**An application for participation in a competition for grant funding for scientific and/or scientific-technical projects**

The title of the project: "Modeling the fuel-energy balance of Kazakhstan (KZLEAP) to analyze decarbonization scenarios and carbon pricing instruments" (PI - Ph.D. in Physics, Zhakiyev NK ).

**Abstract**

**The aim of the project:** development of Kazakhstan's fuel and energy balance modeling tool (KZLEAP), formation of a low-carbon transition decision-making action plan and analysis of carbon pricing instruments with a holistic cross-sectoral vision of green economy and infrastructure development , bringing Kazakhstan into the leading region for carbon neutrality.

**The scientific novelty** and importance of the project is to develop a new model of the fuel and energy system of Kazakhstan to analyze low-carbon development scenarios, which considers the application of “operational decarbonization” measures, the region's capabilities and the development of the most optimal carbon pricing trading instruments.

**Research hypothesis** - a quantitative cross-sectoral model provides a comprehensive description of possible scenarios for the development of the fuel and energy system, taking into account the prioritization of policies and measures for decarbonization based on a techno-economic approach, quantitative and qualitative analysis of carbon pricing instruments in the Central Asian region.

**Project objectives:**

1. Analysis of the fuel and energy balance;

2. Development of the KZLEAP model;

3. Modeling of development scenarios, quantitative and qualitative analytics.

**As a result of the project,** an analysis of the most optimal scenarios for low-carbon development of the country and the possibility of developing trading instruments for carbon pricing in the region will be carried out. It is expected to develop a new model for optimizing the Kazakhstan market for integrated energy planning and assessment of climate change mitigation based on LEAP (Long-range Energy Alternatives Planning). LEAP is an integrated modeling tool that can be used to track energy consumption, production and resource extraction across all economic sectors over medium to long term forecast periods. The project involves solving current problems of ecology, personnel training, socio-ecological and scientific and technical development of the Republic of Kazakhstan. A key factor in conducting this study is the environmental, economic and energy aspects of decarbonization of the national economy for decision makers in the development of government Strategies: ( i ) The Kazakhstan 2050 Strategy includes long-term goals to increase the share of alternative energy in electricity production (renewable and nuclear) up to 50% by 2050; (ii) The strategy to achieve carbon neutrality by 2060 is a trigger to attract significant investment in alternative energy sources. The country's regions have great potential for renewable energy: solar, wind, bio, hydro, and geothermal energy. (iii) By leveraging the region's diverse energy sources and production mix, the carbon market will pave the way for accelerated regional decarbonization and realize the benefits of sustainable energy cooperation in Central Asia. More than three articles will be published in ranking scientific journals with a high impact factor.

**Key words:** LEAP modeling, fuel and energy balance of Kazakhstan; low carbon development; reduction of emissions; carbon neutrality.

**2. Explanatory note**

 **1. General information**

1.1. Title of the project topic:

“Modeling of fuel and energy balance of Kazakhstan (KZLEAP) for the analysis of decarbonization scenarios and carbon emission pricing instruments.”

1.2. Name of the priority direction of scientific development for which the application is submitted: 1. Ecology, environment and rational use of natural resources

1.3. Name of the specialized scientific area for which the application is submitted: 26. Interdisciplinary scientific research and development in the field of ecology and technology with the aim of developing innovative methods for the sustainable use of natural resources.

1.4. Area of research in accordance with the Classifier of scientific fields: 87.35.91

1.5. Type of research: applied.

1.6. Estimated start and completion date of the project, its duration in months: 03/01/2024-12/31/2026 (34 months).

1.8. Key words characterizing the industry and the direction of the application for selecting experts: Kazakhstan; modeling of fuel and energy balance; low carbon development; reduction of emissions; carbon neutrality.

 **2. 2. General concept of the project**

**2.1. Introduction**

Kazakhstan's energy sector and economy as a whole are dependent on fossil fuels, with coal being the backbone of Kazakhstan's electricity sector, accounting for 67% of the country's electricity production and CO₂ emissions. The transition from fossil fuels to clean energy solutions for Kazakhstan is now high on the national strategy agenda. This requires a transformation of energy policy and a revision of traditional industrial development strategies, the introduction of innovative technologies and the application of “rapid decarbonization” measures. Energy modeling of development scenarios has an important role in shaping policy and investment decisions.

**2.2. The aim of the project**

Development of a modeling tool for the fuel and energy balance of Kazakhstan (KZLEAP), formation of an action plan for decision-making on a low-carbon transition and analysis of carbon pricing tools with a holistic cross-sectoral vision for the development of a green economy and infrastructure, leading Kazakhstan to a leading region in carbon neutrality.

