum allowable daily average concentrations by 3.0, 1.2, and 10.1 times, respectively. Maximum short-term concentrations were higher than allowable levels by 8.2 times for carbon monoxide; 5.4 times for nitrogen dioxide; 3.9 times for hydrogen sulfide and formaldehyde; 4.4 times for particulate matter; and 2.9 times for sulfur dioxide and phenol. The highest registered mean monthly concentration of benzo[a]pyrene exceeded the maximum allowable level by 35.2 times.[39]

The most comprehensive study of ecological impacts of thermal power plants and the resulting health effects for the local population has been performed using the example of Veliky Novgorod, Novgorod Region.

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[38] Государственный доклад "О состоянии и охране окружающей среды Кемеровской области в 2010 году"

[39] National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf, citing State Environmental Expert Evaluation, February 22, 2000.

In Veliky Novgorod, heat and power are provided by a central cogeneration plant, municipal boiler plants and boiler plants supplying heat to industrial enterprises. Calculations show that if the city raises the share of coal in its fuel mix – including by converting the large combined heat and power plant to coal – health risks for the population will spike due to impact of increased levels of atmospheric pollution. In particular, increased use of coal as fuel will double the rate of mortality caused by the most hazardous fine particulate matter and sulfur dioxide emissions; triple the additional incidence rate of lower airway diseases in children; and increase bronchitis incidence by 15%, incidence of bronchial asthma (caused by sulfur dioxide emissions) by 35%, and cancer risk associated with emissions of soot by 30%[40].

Table 2. Average public health impact as an economic indicator, in roubles per kilowatt-hour.[41]

Pollutant	Thermal power plants in Moscow Region		Thermal power plants in Central Russia	
	Operating	Planned	Operating	Planned
Powered by Kuzbass coal				
Solid particles	0.30	0.05	0.12	0.008
Nitrogen oxides	0.50	0.33	0.24	0.160
Sulfur dioxide	0.40	0.08	0.16	0.034
Total	1.20	0.56	0.52	0.202
Powered by natural gas				
Nitrogen oxides	0.07	-	0.03	-

The demographic situation in Kemerovo Region is rated as “poor.” Life expectancy in the region is 2 to 3 years lower than on average in the Russian Federation. [42] The high mortality rate, which exceeds birth rate by 1.8 times, remains a serious concern. The mortality rate among the working age population in Kuzbass is higher than the Russian average by 17% to19% for men, and 33% to 39% for women.[43] Men account for 78% of the overall mortality rate at working age[44].

One fact is telling: Kemerovo Region holds 11th place in volumes of industrial output in Russia, but on the Human Development Index – a composite statistic of life expectancy, education, and income indices – it only ranks 52nd among Russian regions.[45]

Impact on small indigenous peoples

The coal industry has become a real “resource curse” for the indigenous populations of Russia’s coal mining regions. In the village of Kazas, Kemerovo Region, which is home to a small population of Shors (Shorians), three coal pits are being developed. Coal mining activities have resulted in disturbance of land – which the native population has historically relied upon for subsistence – contamination of rivers, and devastation of forests and wildlife. Local residents are

[40] Ревич Б.А. «Горячие точки» химического загрязнения окружающей среды и здоровье населения России. - М.: Общественная Палата РФ, 2007

[41] National Human Development Report in the Russian Federation 2009. Energy Sector and Sustainable Development, Moscow, 2009, http://www.undp.ru/documents/NHDR_2009_English.pdf, citing Куликов М.А., Гаврилов Е.И., Демин В.Ф., Захарченко И.Е. Риск воздействия атмосферных выбросов электростанций на здоровье населения // Теплоэнергетика. – 2009. - №1. - С.71-76 / M.A.Kulikov, E.I.Gavrilov, V.F.Demin, I.E.Zakharchenko, Health risks caused by power plant emissions // Teploenergetika, 2009 No.1, pp.71-76.

