Brief information about the project

Name of the project	AP09057876 «Investigation of Kazakhstani low-rank coals for their biogenic coal-to-methane conversion potential» (0121PK00072)
Relevance	Over the past decades, coal bed methane (CBM) has emerged as a valuable energy resource and is expected to be a key component in the world energy portfolio in the future. CBM is considered a non-conventional type of clean fuel because its combustion produces almost no or much less by-products/greenhouse gases than the combustion of fossil fuels. Because of these advantages and in response to the rapidly growing energy demand, it tends to put a great deal of effort into investigating the CBM potential of Kazakhstani low-rank coals with the ultimate goal of deeper understanding and employing this very promising gas resource.
Purpose	To implement a novel approach with lab-to-scale-up strategy for assessing the biogenic coal-to-methane conversion potential of Kazakhstani low-rank (lignite and sub-bituminous) coals.
Objectives	• Collection and characterization of coal samples from different Kazakhstan coal basins in terms of their disparate geography and depositional history. Knowledge of coal nature and structure is critical to formulating an effective exploration/exploitation strategy. • Collection and identification of the indigenous-exogenous microbial communities from geographically distinct regions and gaining insight into their usability for coal bioconversion by means of metagenomic approaches based on 16S rRNA analysis. • Cultivation and adaptation of the isolated microbial communities using coals of different ranks as the sole carbon and energy source. Detailed characterization of how microbial community composition and abundance influence coal bioavailability will aid in the development of strategies for increasing the rate and extent of coal metabolization. • Studying the combined effects of selected aerobic and anaerobic microbial communities on pretreatment and bioconversion (fermentation and methanogenesis) of coal. Understanding the limitations and conditions that support microbial growth are conducive to biogenic CBM production. • Measurement and assessment of coal bioavailability as well as methane yield under a set of controlled conditions. Determination of biogeochemical indicators of metabolic pathways and methane biosynthesis. Understanding of the relationship between community composition, coal rank, and methane production. • Examination of a broad range of operational conditions and the important environmental factors (temperature, pH

	and salt concentration) in order to achieve the best system performance. • Investigation of possible reasons for the cessation of methane generation during coal bioconversion. Understanding of the inhibition mechanisms in bioconversion of coal to methane. • Optimization of coal biogasification for reaching maximum productivity. Strategies may include microbial-chemical stimulations, coal pretreatment, and parameter manipulation of coal methanogenesis. • Scaling-up biogenic methane-to-coal conversion and running experiments in a reactor under field-relevant conditions. Identifying the parameters and conditions to be considered when transferring strategies for enhancement of coal biogasification developed in small-scale laboratory studies to prospective large-scale applications. • Determination of the fate of residual (biotreated) coal after regeneration of methane. The successful ventures of biogenic coal-to-methane conversion will also address the possibilities of using residual coal.
Expected and achieved results	The project will result in the investigation, evaluation and characterization of chemically and geographically disparate Kazakhstani low-rank coals for their ability to support microbial methane production in ex-situ conditions. The potential importance of biogenic CBM as a domestic energy source calls for understanding the biological and chemical background that lead to methanogenesis. Results of this research will advance our understanding of this background and provide insight for effective strategy development to improve the future methane producibility of low-rank coal reservoirs.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	1. Akimbekov S. Nuraly - Ph.D., professor: *h*-index – 10. Scopus: 45160897400, Web of Science: A-5130–2014; ORCID: 0000-0002-5262-5155. 2. Tastambek T. Kuanysh, PhD: *h*-index – 6. Scopus: 57200176041, Web of Science: AAO-3781–2020; ORCID: 0000-0002-2338-8816. 3. Кожахметова Маржан Халидоллаевна, магистр технических наук, докторант: *h*-index – 1, Scopus: 57451762600, Web of Science: AAS-4987–2020; ORCID ID: 0000-0002-5879-3475
List of publications with links to them	1. М.Х. Кожахметова, А.А. Алибекова, Д.А. Нусипов, Б.К. Каменов,. Isolation and identification of coal acclimated microorganisms from the activated sludge. «Вестник КазНУ. Серия Экологическая» №4 (77), 2023 год (КОКСОН). https://doi.org/10.26577/EJE.2023.v77.i4.09 2. Биогенная конверсия казахстанских низкосортных углей в метан: монография / Н.Ш. Акимбеков, А.А. Жұбанова, Қ.Т. Тастамбек, А.Б. Мылтықбаева, Д.К. Шерелхан, М.Х. Кожахметова, Н.П. Алтынбай. – Алматы: Everest, 2023.