**2.3. Project objectives**

The concept of this research provides for 3 work packages (WP-work package) of implementation:

**WP 1.** **Analysis of fuel and energy balance.** Data analytics, building forecast models, correlation analysis, comparison of indicators with other countries, dependency graphs, repository architecture. The necessary data (datasets in monthly and seasonal resolution) included in the fuel and energy balance and collection of emissions data will be officially requested from the Bureau of National Statistics of the Ministry of Economy of the Republic of Kazakhstan, Zhasyl Damu JSC of the Ministry of Ecology of the Republic of Kazakhstan, KEGOC JSC and Kazakhstan Operator JSC Electric Energy and Capacity Market (KOREM)" of the Ministry of Energy of the Republic of Kazakhstan.In the future, the obtained data will be processed in the software environment SQL, Python, MS Excel, Wolfram Mathematica.

**WP2. Development of the KZLEAP model.** Design and build an open, transparent and integrated modeling platform to assess low-carbon transition pathways for Kazakhstan's energy system in LEAP. Training in the field of modeling in LEAP and the formation of human capital of experts. Improving the qualifications of scientific staff in improving the KZLEAP model (participation in seminars, reporting at conferences, improving scientific methods, training undergraduates). Quantitative exploration of scenarios for medium- and long-term decarbonization pathways. Improving the qualifications of government employees to use the KZLEAP model and involving them in scientific research.

**WP3. Modeling of development scenarios, quantitative and qualitative analytics.** Building energy pathways using the LEAP model for energy planning and climate change mitigation assessment. Emission limits vary across scenarios and are optimized endogenously by the model based on GDP growth or based on current emissions. Energy modeling of development scenarios has an important role in shaping policy and investment decisions. Exploring the potential of Central Asia to develop carbon market pricing instruments to accelerate regional decarbonization and realize the benefits of sustainable energy cooperation in the region.

**WP3: Scenario Modeling, Analytics**

**WP2: KZLEAP model**

**WP1: Fuel and Energy Balance Analysis**

Development of an algorithm for modeling optimal decarbonization scenarios

Development of the KZLEAP modeling tool (testing, calibration)

Formation of a database of the fuel and energy balance of Kazakhstan for 2000-2023

Assistance to the Ministry of Ecology of the Republic of Kazakhstan in prioritizing policies and measures for decarbonization (technical and economic approach, quantitative and qualitative analysis)

Advanced training of scientific staff in improving the KZLEAP model (participation in seminars, reporting at conferences, improving scientific methods, training government employees, students)

Data analytics, building forecast models, correlation analysis, comparison of indicators with other countries, dependency graphs, repository architecture

Improving the qualifications of government employees in the use of the KZLEAP model and involving them in scientific research

Analysis of carbon pricing instruments for the CA region.

Assistance to the National Bureau of Statistics in improving the methodology for collecting data on the fuel and energy balance of Kazakhstan

**Forming an action plan for decision-making for low-carbon development**

Figure 1. Project implementation matrix

**3. Scientific novelty and significance of the project**

Kazakhstan is a leading producer and exporter of fossil energy: the 9th largest exporter of coal, the 9th largest exporter of crude oil, and the 12th largest producer of natural gas [1,2]. The economy of Kazakhstan is largely dependent on energy production mainly from fossil fuels, energy-intensive industry and natural resource processing. Kazakhstan, a leading exporter of hydrocarbons, is currently faced with the need to decarbonize economic sectors and transition to a new energy paradigm based on the climate agenda. The transition from fossil fuels to clean energy solutions is now prominent in national strategic documents [3,4].

A key factor in conducting this study are the environmental, economic and energy aspects of decarbonization of the national economy: (i) The Kazakhstan 2050 Strategy includes long-term goals to increase the share of alternative energy in electricity production (renewable and nuclear) to 50% by 2050; (ii) The strategy to achieve carbon neutrality by 2060 is a trigger to attract significant investment in alternative energy sources. The country's regions have great potential for renewable energy: solar, wind, bio, hydro and geothermal energy; (iii) By leveraging the region's diverse energy sources and production mix, the pilot market will pave the way for accelerated regional decarbonization and realize the benefits of sustainable energy cooperation in CA. These benefits include lower investment costs for new generation capacity, increased development of renewable energy sources, and improved operation and management of regional energy resources.

The necessary modernization of Kazakhstan's energy system can be accompanied by a transition to environmentally green energy sources. With the average age of the coal-fired power plant fleet being 50 years, expanding the use of renewable energy to replace thermal power plants will allow the country to avoid investing in assets that will not be needed in the future [5].

Accelerating the deployment of renewable energy sources requires changes in energy policy [6]. Currently, fossil fuel subsidies, low tariffs for coal and gas power, the dominance of CHP in electricity and heat production, and shortages of transmission and distribution capacity hinder the expansion of wind and solar energy.

To transition to a renewable energy system, the following three steps are necessary. First, modernize and further develop networks capable of integrating a high share of renewable energy. Second, increasing the flexibility of the energy system through demand management, energy storage systems, hydropower capacity and other technologies. Third, a clear plan for phasing out coal, including support for structural changes in coal regions.