[42] Государственный доклад "О состоянии и охране окружающей среды Кемеровской области в 2010 году"

[43] Состояние здоровья населения Кемеровской области. Сайт департамента охраны здоровья населения Кемеровской области

[44] Государственный доклад "О состоянии и охране окружающей среды Кемеровской области в 2010 году"

[45] Мекуш Г.Е. Макроэкономическая оценка заболеваемости населения от экологического фактора на региональном уровне.

not compensated for the disturbed land nor for the damage done to their traditional ways of life. One of the villages, Kurya, was completely destroyed in the 1950s, with all of its inhabitants – Shors, mostly – forced to relocate, abandoning their traditional lands.

3. Plans and prospects of coal industry development in the Russian Federation

State strategy for coal industry development

Earlier government documents outlining state strategies for Russian coal industry development – the 2003 *Energy Strategy of Russia for the Period up to 2020* and the 2008 *Master Layout for Prospective Electric Power Producing Sites for the Period up to 2020* – set a future growth oriented goal of priority development for coal power. Yet, in subsequent documents – the 2009 *Energy Strategy of Russia for the Period up to 2030*, the 2010 *Master Layout for Prospective Electric Power Producing Sites for the Period up to 2020, with Prospects for until 2030*, and the 2012 *Long-Term Program for the Development of the Coal Industry for the Period up to 2030* – this policy direction of "priority development" was effectively replaced by a "modest rate of growth."

The target coal consumption figure at Russian thermal power plants projected for 2030, as per the *Coal Industry Development Program up to 2030*, is lower than the same in the *Energy Strategy up to 2030*: 102 million and 158 million tons, respectively.[46]

The forecast for coal consumption in the Russian energy generation sector, as laid out in the *Coal Industry Development Program up to 2030*, factors in the generating companies' actual plans with regard to the expected launch of new coal-based capacities and modernization of existing ones. Combined, these capacities are to total 26.1 gigawatts by 2030. [47]

Plans for the period between 2012 and 2020 also include implementation of pilot projects for introducing modern coal combustion technologies at thermal power plants – initiatives seen as necessary for further scale-up to commercial application. The generating companies and coal enterprises are recommended to coordinate their development programs with government ministries and agencies so that the modernization efforts at coal-fired power plants would conform with the goal of using cleaned – or processed – coal as the primary fuel.[48]

According to the *Coal Industry Development Program up to 2030,* state budget funding to be allocated for the implementation of the program is less than 9% of its total funding (RUR 251.8 billion out of the total of RUR 3.7 trillion); the program envisages a new level of public-private partnership for the industry.[49]

The program also projects that by 2030, national coal production will grow to 430 million tons, with coal mined at 82 open cast mines and 64 subsurface mines, and that labor productivity (output per one worker employed) will be five times as high as the same in 2010. Before the program is completed, plans also include launching 505 million tons in new and modernized coal production capacities, while retiring 375 million tons in unviable and loss-making capacities and reducing the level of wear and tear of fixed assets from 70-75% to 20%.

On the whole, according to the program, and in line with the adopted rate of establishing new major coal mining areas, coal mining activities are to be gradually shifted eastward. The contribution of mining operations in Eastern Siberia to total national coal production is expected to increase from 25.8% to 32%, and the share of coal production in the Far East will grow from 9.7% to 15.2%.[50]