	3. Nuraly S. Akimbekov, Ilya Digel, Kozhahmetova Marzhan, Kuanysh T. Tastambek, Dinara K. Sherelkhan, and Xiaohui Qiao. Microbial Co-processing and Beneficiation of Low-rank Coals for Clean Fuel Production: A Review. Engineered Science, 2023, 25, 942. 10.30919/es942. Процентиль 98, Q1. 4. Nuraly S. Akimbekov, Ilya Digel, Kuanysh T. Tastambek, Marzhan Kozhahmetova, Dinara K. Sherelkhan, Zhandos Tauanov, Hydrogenotrophic methanogenesis in coal-bearing environments: Methane production, carbon sequestration, and hydrogen availability, International Journal of Hydrogen Energy, 2023 https://doi.org/10.1016/j.ijhydene.2023.09.223. Процентиль 95, Q1.
Patents	-
!!! Along with the completed form, please attach to email relevant photographs and video materials that can be used to visualize and present the project on the web page.	

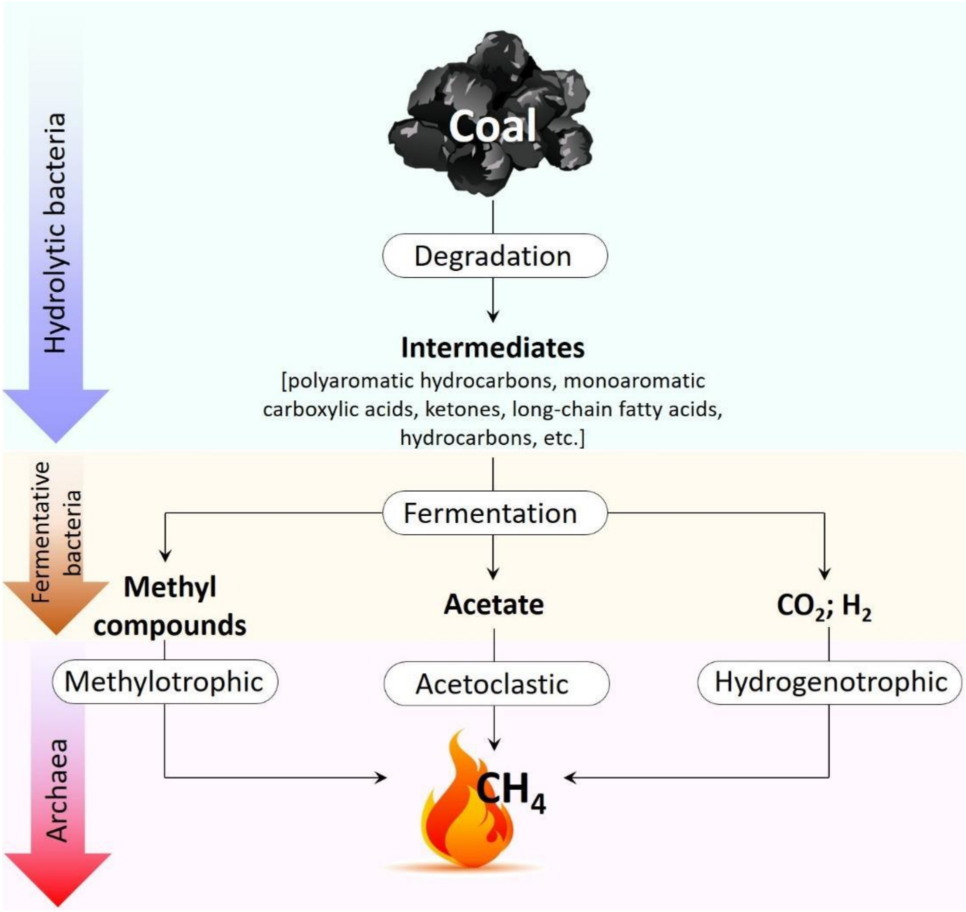

Figure 1. Proposed pathway for biogasifying coal to methane. The bacterial communities (*Firmicutes*, *Spirochetes*, *Bacteroidetes*, and all subgroups of *Proteobacteria*) sequentially break down the complex carbon in coal to intermediate and simple byproducts. Some of the byproducts of the bacterial biodegradation are the substrates required by methanogenic archaea (*Methanobacteriales*, *Methanomicrobiales*, *Methanosarcinales Methanococcales*, and *Methanopyrales*) to produce methane gas.