Interest in renewable energy production is growing throughout the region, motivated by current energy needs and the implementation of long-term CC mitigation strategies. The global push for clean technologies demonstrates that the energy crisis is certainly not a setback for the climate, but rather is accelerating the energy transition. In fact, the IEA's WEO 2022 report leads us to the conclusion that the famous energy trilemma can be solved with clean energy, providing solutions for energy security, economic competitiveness and sustainability [7].

The processes of decarbonization and energy transition in the current geopolitical conditions are an objective reality, as a result of which the development of carbon-free green energy is a key condition for the compliance of the energy policies of energy exporting countries with modern energy trends, which ultimately expands the prospects for effective energy dialogue. The implementation of projects in the field of renewable energy sources for the oil and gas economy acts as a driver for the innovative development of the fuel and energy complex. The implementation of the existing potential of renewable energy sources in countries exporting fossil energy resources will contribute to the expansion of new scientific areas, industrial growth in related industries, the creation of new jobs, etc. For a number of countries, by increasing the share of renewable energy sources in the energy balance, the opportunity to increase hydrocarbon exports is used.

However, there is a lack of comprehensive analysis and modeling that provides optimal solutions and considers all aspects of implementing long-term mitigation strategies.

 Kazakhstan, a leading exporter of hydrocarbons, is faced with the need to decarbonize its economy and transition to a new energy paradigm.

Further analysis is needed of opportunities for a managed phase-out of coal and the phasing of renewables, along with increased agility in the energy sector. The President's recent announcement of Kazakhstan's goal of carbon neutrality by 2060 requires significant work to regulate each sector of greenhouse gas emissions (Table 1) [8,9]. According to the strategy, alternative and “green” energy technologies should provide up to 50% of all energy consumed by 2050.

Table 1. Kazakhstan's greenhouse gas emissions targets

|  |  |  |
| --- | --- | --- |
| Period | Greenhouse gas emissions, million tons CO2 eq | Regulatory document |
| 1990 ( basic ) | 386 | Not regulated |
| 2030 | 328 (unconditional target )290 (conditional target) | Paris Agreement |
| 2060 | 0 (including absorption of land use and forestry (L&F)) | Carbon neutrality doctrine (approved) |

However, few local experts believe it is possible even in the long term, and so far there are no concrete plans for a phase-out or even a gradual reduction. In any case, reducing carbon emissions will require a transition to lower-emitting sources such as renewable energy sources, possibly in combination with gas. In general, Kazakhstan's geolocation and low population density are an ideal option for selecting sites for the construction of wind and solar power plants. The average wind speed in some regions of Kazakhstan is 8–9 m/s at an altitude of 100 m, which is ideal for the production of inexpensive electricity. In the southern part of the country, the intensity of solar radiation reaches 4.79 kWh/m2, which is good indicators for thermal energy.

Kazakhstan needs a dedicated strategy or roadmap to decarbonize the country to accelerate the transition from a hydrocarbon economy to a green economy. The green economy roadmap must provide confidence to stakeholders in the carbon pricing chain. Controlling carbon emissions is a policy tool for decarbonization and an important driver of a green economy.

As shown in Table 2, there are still significant gaps and threats to the adoption of decarbonization activities in Kazakhstan, but there are also significant strengths and opportunities that can facilitate their adoption and implementation [8].

Table 2. SWOT Analysis of Low Carbon Transition and Carbon Pricing in Kazakhstan

|  |  |
| --- | --- |
| **Strengths:**- Governments are already supporting decarbonization through programs and projects;- Application of existing MRV (stands for measurement, reporting and verification) tools;- Continuous regional cooperation through regional platforms;- Kazakhstan's main emission sectors are eligible for ETS; | **Weaknesses:**- The CPI is not consistent with some national policies and initiatives;- Limited experience in determining the CPI in the region;- Insufficient government support for the implementation of the CPI;- Insufficient technical information in the Kazakh language;- Lack of local experts with sufficient technical experience to develop and implement CPI programs and initiatives; |
| **Opportunities:** - Less competition between public and private organizations for the implementation of the CPI than in some other countries;- Existing support structures from international organizations, including the UN, World Bank, USAID, EBRD, ADB and GIZ.- Significant opportunities to reduce greenhouse gas emissions;- Opportunities for diversifying the economy and creating new sources of exports;- Opportunity to reduce fossil fuel subsidies;- Significant potential for wider deployment of renewable energy sources;- Wider regional cooperation in the electricity sector could contribute to the development of a regional ETS; | **Threats:** - Emissions trading costs will be an additional cost for businesses, which some businesses will not be welcome, and which may be passed on to consumers;- Unless effective compensation systems are put in place for vulnerable groups and financed by revenues from carbon prices, rising prices (for example for electricity or fuel) could lead to social tensions;- The CPI is perceived as an additional burden of administrative costs;- The CPI may affect trade relations with countries outside CA. |

Global efforts to combat climate change will lead to reduced investment and devaluation of fossil fuel resources, while the economies of CA countries are largely dependent on revenues from the export of oil and gas and coal resources.