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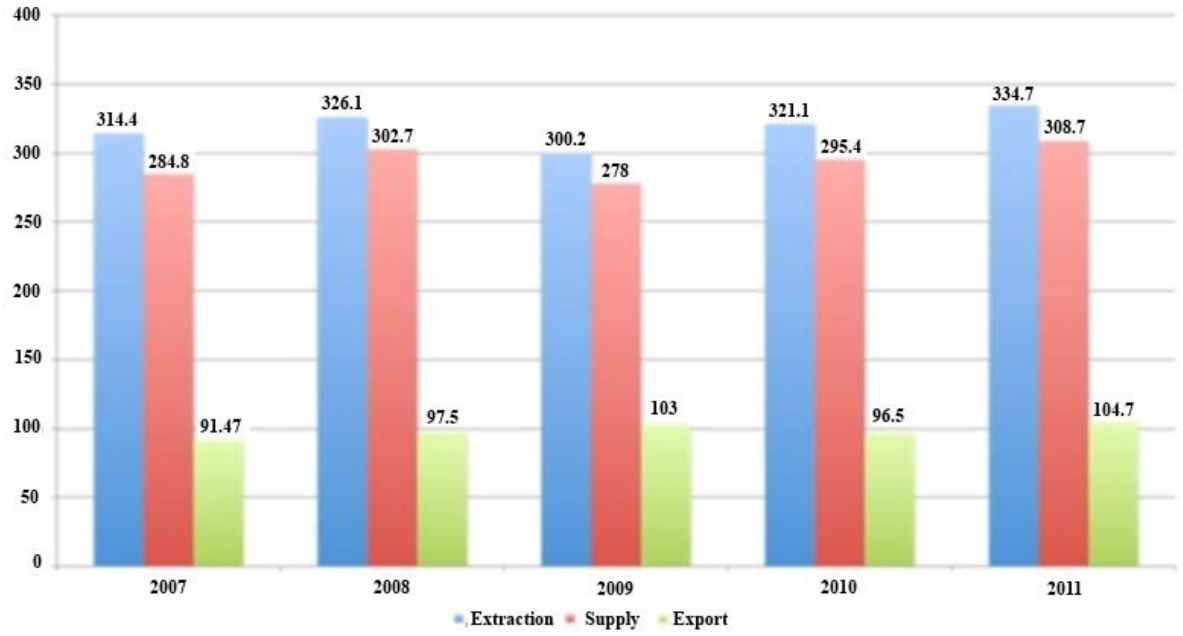
[46] Энергетика и промышленность России 11 (199) июнь 2012 года
[47] Энергетика и промышленность России 11 (199) июнь 2012 года
[48] Энергетика и промышленность России 11 (199) июнь 2012 года
[49] Долгосрочная программа развития угольной отрасли на период до 2030 года
[50] Долгосрочная программа развития угольной отрасли на период до 2030 года

*Fig. 1. Russian coal industry's production figures for 2007 to 2011.**



* *Sources: Rosinformugol, Ministry of Energy of the Russian Federation, Russian Federal State Statistics Service*

In European Russia, nuclear power plants and new coal-based thermal power plants will operate in combination with electricity supplies from Siberia's hydropower plants and thermal stations, the latter located in the immediate vicinity of coal mines. In the Urals, power supply is expected to rely on energy produced by gas-fired thermal power plants and plants running on coal shipped from elsewhere, complemented, likewise, with electricity supplies from stations in Siberia. Siberian and Far Eastern power stations are envisaged to become "electricity donors" for Russia's European regions and the Urals.

Plans for public-private partnership

One major event that marked a strategic shift in the development of the Russian energy industry was the merger of the energy assets of the state-controlled gas giant Gazprom and Russia's largest coal supplier, the privately owned Siberian Coal Energy Company (SUEK). This was what some observers refer to as the defining step in the country's transition from gas to coal as the primary resource in the future domestic fuel mix.

Experts, however, have great doubts as to whether this move will prove beneficial to Russia's national interests. SUEK currently controls some 30% of Russia's total coal mining capacities. In expert estimates, the joint Gazprom-SUEK venture defeats the very idea of reforming Russia's power sector: While the industry seeks to attract private investor funds from Russia and abroad, 70% of its assets will still remain in the hands of entities operating under a great deal of influence from the state. This threatens to hinder the development of market relations and private initiative in the industry and that of the power market itself.

Coal industry economics

The Russian coal industry is in a difficult situation: Coal consumption on the domestic market has continued to decline. The average price of Russia's thermal coals on foreign markets dwindled, according to the Russian Ministry of Energy, from $119 to $89 per ton between September 2011 and May 2012.

The industry continues to face a variety of problems that hamper its economic growth:

High degree of equipment wear. The industry has long been in dire need of modernization. Operational safety requires efficient gas drainage to remove methane from the coal beds – a necessity that becomes painfully obvious every time news of another explosion is reported.

High energy intensity of production processes. The coal industry is a major consumer of fuel and energy resources, absorbing annually around 15 billion kilowatt-hours of electricity.