The three primary pathways for archaeal methane production are hydrogenotrophic (Eq. 1), acetoclastic (Eq. 2), and methylotrophic (Eq. 3) reactions:

$$CH_3COOH \rightarrow CH_4 + CO_2 \quad (1)$$
Acetoclastic reaction: $\Delta G = -31$ kJ/mol

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (2)$$
Hydrogenotrophic reaction: $\Delta G = -136$ kJ/mol

$$4CH_3OH \rightarrow 3CH_4 + CO2 + 2H_2O \quad (3)$$
Methylotrophic reaction: $\Delta G = -105$ kJ/mol

Different coal seams may have various methanogens present and different pathways resulting in methane formation. The requisite methanogenic pathways can also vary among coal basins, fields, and wells and can depend on the physicochemical properties of the microenvironment.

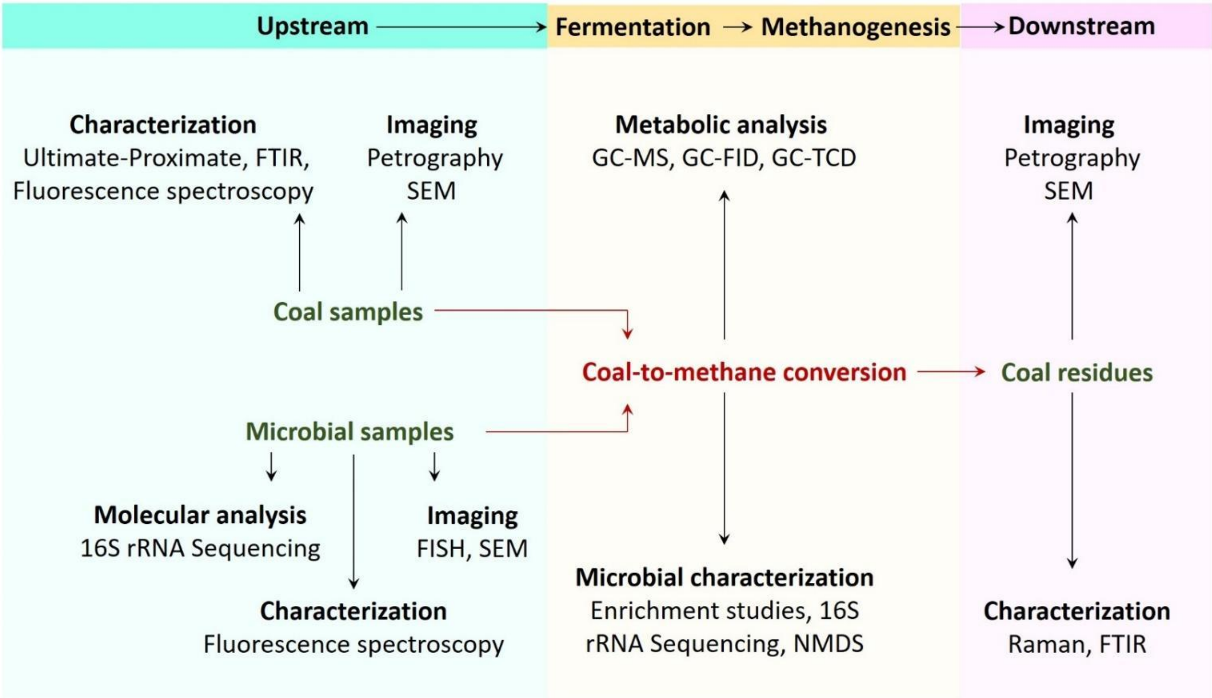

Figure 2. Methods for the analysis of coal, microbial communities and metabolites in coal-to-methane conversion. FTIR, Fourier-transform infrared spectroscopy; FISH, fluorescence in situ hybridization; SEM, scanning electron microscopy; GC-MS, gas chromatography-mass spectrometry; GC-FID, gas chromatography with flame-ionization detection; GC-TCD, gas chromatography with thermal conductivity detector; NMDS, nonmetric multidimensional scaling.