Although the literature on the CA energy sector is slowly developing, it still needs to be improved in terms of methodology, its transparency and critical reflection of the technical, economic and social implications of the envisaged sustainable transformation process [10]. This is one of the questions that the proposed study addresses by analyzing the economic and technical implications of sustainable transformation. This leads to the following scientific questions underlying this study:

- Can the low-carbon transition serve as a driver of cooperation and coordination in Central Asia? Should CA countries provide options for interstate cooperation in the development of the energy system? What are possible strategies for sustainable transformation for CA countries, considering their characteristics (for example, strong oil, gas and coal industries, harsh winters, long transportation distances, location, etc.)?

Currently, in the CA power system, little attention is paid to operating the system at the lowest cost and excessively meeting demand. This results in excessive fuel consumption, associated emissions and aging infrastructure. At the same time, the electricity market in each CA country is developing and is currently at a transition stage, characterized by the emergence of schemes to support renewable energy. To achieve the global goal of reducing greenhouse gas emissions, the CA electricity sector plays an important role. Additionally, this study evaluates cooperation with Russia and China, as well as Afghanistan and Pakistan, through a new transmission line called CASA-1000. Regional cooperation is not a new concept for CA [11]. In fact, electricity supply in CA was organized on a centralized basis, with hydroelectricity production in Tajikistan and Kyrgyzstan in the summer and thermal electricity production in Uzbekistan and Southern Kazakhstan in the winter. Cross-border electricity exchanges in the region reduce the need for peaking and reserve power in the system and reduce the required reserve capacity within the respective national systems. Optimizing the export of hydroelectric power from higher to lower states minimizes water spills in summer.

The development of an open-source LEAP model for assessing technical barriers and solutions to various transformation scenarios with a detailed cross-sector view will be developed based on mathematical modeling approaches [12-14]. Feasibility studies for tightening CO2 emissions limits, subsidizing green technologies and energy storage will be considered.

Availability of emissions data is a precondition for the implementation of the ETS carbon trading system. Kazakhstan's national cap-and-trade system (CTS) was launched in 2013 as the main instrument for regulating domestic CO2 emissions and developing low-carbon technologies. Today, STV KZ covers all major companies in the energy, oil and gas, mining, metallurgical and chemical industries. In particular, data on emissions from large-scale emission facilities are required for the ETS. One of the key elements of ETS implementation is the measurement, reporting and verification (MRV) system, which allows for the collection, management, analysis, use and verification of climate change-related data. Kazakhstan has implemented facility-level MRV as the basis for its domestic ETS [15-19]. In February 2019, Kazakhstan introduced an online platform that allows large emitters in the region to transmit and record greenhouse gas emissions data and emissions trading rights online: <https://ecocarbon.gov.kz/> and <https://oos.ecogeo.gov.kz/>. The Unified Information System for Environmental Protection of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan is one of the important MRV tools; similar national platforms can become one of the important elements of emissions pricing [20, 21].

**4. Research methods and ethical issues [no more than 1500 words]**

Energy system models are used to analyze long-term policies and pathways to reduce greenhouse gas (GHG) emissions. It is necessary to create 'net zero' or 'net-negative emissions' energy systems that decarbonize the entire economy, covering energy supply and demand, as well as other sources of emissions, including industrial processes, agriculture, and land use. A subset of these models are engineering-economic models that minimize the costs of achieving exogenously given annual reductions in GHG emissions to limit the increase in average global temperature. Their results, called deep decarbonization models (DDMs), include levels and timing of energy investment that meet projections of future energy demand across all energy sectors over several decades.

**The novelty of the research** lies in the development of a new model of the fuel and energy system of Kazakhstan to analyze low-carbon development scenarios, which takes into account the application of “operational decarbonization” measures, the region's capabilities and the development of the most optimal trading instruments for carbon pricing.

**Research hypothesis** - a quantitative cross-sectoral model provides a comprehensive description of possible scenarios for the development of the fuel and energy system, considering the prioritization of policies and measures for decarbonization based on a techno-economic approach, quantitative and qualitative analysis of carbon pricing instruments in the CA region.

**Data** on energy system often includes statistics on current and projected fuel availability and prices, electrical capacity and generation, energy demand and prices, geospatial data on renewable energy sources and policies.Models may also include various technological, economic, political, and environmental constraints. For example, the modeling process to determine the least-cost path to achieving net-zero emissions may include limiting the ratepayer impact for low-income residential customers. The models then use these inputs to generate outputs using sophisticated mathematical optimization techniques. Energy modeling relies on multiple data sources. There are three main categories of data:

• Data on the existing energy system;

• Forecasts of future costs, policies, fuel prices, demand and other data;

• Various constraints such as technological, economic, political and equity.