Transport costs. The share of transport costs in the electricity tariff reaches 45-50%, and the transport component of the heating cost can even exceed the actual cost of heat energy in the heat distribution networks of cogeneration plants. Hauling distances for coal deliveries in Russia generally average some 4,000 kilometers.

Lack of major investments to improve efficiency and environmental performance. Neither the industry's efficiency nor its ecological footprint have ever been seriously considered when assessing the costs and benefits of coal power. In the twenty years of reforms, Russia has undertaken no investment programs to develop clean and efficiency-enhancing technologies for the industry. This means that if Russia chooses to re-orient itself toward a heavily coal-based economy, the coal industry will have to look to foreign markets to shop for these technologies.

Equipped with modern technologies – boilers and coal ash and slag disposal systems – a coal-fired power plant's cost ranges today between $1,400 and $1,700 per kilowatt of capacity (see Table 3).[51]

Table 3. Operating and economic characteristics of standard 1,000-megawatt power plants, with breakdown by fossil fuel type[52]

	Modern Russian coal-fired plants	**Coal-fired plants in developed countries**	**Modern Russian natural gas plants**
Capital costs (U.S. dollars per kilowatt installed capacity)	1,400–1,700	1,400–1,700	800–1,000
Capacity factor (%)	35–36	40	45–55
Sulfur dioxide emissions (tons per year)	11,0000	5,500	20
CO_2 emissions (tons per year)	2,000	1,051	600
Nitrogen oxides emissions (tons per year)	27,000*	600–1,600	200–1,700*
Area of land condemned for power plant construction (hectares)	24,000	15,000	

This cost does not include the costs incurred with the power plant's own water intake, its purification systems, establishing the sanitary protection zone, charges paid for emissions and discharges of considerable quantities of pollutants into the atmosphere and water bodies, and investments into ecological improvements.

Capital costs of more technologically advanced coal-fired combined heat and power plants are 1.5 to 2 times higher than for less sophisticated designs. In other words, the measures that energy companies are touting as aimed at "balancing out" the national fuel mix will in reality translate into a considerable hike in heat and electricity prices and may prove a severe financial burden for domestic consumers – ordinary citizens, primarily. This would mean that the liberalization of the energy market Russian style will hardly lead to positive changes – the way that such reforms are implemented in countries with developed market mechanisms – but may result in an extremely adverse social effect, placing a tremendous strain on the budgets of less-than-affluent consumers, especially those residing in rural areas.[53]

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[51] "Приватизация энергобаланса страны" «Эксперт» №7 (548) 19 фев 2007

[52] Источники: Экология энергетики. Учебное пособие. Под ред. В. Я Путилова. М., Изд-во МЭИ, 2003; оценки «Эксперта», СУЭК

[53] В трубе равных не бывает», «Эксперт» № 8 за 2005 год

Export of coal

Representatives of the coal industry, government officials, and market experts acknowledge that the current split between the domestic and foreign market sales of Russian coal spells an unfavorable situation for the industry. Furthermore, this ratio has changed drastically in the past two decades. Where in 1990 the domestic consumption rate for Russian coals totaled 323 million tons versus 52 million tons sold for export, in 2012, already twice the 1990 export figure was shipped for export out of the total 308.7 million tons supplied by the Russian coal mining enterprises that year.

The reason that Russia has seen a rise in its export of coal is by no means because there is an excess of coal on the domestic market, nor because of a rising demand for Russian coal on the markets abroad. This is a move borne of necessity – the result of technical limitations of boiler equipment in use at the thermal power plants operating in Russia. These stations have no need for high-rank coal as they are designed to burn fuel supplied from specific coalfields. Of the total annual volume of coal burnt at Russia's thermal power plants today, 90% is coal of lower ranks, and high-quality coal is shipped for export. Even though thermal coal beneficiation capacities have lately been growing in Russia, cleaned coal is not supplied to the country's power stations, just as it was never supplied before.

Export has become the largest consumption sector for Russian thermal coals, while the share of supplies to the country's own power stations has declined from 39.8% to 31.4%.

