Brief information about the project

Title	AP22687016 «Ecological and energy efficiency of plasma technology: numerical modeling and experiment».
Relevance	Global long-term forecasts of the fuel and energy balance confirm that coal will remain the most important non-renewable energy source until 2050. According to International Energy Agency, the world's coal reserves are estimated at 1 trillion tons. At the current level of consumption, these reserves will last for 250 years. For comparison, natural gas and oil reserves are 65 and 45 years old, respectively. Global coal consumption is growing by about 2% per year, and at the same time, coal prices are quite stable, unlike oil and gas. Kazakhstan has large reserves of thermal coal, which can be extracted in a cheap open-pit way. For example, the Ekibastuz coal basin contains a high concentration of high-ash coal reserves in layers of unique capacity (in general, about 8 billion tons in the basin), which are suitable for open-pit mining. Currently, to increase the ignition efficiency and stabilize combustion of coals with high ash content and low volatile yield in the heat power industry, the following methods are used: high heating of the air mixture (up to 410 K) and secondary air (up to 673 K), increase the grinding tonin (up to R90 = 6-8%) and the supply of high concentration coal dust (up to 50 kg/kg) with subsequent heating, as well as co-combustion of coal with fuel oil. Nevertheless, the above methods have significant disadvantages. In particular, an increase in the fineness of grinding leads to a significant overspending of energy consumption for grinding, which reduces the efficiency (net) of the boiler. An increase in the temperature of the air mixture above 410 K and secondary air above 673 K is unacceptable due to the risk of fire. To stabilize the combustion of the pulverized coal torch and the kindling of boilers, the co-combustion of coal and heavy oil (fuel oil) is used, which increases emissions of vanadium pentoxide, sulfur oxides, and nitrogen, at the same time, mechanical underburning of fuel, which negatively affects the environment. In recent years, much attention has been paid to improving environmental safety and efficiency in the processes of burning energy coals at pulverized coal thermal power plants, which produce 40% of electric and 25% of thermal energy. In addition, the trend of negative changes in the quality of solid fuels leads to an increase in the use of non-project fuels and a decrease in the technical, economic, and environmental performance of boilers. In this regard, the introduction and creation of new innovative technologies for the efficient combustion of energy coals is becoming quite an urgent task. According to observations, the processes of ignition and stabilization of combustion of energy coals using plasma technologies have received significant development and spread, characterized by high environmental safety and productivity, as well as relatively inexpensive equipment. In this technology, the heating of the air mixture (a mixture of coal particles with air) can be carried out by burning gaseous, liquid, or solid fuel, electric arc plasma, or another method of supplying thermal energy. Therefore, it must ensure reliable operation even when using coals of different quality (with different ash content, humidity, and volatile yield). The use of electric arc plasma, as a rule, is more effective compared to traditional ignition methods. With a high concentration of

	energy, plasma is characterized by the presence of a large number of chemically active atoms, ions, radicals, and electrons. This greatly accelerates the process of thermochemical transformations of coal and oxidizer, which leads to a more complete and rapid combustion of the pulverized coal torch. At pulverized coal power plants in Kazakhstan, heavy fuel oil is used to kindle boilers. For example, Ekibastuz CRES-1 uses about 6.6 thousand tons of fuel oil for these purposes, or 1 billion KZT per year, which has a negative impact on the economy and ecology of the country. Modernization of domestic refineries leads to a negative impact on fuel oil production, which in January-July 2023 decreased by 12% compared to the same period in 2022 to 1.126 million tons from 1.284 million tons. This will also affect the price of fuel oil, which has increased from 52,800 KZT per ton (2017) to 140,000 KZT (2023). A promising technology for oil-free kindling of boilers is a plasma-coal burner, which was presented at the international exhibition EXPO-2017 and is already widely used in the world. For example, in China, installations using this technology account for about 40% of the total installed capacity in the country. During the operation of a plasma-coal burner, highly reactive fuel (fuel oil, diesel fuel, or natural gas) is replaced by crushed solid fuel (coal dust). The burner operates on the principle of heating an air mixture (a mixture of coal dust with air) with electric arc plasma to the temperature of the output of volatile coal and partial gasification of the coke residue. As a result, at the outset of this installation, the resulting fuel mixture or highly reactive two-component fuel (gas + coke residue) ignites when mixed with secondary air and burns steadily without using fuel oil in the furnace. The use of plasma technology at pulverized coal thermal power plants allows for minimizing fuel oil costs and improving the reliability of the boiler. At the same time, the project also has a very significant impact on the environment, reducing NOx and sulfur emissions by 30-40%.
Goal	The main goal of the project is to assess the environmental and energy efficiency of using plasma technology at pulverized coal thermal power plants.
Tasks	To achieve the goal of the project, a detailed work plan was developed, and divided into tasks. Each task has its own scientific significance, and at the same time, they are all interrelated. The objectives of the project include analysis and methods for improving the efficiency of using or burning low-grade energy coals; thermodynamic analysis of the products of thermochemical preparation of fuel for combustion in a plasma-coal burner (PCB) at various concentrations of coal in an air mixture using the TERRA computer program; kinetic calculations of ignition processes of low-grade high-ash coals in PCB using the PlasmaKinTherm computer program; determination of the influence of thermal engineering indicators (temperature, speed, and concentration of combustion products, degree of carbon gasification, and level of harmful emissions) and mechanisms occurring in the boiler furnace on the efficiency of the process by comparing studies with and without the use of plasma technology for ignition and stabilization of combustion pulverized solid fuel in the boiler furnace; based on the analysis of the results obtained, the