**Modeling tool.** There are a number of open-source tools for automatically extracting energy transfer data, but reproducibility can be an issue.

LEAP is a transparent and user-friendly tool for energy planning and climate change mitigation that has been adopted by thousands of organizations in nearly 190 countries, including government agencies, scientists, non-profit organizations, consultancies and energy companies.It can be used at a variety of scales, from cities and states to national, regional, and even global applications. At least 37 countries have used LEAP to help develop their Nationally Determined Contributions (NDCs) presented at the 2015 UNFCCC Paris Climate Conference, and LEAP is quickly becoming the de facto standard for countries undertaking integrated resource planning and assessments mitigating the effects of greenhouse gas emissions , especially in the developing world.

LEAP is quickly becoming the de facto standard for countries undertaking integrated resource planning, greenhouse gas (GHG) reduction assessments and low-emission development strategies (LEDS), especially in developing countries, and many countries have also chosen to use LEAP as part of them commitments report to the United Nations Framework Convention on Climate Change (UNFCCC). Many countries have primarily used LEAP to create energy and emissions scenarios that formed the basis of their Intended Nationally Determined Contributions (INDC): the basis of the landmark Paris Climate Agreement designed to demonstrate countries' commitment to begin decarbonizing their economies and investing in resilience to climate change [5].

LEAP is an integrated scenario-based modeling tool that can be used to track energy consumption, production and resource extraction across all sectors of the economy. It can be used to account for sources and sinks of greenhouse gas (GHG) emissions in both the energy and non-energy sectors. In addition to tracking GHG emissions, LEAP can also be used to analyze emissions of local and regional air pollutants, as well as short-lived climate pollutants (SLCPs), making it well suited for studying the climate co-benefits of local air pollution reductions (Figure 2) [12,14].

Figure 2. LEAP calculation structure

The study will integrate DDPP, a collaborative initiative that aims to physically and economically demonstrate how countries can transform their energy systems to achieve deep decarbonization in line with national development priorities. This transition is represented by the deep decarbonization (DDM) pathways of individual countries. A key advantage of the approach is that country DDPs are prepared by in-country teams with local knowledge independent of government, with careful consideration of the national political, economic, technological, and geographic context. The pathways also implement the types of actions needed now and, in the future, up to 2050, using reliable, credible, and transparent modeling approaches. In doing so, they can also catalyze debate among stakeholders about the technical paths and policies to achieve them. However, developing and implementing approaches across all economic sectors over the long term in a systematic and defensible manner is not a trivial task.

**5. Research team and project management**

The project will be implemented by a team of researchers with extensive experience in energy system modeling. The scientific investigator of the project is Zhakiev Nurkhat, who has experience in implementing two similar scientific and applied projects together with scientists from Germany and Great Britain in the field of mathematical modeling of energy systems, optimization methods and issues of integration of renewable energy sources. The main participants of the project are young scientists in the field of energy, modeling, programming, and data visualization.

The project will be regularly assessed in group meetings to monitor scientific progress, define goals, and develop new strategies in case of risks of not achieving results. Within the framework of the project, *Dr. Zhakiev Nurkhat (PI)* will be responsible for the effective management of the research project and the development of forecast models. *PhD Candidate* *Gulden Ormanova (main executor)* will manage the project, process emissions data, statistical analytics on renewable energy sources. *Aidyn Bakdolotov (executor)* will be involved in LEAP and TIMES modeling. *Ayagoz Khamzina (executor)* and *Nadezhda Sagadatova ( executor )* will be updating models and developing script files.

**Nurkhat Zhakiev** has a PhD in Physics. The main topics of scientific research are devoted to mathematical and computer modeling of system processes, optimization methods and modeling in the PyPSA , GAMS and Wolfram Mathematica environments. He was involved in modeling the electrical power system, improving the energy efficiency of thermal power plants, and integrating renewable energy sources. Below is a list of publications and copyright certificates.

[https://www.mendeley.com/authors/560 4 3145000/](https://www.mendeley.com/authors/56043145000/)

[https :// https://orcid.org/0000-0002-4904-2047](https://orcid.org/0000-0002-4904-2047)

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<https://publons.com/researcher/D-6159-2017/>

**Realized projects:**

2021 - 2023, “Hybrid modeling of the energy system to create a renewable energy roadmap for Kazakhstan with high spatial, temporal and technical disaggregation” (Project Manager, Ministry of Education and Science of the Republic of Kazakhstan);

2021, “Application of modeling and machine learning methods for optimal planning of the composition of generating equipment at Pavlodar CHPP-1.” (Project Manager, Ministry of Education and Science of the Republic of Kazakhstan);

2022, “Knowledge Exchange Towards Sustainable Smart Cities: Energy Efficiency and Air Quality of Astana” (Project Manager, RAENG UK Grant. Frontiers Champions).