Russia's domestic market has faced a shortage of quality coals of grades SS and T[54]. It has become increasingly common for power stations to find they are unable to purchase coal of a needed grade in the volumes required or that suppliers offer the commodity at prices exceeding the range that would comport with the established electricity price caps. Power stations have, as a result, started using coal of grades not provided for by plant design specifications, or even burning coal extraction and processing wastes – solutions that are prone to increase the equipment's breakdown rate.

Top executives at Russian coal companies believe this puts the national coal industry into a rather vulnerable position: The internal consumption sector offers hardly any margin for growth, while foreign markets are becoming ever more competitive. The rise in competition is attributed to declining energy consumption rates in Europe – the main importer of Russia's energy resources – a developing trend toward globalization in the natural gas market, and the stiffer competition anticipated on the Asian markets.

In global coal exports, as well as in the global coal pricing trends, the market is shaped by five heavyweights that together account for between 70% and 80% of all export shipments of coal: Australia, Indonesia, Russia, China, and South Africa. As for demand for coal, this is determined by developing countries – first and foremost, by the fast-growing economies of China and India. The primary consumers of coal products are Japan, China (including Taiwan), and South Korea. Japan, South Korea, India, and Taiwan are also the largest importers of coal on the Asian market, with Germany and Great Britain being the principal importers in Europe. The United States and China, the world's leading coal producers, are both major exporters and importers of coal. China became a net importer of coal in 2006. Japan remains a net importer and the largest importer of coal.

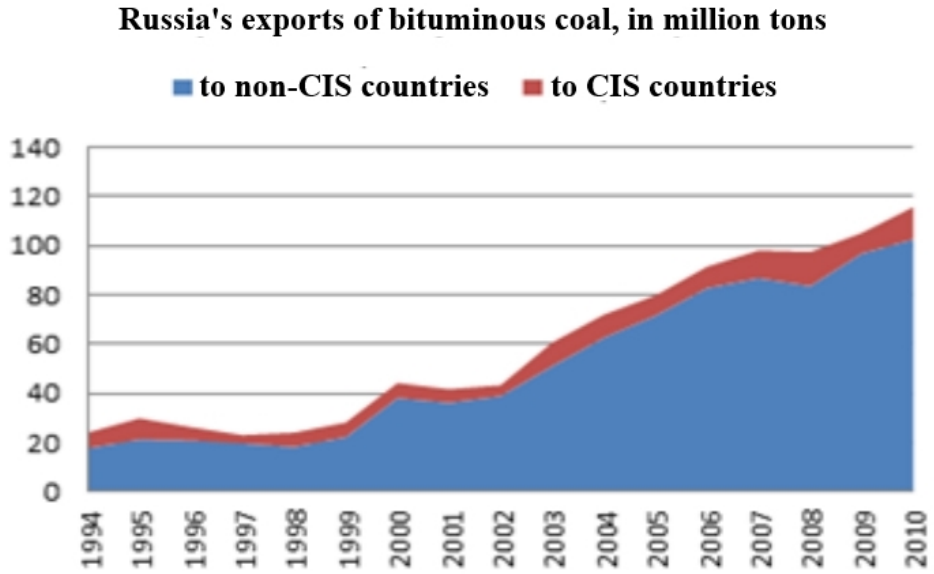
Russia supplies coal to over thirty countries. In 2008, the list of the world's largest consumers of Russian coal included Cyprus, Ukraine, Japan, Poland, Turkey, Finland, Bulgaria, Belgium, the Netherlands, Slovakia, Spain, South Korea, Great Britain, Switzerland, Romania, Italy, Germany, Kazakhstan, Hungary, and Lithuania, accounting for over a third of all export

[54] The designations "SS" (rendered sometimes as "CC") and "T" stand for Russian abbreviations "CC" (*slabospekayushchiisya*) and "T" (*toshchi*) to denote coal grades classified as "low-caking" and "mean," respectively. See, for instance, here: http://www.russiancoal.com/coalminingrussia/classificationrussia.html and here: http://pubs.usgs.gov/of/2001/ofr-01-104/fsucoal/html/readme.htm#Classification for further information on Russian coal grade classification. – Translator.