	optimal parameters for the ignition and combustion solid fuel processes will be selected; development of technological recommendations to improve the ecological and economic indicators of pulverized coal thermal power plants and boiler houses; assessment of the ecological and energy efficiency of PCB; preparation of a feasibility study of the efficiency of the use of PCB at thermal power plants operating on pulverized coal fuel.
Expected and Achieved Results	1. An analysis was conducted on the current state of issues related to the combustion of low-grade energy coals and methods to improve their utilization efficiency, with a justified selection of a plasma-coal burner (PCB) for boiler ignition at pulverized coal-fired thermal power plants. 2. The TERRA program database was expanded with thermodynamic properties of individual substances characteristic of the mineral component of high-ash energy coals, and initial data were determined for the thermodynamic analysis of products resulting from the thermochemical preparation of fuel for combustion in the PCB. 3. Thermodynamic calculation results were obtained for the products of thermochemical fuel preparation for combustion in the PCB at various coal concentrations in the air-fuel mixture. 4. Kinetic calculation results were obtained for the ignition processes of low-grade energy coal in the PCB using the PlasmaKinTherm software, and operational parameters for experimental studies of the PCB were determined. An article was published in a peer-reviewed national journal recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan. 5. Coal dust, a plasma torch, and the PCB were prepared for the combustion of low-grade pulverized coal fuel. 6. A direct current plasma torch with a nominal power of 100 kW, used as part of the PCB, was tested. Preparations and document collection are underway for the subsequent defense of the doctoral dissertation. Pre-defense protocol No. 08 dated April 17, 2025. 7. The results of the tests of the PCB 1 t/h by obtaining reliable ignition and stable combustion of the pulverized coal torch. 8. The results of experimental studies of ignition and combustion stabilization processes in PCB will be analyzed and compared with the results of numerical (thermodynamic and kinetic) studies of plasma thermochemical preparation for coal fuel combustion. 9. An assessment of the environmental and energy efficiency of the PCB will be carried out. 10. A feasibility study of the effectiveness of the use of PCB at pulverized coal thermal power plants will be compiled. 11. Technological recommendations will be developed for equipping pulverized coal thermal power plants and boiler houses with a plasma-coal burner. Two articles will be published in peer-reviewed foreign scientific publications indexed by international databases Web of Science or Scopus.

Names and Surnames of Research Group Members with Their Identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and Links to Corresponding Profiles	1. Orynbasar Magzhan Nurlanuly, Scientific director, Scopus Author ID – 58659841700, ORCID – 0009-0009-4392-1022, The Hirsch Index – 2. 2. Messerle Vladimir Efremovich, Doctor of Technical Sciences, Professor, Scientific consultant, The Hirsch Index - 18, Researcher ID Web of Science – B-1735-2016, Researcher ID in Publons – B-1735-2016, ORCID – 0000-0003-4281-1429, Scopus Author ID - 6602472315
Publications list with links to them	Orynbasar, M., Messerle, V., Ustimenko, A. Modeling and experiments on plasma ignition of Ekibastuz coal in the form of dust. Combustion and Plasma Chemistry 2024, 22(3), 179-186. https://doi.org/10.18321/cpc22(3)179-186
Patent information	-