**List of selected publications:**

1. **Zhakiyev N, Khamzina A,** Zhakiyeva S, De Miglio R, Bakdolotov A, Cosmi C. Optimization Modeling of the Decarbonization Scenario of the Total Energy System of Kazakhstan until 2060. Energies. 2023; 16(13):5142. <https://doi.org/10.3390/en16135142>(WoS-Q3, Scopus percentile 83%)
2. Abdi, G., **Zhakiyev, N.,** & Toilybayeva, S. (04.2023). Decarbonisation Opportunities and Emerging Carbon Pricing Instruments in Central Asia. In Climate Change in Central Asia: Decarbonization, Energy Transition and Climate Policy (pp. 51-65). Cham: Springer Nature Switzerland. <https://doi.org/10.1007/978-3-031-29831-8_5>
3. **Zhakiyev, N.,** Kalenova, A., & Khamzina, A. (2022). The Energy Sector of the Capital of Kazakhstan: Status Quo and Policy towards Smart City. International Journal of Energy Economics and Policy, 12(4), 414–423. <https://doi.org/10.32479/ijeep.13126> (Scopus , Q1)
4. **Zhakiyev, N.,** Sotsial, Z., Salkenov, A., & Omirgaliyev, R. (2022). Set of the data for modeling large-scale coal-fired combined heat and power plants in Kazakhstan. Data in Brief, 44, 108547. <https://doi.org/10.1016/j.dib.2022.108547>
5. Omirgaliyev, R., **Zhakiyev, N.,** Aitbayeva, N., Akhmetbekov, Y. (2022). Application of machine learning methods for the analysis of heat energy consumption by zones with a change in outdoor temperature: Case study for Nur-Sultan city. International Journal of Sustainable Development and Planning, Vol. 17, No. 4, pp. 1247-1257. <https://doi.org/10.18280/ijsdp.170423>
6. Assembayeva, M., Egerer, J., Mendelevitch, R., & **Zhakiyev, N.** (2018). A spatial electricity market model for the power system: The Kazakhstan case study. Energy, 149, 762-778. <https://doi.org/10.1016/j.energy.2018.02.011> (Q1)
7. Assembayeva , M., Egerer, J., Mendelevitch , R., & **Zhakiyev, N.** (2019). Spatial electricity market data for the power system of Kazakhstan. Data in Brief, 103781. <https://doi.org/10.1016/j.dib.2019.103781>
8. Kopanos G., Murele O.C., Silvente J., **Zhakiyev N.,** Akhmetbekov Y., Tutkushev D. (2018). Efficient planning of energy production and maintenance of large-scale combined heat and power plants. Energy Conversion and Management,169,390-403. IF=5.589 (Q1)
9. Otarov R.,Akhmetbekov Y., **Zhakiyev** N. ( 2017). Determination of optimal CO2 allowance prices for stimulation of investments in CCS, RES and other carbon-clean technologies in Kazakhstan. Sustainable Energy in Kazakhstan: Moving to Cleaner Energy in a Resource-Rich Country, 125 , [Routledge Taylor and Francis Group](https://www.routledge.com/Sustainable-Energy-in-Kazakhstan-Moving-to-cleaner-energy-in-a-resource-rich/Kalyuzhnova-Pomfret/p/book/9781138238442) .
* **Intellectual property associated with the project:**

**Zhakiyev N.,** Kulmukhanova A., **Akhmetbekov Y.,** Assembayeva M. The energy system planning tool “Toward a Green Economy” // Copyrights for software from the Ministry of Justice No. 496 03/31/2017

**Gulden Ormanova,** PhD Candidate in Science, Engineering and Technology , School of Engineering and Digital Sciences at Nazarbayev University. She g graduated BSc in Geodesy and Cartography from Al-Farabi Kazakh National University; She has (1) Master in Engineering Sciences from Al-Farabi Kazakh National University; (2) MSc in Geographic Information Sciences from the University of West Hungary. She is owner of several international scholarships: DAAD scholarships (Deutscher Akademischer Austauschdienst ); Erasmus Mundus Action 2 scholarships, “ gSmart - Spatial ICT Infrastructures for Smart Places”. Winner of the annual republican competition of scientific research works in the specialties of technical, social, humanitarian, and economic sciences of the Ministry of Education and Science of the Republic of Kazakhstan. Author of more than 10 scientific publications on topics related to air quality analysis, sampling and chemical characterization of fine atmospheric particles, ecology and GIS, remote sensing. She is studying ways to reduce greenhouse gas emissions and apply MRV techniques in Kazakhstan. She has practical experience working with meteorological stations and air quality samplers. In 2019-2022 installed the historically first PM 2.5 sampling stations in Kazakhstan. Has experience working as a research assistant at Nazarbayev University, international organizations such as ADB, UNDP. She conducted PhD study on the topic: “Chemical characterization and source apportionment of atmospheric fine particulate matter”. She specializes in big data modeling on air quality, using statistical data processing methods and GIS visualization.