shipments.[55] In 2009, Russia became the world's third largest coal exporter, next to Indonesia and Australia, with around 100 million tons of coal supplied to the global market.[56]

In early 2012, speaking at a meeting discussing the development of the country's coal industry, Russian Minister of Energy Sergei Shmatko projected that Russia's coal exports to the countries of the Asia-Pacific Region would by 2030 grow to 85 million tons.[57]

Fig. 2. Russian bituminous coal exports (total exports and exports to CIS and non-CIS countries in particular) in 1994 to 2010, in million tons.[58]



European markets will unlikely become major destinations for Russian coal. Conversely, the Asia-Pacific markets are acquiring a greater importance for Russian coal exports. In that region, the greatest demand for coal imports, in Shmatko's view, is seen from China, Japan, South Korea, Taiwan, and Vietnam. According to a 2009 McKinsey report, by 2020, demand for imported coal in the Asia-Pacific Region is set to double, as compared to current figures, growing by between 550 million and 560 million tons of coal a year.[59] The additional annual 50 million tons that Russia is planning to export to the Asia-Pacific markets by 2030, on top of the current volumes, may prove quite competitive. For now, the share of Russian coal on the Asia-Pacific markets does not exceed 4%.

Between January and July 2012, Russia supplied 9.034 million tons of coal to its customers in Asian markets (or 12.5% of total coal exports for that period), an increase of 1.388 million tons over the shipments delivered in the first six months of 2011.[60]

Plans to boost coal power generation in Siberia and the Far East, which could rely on locally available coal reserves (the coalfields Yelginskoye, in South Yakutia; Syradasaiskoye, in Krasnoyarsk Region; and Udokanskoye, in Chita Region, among others), mean that a series of power plants with a total combined installed capacity of over 10 gigawatts could be taken online between 2020 and 2022. These prospects also pave the way for a major investment project that envisions selling over 50 billion kilowatt-hours in export electricity to China.

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[55] Горкина Т. И. Угольная промышленность мира. Региональные аспекты развития
[56] Горкина Т. И. Угольная промышленность мира. Региональные аспекты развития
[57] http://www.tass-sib.ru/news/one/1302
[58] Source: Export breakdown by commodity and commodity groups in the Foreign Economic Activity Commodity Nomenclature of Russia (http://www.gks.ru/dbscripts/Cbsd/DBInet.cgi?pl=2123011), retrieved in March 2013 via the page Coal Industry of Russia at Newsruss.ru.
[59] Эффективная Россия. Производительность как фундамент роста. McKinsey Global Institute. 2009
[60] "Рост объемов на фоне ценового снижения" Континент Сибирь on-line. 27 Августа 2012

4. Conclusions

At each step of its operation, from coal mining to burning at thermal power plants to waste disposal, the coal industry represents a hazard for the environment and human health. Mining sites and generating stations are, as a rule, located in populated areas, where high pollution levels are recorded – revealing values extreme enough to have earned some of these regions the status of ecological emergency zones.

Observations in the coal mining cities of Kuzbass show that pollution data are in direct relation with the morbidity and mortality rates in these areas. In Russia's coal mining regions, these pollution values are several times as high as on average across the country.

The coal industry remains one of the most hazardous with respect to accident rates and occupational disease incidence. Furthermore, coal mining is losing its investment appeal in a whole range of cities and regions, which exacerbates social problems. Additionally, coal mining activities threaten to upset the traditional practices and way of life of local populations, small indigenous peoples especially.

Compiling an objective and well-systematized overview of the levels of environmental pollution in all areas of coal mining operations in Russia is a challenging task. The archaic system employed by the Russian hydrometeorology and environmental monitoring agency, Rosgidromet, makes it impossible to fully assess air quality in these regions using the parameters adopted in developed countries and those recommended by the World Health Organization. There are no standards establishing health limits for the content in the atmospheric air of the extremely hazardous fine suspended particles – emissions that are typical for the coal industry.