<https://scholar.google.com/citations?user=eV4q4YcAAAAJ&hl=en>;

<https://orcid.org/0000-0002-9667-2498>

**Participation in projects as a performer:**

* “Ecological-geomorphological systems of platform-denudation plains in mining regions of the arid zone of Kazakhstan”, Al-Farabi Kazakh National University, (2013-2014);
* "Satellite Enhanced Snowmelt Flood and Drought Predictions for the Kabul River Basin (KRB) with surface and groundwater modeling", USAID PEER supported project , (2018);
* “Comprehensive assessment of the ecosystems of the Shchuchinsk-Borovsky resort area with determination of environmental load for the purpose of sustainable use of recreational potential”, Nazarbayev University Research and Innovation System, (2019);
* “Methodology for monitoring the impact of climate change on the state of forests in pilot protected areas”, UNDP Project , (2020);
* "BR10965311 - Development of intelligent information and telecommunication systems for urban infrastructure: transport, ecology, energy and data analytics in the Smart City concept", Astana IT University (2022) ;
* “OPCRP2020016 - Ventilation system optimization to reduce particulate matter (PM) and gas concentrations in Kazakhstan underground mines: simulation and experimental validations”, Nazarbayev University, (2023).

**Aydin Bakdolotov** (executor), employee of the Central Scientific Research Center of the Institute of Economic Management JSC, has a MSc in Energy from Purdue University, USA. He is an expert in energy efficiency and economic sustainability, has experience in energy modeling and will always be working on packages W1 and W2, results publication and LEAP and TIMES modeling, has H-index=4 https://www.mendeley.com /authors/56405546400/

**Participation in projects as an executor:** “Hybrid modeling of the energy system to create a road map of renewable energy for Kazakhstan with high spatial, temporal and technical disaggregation”, Ministry of Education and Science of the Republic of Kazakhstan (2021 – 2023);

**Ayagoz Khamzina** (executor), holds a MSc degree in technical sciences from Al-Farabi Kazakh National University. She completed an internship in Poland under the project of the Republican public association "National Engineering Academy of the Republic of Kazakhstan". He has experience working as a researcher at Al-Farabi Kazakh National University. Conducted research work in the project “Development of intelligent information and telecommunication systems for urban infrastructure: transport, ecology, energy and data analytics in the Smart City concept.” Author of three publications in Scopus, H-index=1. ORCID iD: 0000-0001-7793-239X . As part of the project, s he will be involved in updating models and developing scenario files.

**Zhakiyeva Svetlana** (executor), completed her PhD study at LN Gumilyov Eurasian National University with a degree in Mathematical and Computer Modeling. Author of 6 scientific publications on topics related to the development of mathematical models, data analysis, correlation analysis.

**Participation in projects as an executor:** “Hybrid modeling of the energy system to create a road map of renewable energy for Kazakhstan with high spatial, temporal and technical disaggregation”, Ministry of Education and Science of the Republic of Kazakhstan (2021 – 2023);

**Nadezhda Sagadatova** (executor) will be updating models and developing script files. Sh e has a M Sc in Computer Engineering from Astana IT University. She has several scientific publications on topics related to data-driven forecasting. She conducted research work in the project “Development of intelligent information and telecommunication systems for urban infrastructure: transport, ecology, energy and data analytics in the Smart City concept”. She will be responsible for the development of the LEAP model, GIS visualization, and data analytics. As part of the project, s he will be involved in updating data and requesting data as an assistant, programmer, and data analyst.