Rising coal production volumes will result in considerable increases in the levels of dust and gas emissions into the atmosphere, as well as in the volumes of liquid run-off and the extent of soil disturbance. The hazards of these adverse technogenic impacts on the environment are compounded by the concentration of pollution sources in mining regions – areas where the lithosphere is subjected to aggressive interference from mining operations. With plans to boost power production output and increase the share of coal in the country's fuel mix, public health and environmental problems may likewise exacerbate significantly.

Coal production and coal combustion at energy generating sites are also responsible for emissions of such climate forcing agents as methane and black carbon. The anticipated rise in coal use in the Russian energy sector will also aggravate the industry's negative impact on the climate.

If one were to objectively evaluate the current development strategy envisioned for the Russian coal industry, one would have to conclude that where cooperation between the public sector and private enterprises is concerned, these plans are based less on the needs of the residents of regions where coal companies currently operate or expect to operate in the future, and more on theoretical business-as-usual scenarios that in the long run only cater to the interests of individual companies involved. Furthermore, the *Energy Strategy of Russia for the Period up to 2030* provides specific target figures for the energy sector's development, but it fails to stipulate any targets for emissions reductions, suggesting that these intentions are either declarative or aimed to serve short-term purposes.

The recent increases in exports of Russian coal have by no means resulted from an increased demand on the international market, nor from an excess of available reserves, but from the obsolete operating parameters of Russia's own enterprises that run on coal – limitations that make it technologically impossible to use higher-quality coal for energy needs. At the same time, the situation on the global coal market hardly seems especially promising for future Russian coal exports.

Both Russia's export ambitions and the projected rise in coal production volumes will require not just a favorable market climate, but also the need to build new capacities and rely more heavily on the resource of the old ones. Yet, operating old capacities is becoming a risk due

to the worn-out state of the equipment. Russia trails behind European nations, China, and the United States in the application of environmentally friendly coal technologies.

The latest trend in the coal industry – merging privately held coal assets with those of a major gas corporation – will lead to a monopolization of the energy sector. Instead of spurring the development of the energy market for the benefit of the consumers, deregulation of prices for energy sources may have a highly negative social effect.

Operation of new coal industry sites will be severely detrimental for the environment of those regions where these sites are expected to appear. Building cheap and environmentally harmful coal power plants is impractical at best, but the lack of necessary technologies and the need to secure enormous capital investments make construction of more technologically advanced stations a challenging prospect as well.

New coal mining operations are planned, for instance, in the Russian Far East. But, in expert estimations, coal mining in those areas will result in even more severe ecological damage than in European Russia because of the specific climate and the more vulnerable ecosystem of the region. Furthermore, these new capacities will require developed infrastructure that the region so far does not have.

The economics of coal mining and coal-based energy production suggest that further development of the coal industry is economically inadvisable. One kilowatt-hour of coal power is currently more expensive than that produced from natural gas, since, calculated in standard fuel values[61], the price of coal is some 1.5 times lower than the price of gas. And for coal power to be competitive against gas-based energy generation, this ratio has to be at least 2:3, because a coal-fired thermal power plant's total combined costs are considerably higher. In European Russia, the cost of coal-generated energy is around RUR 1.6 per kilowatt-hour, compared to RUR 1.1 per kilowatt-hour of electricity derived from natural gas. [62]

Both the ecological burden and economic disadvantages of coal mining and coal power compel the public and the expert community in Russia to oppose the current development plans for the industry. Should coal production and use of coal at energy generation sites increase in Russia, with coal taking a more prominent share in the national fuel mix, the additional toll these changes are likely to take on public health and environmental well-being will be equally devastating. Such prospects call for a broad public discussion of the coal industry's current impact and future plans, and for a search for alternative options to stimulate regional development in Russia.

[61] Standard fuel (or fuel equivalent) is a concept used in the USSR and Russia to measure comparative efficiencies of various types of fuel, with one unit corresponding to one kilogram of fuel with a heat combustion of 7,000 kilocalories per kilogram. A common international unit of energy is the ton of oil equivalent, or the amount of energy released by burning one ton of crude oil. The International Energy Agency (IEA) determines one ton of oil equivalent to be equal to 41.868 gigajoules. – Translator.

[62] Энергетика и промышленность России 11 (199) июнь 2012 года