1. **Project Implementation Plan**

 Table 5. Project implementation plan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No.  | Name of tasks, activities to implement project tasks | Duration ( inmonths ) | Start and end of work\* (dd/mm/ yy ) | Years of project implementation, expected results of project implementation (by tasks and activities) |
| 2024  | 2025  | 2026  |
| 1.  | WP1. Formation and analysis of the fuel and energy balance | 10  | 01.03.2024-31.12.2025 | Collection of factual data on the production and consumption of fuel and energy resources. |   |   |
| 1.1 |  Data analytics, building forecast models, correlation analysis, comparison of indicators with other countries, dependency graphs, repository architecture. | 12  | 03.01.2025-31.12.2025 |   | Analytics, predictive models, correlation analysis, dependency graphs, repository architecture. |   |
| 1.2  |  Assistance to the National Bureau of Statistics in improving the methodology for collecting data on the fuel and energy balance of Kazakhstan | 12 | 03.01.2026-31.12.2026 |   |   | Studying ways to improve the methodology for collecting data on the fuel and energy balance of Kazakhstan.  |
| 2 .  | WP2 . \_ Development of the medium- and long-term KZLEAP model | 6 | 01.07.2024-31.12.2024 | Development of the initial version of the medium- and long-term KZLEAP model |   |   |
| 2.1  | Participation in seminars, presentation at conferences, improvement of scientific methods. Testing , calibration . | 12  | 03.01.2025-31.12.2025 |   | Analytics, improvement of scientific methods of analysis. Refinement of the KZLEAP model. |   |
| 2.2  | Quantitative exploration of medium- and long-term decarbonization pathway scenarios in KZLEAP | 12 | 03.01.2026-31.12.2026 |   |   | Quantitative study of scenarios for medium- and long-term decarbonization paths in KZLEAP with the involvement of government agencies in scientific research.  |
| 3.  | WP 3: Modeling of development scenarios, quantitative and qualitative analytics. | 6 | 01.07.2025-31.12.2025 |   | Development of an algorithm for modeling optimal decarbonization scenarios |   |
| 3.1  | Obtaining results from long-term KZLEAP scenario models | 12 | 03.01.2026-31.12.2026 |   |   | Building scenario analyzes using the LEAP model for energy planning and climate change mitigation assessment. |
| 3.2 \_  | Analysis of carbon pricing instruments for the CA region. | 12 | 03.01.2026 –12.31.2026  |   |   | Analysis of carbon pricing instruments for the Central Asia region. Preparation of the manuscript. |

**9. Expected results [no more than 750 words]**

**As a result of the project,** an analysis of the most optimal scenarios for low-carbon development of the country and the possibility of developing trading instruments for carbon pricing in the region will be carried out. It is expected to develop a new model for optimizing the Kazakhstan market for integrated energy planning and assessment of climate change mitigation based on LEAP (Long-range Energy Alternatives Planning). LEAP is an integrated modeling tool that can be used to track energy consumption, production, and resource extraction across all economic sectors over medium to long term forecast periods. It can be used to account for sources and sinks of greenhouse gas emissions from both the energy and non-energy sectors, as well as emissions of local and regional air pollutants. The project involves solving current problems of socio-ecological and scientific-technical development of the Republic of Kazakhstan.

Table 6 shows the expected results for the purposes of this study based on the planned manuscripts:

Table 6. Tasks with expected results

|  |  |
| --- | --- |
| **Tasks (WP- work packages)** | **Expected results** |
| **WP1. Analysis of fuel and energy balance** | Data analytics, building forecast models, correlation analysis, comparison of indicators with other countries, dependency graphs, repository architecture. Collected data (datasets in monthly and seasonal resolution) included in the fuel and energy balance and collection of emissions data. Data processing in the SQL, Python, MS Excel, Wolfram Mathematica software environment. |
| **WP 2.** **Development of the KZLEAP model** | Simulation and simulation of various scenarios;Design and build an open, transparent and integrated modeling platform to assess low-carbon transition pathways for Kazakhstan's energy system in LEAP. Training in the field of modeling in LEAP and the formation of human capital of experts. Improving the qualifications of scientific staff in improving the KZLEAP model (participation in seminars, reporting at conferences, improving scientific methods, training undergraduates). Quantitative exploration of scenarios for medium- and long-term decarbonization pathways. Improving the qualifications of government employees to use the KZLEAP model and involving them in scientific research. |
| **WP 3: Development scenario modeling, quantitative and qualitative analytics** | Building scenario analyzes using the LEAP model for energy planning and climate change mitigation assessment.Exploring the potential of CA to develop carbon market pricing instruments to accelerate regional decarbonization and realize the benefits of sustainable energy cooperation in the region. |

 As indicated in Table 6, each WP (work package) requires the publication of an article. Based on the results of the study, the project team will provide proposals and recommendations for the continuation and further implementation of the decarbonization and low-carbon transition strategy of Kazakhstan.

The main result of this study is the LEAP model of Kazakhstan with data on geographical location, construction time and investment volume, considering the renewable energy potential in the region and energy demand. The developed tool can also be used for other environmental strategies.

This study is important not only for the Kazakh community, but also for the global scientific community, as it represents the LEAP of Kazakhstan and considers the connection with Central Asia and the introduction of renewable energy sources.

A web page will be created on the AITU website astanait.edu.kz, which will contain complete information about the project: relevance, purpose, expected and achieved results, names and surnames of members of the research group, information about publications in journals.

The project aims to assist decision makers in making informed decisions and successfully implementing Government Strategies. In addition to government agencies, the results of the study will be useful to companies providing consulting to potential investors.

The results of the project will be disseminated at national and international conferences. One workshop will be organized to disseminate the results of the project by inviting stakeholders, including key decision makers, academic institutions, non-governmental organizations and the media.

The research results will be disseminated to other researchers in Kazakhstan through workshops and scientific reports; at least 2 master's theses will be prepared with topics related to the research direction of the project.

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