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DEVELOPMENT OF SUSTAINABLE ENERGY IN THE REPUBLIC OF KAZAKHSTAN BASED ON CIRCULAR ECONOMY MODELS

This article examines the theoretical and practical aspects of implementing a circular economy model for sustainable development in Kazakhstan's energy sector. The relevance of this study lies in the country's heavy dependence on fossil fuels, aging energy infrastructure, growing environmental pressures, and the global shift toward decarbonization and resource efficiency. In this context, traditional linear economic models no longer ensure long-term sustainability, making the transition to a circular approach a strategic priority.

The study's methodological framework is based on systematic, comparative, and analytical approaches. A literature review was conducted on the theoretical foundations of the circular economy and international experience in energy transition. A sectoral analysis of the current state of Kazakhstan's energy system, characterized by heavy dependence on fossil fuels, degrading infrastructure, and environmental pressures, was also conducted. A comparative analysis of five circular economy business models was conducted: closed-loop resource utilization, product life cycle extension, resource recycling, shared platforms, and product-as-a-service. Secondary statistical data from national and international sources were analyzed to identify structural trends. This synthetic method was applied to formulate a strategic direction for the transition to a circular economy. It was found that the transition to a circular economy can improve resource efficiency, reduce environmental impact, and enhance the competitiveness of the energy sector. Effective implementation requires an integrated approach at all levels of the energy system.

Keywords: *circular economy, linear economy, circular resource, recuperation, sharing platform, product life cycle, energy*

Кілт сөздер: *айналмалы экономика, сызықтық экономика, айналмалы ресурс, рекуперация, шерингтік платформа, өнімнің өмірлік циклі, энергетика.*

Ключевые слова: *циркулярная экономика, линейная экономика, циркулярный ресурс, рекуперация, шеринг-платформа, жизненный цикл продукта, энергетика*

Introduction. In the current global economic development, the energy sector is one of the main drivers of sustainable growth. However, the traditional linear economic model leads to excessive use of natural resources and environmental pollution, threatening the long-term sustainability of the energy system. This issue is especially relevant for the economy of Kazakhstan, which is dependent on hydrocarbon resources. In this regard, the introduction of the principles of a circular economy in the energy sector is an important issue from a scientific and practical point of view.

The purpose of the study: to identify the theoretical foundations of the development of the energy sector in the Republic of Kazakhstan based on circular economy models and to propose practical directions for its implementation.

To achieve this goal, the following tasks were set:

1. To determine the content of the concept of a circular economy;
2. To analyze the features of its application in the energy sector;
3. To assess the energy sector of Kazakhstan;
4. To propose directions for the introduction of circular models.

International scientific publications, statistical data and analytical reports related to the energy sector were used as research materials. System analysis, comparative analysis and review of scientific literature were used as research methods.

The results of the study demonstrate the strategic importance of introducing circular economy approaches in the energy sector of Kazakhstan, contributing to the efficient use of resources, waste reduction, and long-term sustainability of the sector.

Literature review. Over the past five years, the concept of a circular economy has been widely studied in the context of sustainable energy development. In the international scientific literature, this model is considered a key tool for efficient resource use and carbon reduction. A number of studies have shown that the introduction of circular approaches in the energy sector is achieved through the development of renewable energy sources, increasing energy efficiency and recycling waste.

Sai-Leng Ng and Chi-Yuan Chen reviewed the trends and future directions of research on the circular economy and energy transition [1], while Muhammad Tayyab Sohail, Sana Ullah, Sdra Sohail examined how the circular economy can contribute to energy security and the development of renewable energy sources [2]. De Xiao, Xiaotian Xu, Zehua Xu studied the impact of circular economy and energy storage technologies on reducing emissions and ensuring sustainable growth through an integrated approach [3]. S. Serhat Karakutuk and Sener Akpinar presented their research on the application of the circular economy approach in the design of energy-saving heat recovery systems [4], while Peruvian scientists studied the prospects of a circular economy in the integration of hybrid energy systems with mechanical storage technologies [5]. Researchers note that environmental and economic efficiency can be achieved by forming closed cycles in energy production, reusing industrial waste, and introducing energy storage technologies. In addition, it was found that the use of digital technologies (smart grids, data analysis) increases the flexibility and stability of energy systems.

Although the issues of sustainable development of the energy sector are considered in Kazakhstani scientific publications, the comprehensive implementation of circular economy models has not been sufficiently studied. A. Zhidebekkyzy et al. analyzed the general circular economy in the context of Kazakhstan [6], N. Zhaksybayeva et al. analyzed circular transformations in the circular business ecosystem in Kazakhstan [7].

As a result of a critical analysis of the literature, it was found that while foreign scientists have conducted comprehensive research on the energy sector and the circular economy, proposing practical and innovative solutions for increasing energy efficiency, waste recovery, and integrating renewable energy systems, Kazakh scientists have conducted research mainly at the theoretical and descriptive level. In addition, institutional support and investment aspects have not been fully studied. This indicates that while international studies have proven the high efficiency of circular models, institutional and technological limitations in developing countries, including Kazakhstan, hinder the full implementation of these models.

Thus, although the theoretical foundations of the introduction of circular economy models in the energy sector have been sufficiently studied, the issue of adapting them to the conditions of Kazakhstan has not been fully resolved. This situation justifies the need to continue research and determines the identification of effective directions for the introduction of circular economy models in the energy sector of the Republic of Kazakhstan as the main direction of this study.

Main part. Before analyzing the prospects for introducing a circular economy model, it is necessary to assess the current state of Kazakhstan's energy sector. The energy industry plays a vital role in the national economy, ensuring energy security, supporting industrial production, and generating substantial export revenue. At the same time, the sector remains highly dependent on traditional fossil fuels, posing challenges to both the economy and the environment.

Kazakhstan possesses substantial reserves of coal, oil, and natural gas, making fossil fuels the primary energy source. Coal continues to play a dominant role in power generation, accounting for the majority of the country's electricity. Oil and natural gas remain the main sources of export revenue and provide the necessary energy for industrial activities. This structure has historically provided a stable energy supply and economic growth; however, it has also led to high resource intensity and significant environmental impacts associated with greenhouse gas emissions and industrial waste generation.

In recent years, Kazakhstan has demonstrated an increasing commitment to sustainable development and energy diversification. One of the most significant trends is the gradual expansion of the use of renewable energy (RES). According to the Ministry of Energy, renewable energy generation reached approximately 6,68 billion kilowatt-hours in 2023, accounting for 5,92% of total electricity generation. This is a significant increase compared to previous years, reflecting the country's efforts to develop low-carbon energy and reduce its dependence on fossil fuels. Despite this, the overall contribution of renewable energy remains relatively modest compared to the dominance of coal-fired power generation. While

renewable energy development has made positive progress, several structural issues continue to constrain the efficiency and sustainability of the energy sector. One of the most significant issues is the aging of energy infrastructure. A large portion of power plants were put into operation during the Soviet era and have been running for decades. As of January 1, 2024, the average depreciation rate of major equipment at power plants reached approximately 56%, while more than one-third of power plants reported equipment wear and tear ranging from 70% to 90%. Fixed asset depreciation reduces operational efficiency, increases maintenance costs, and increases the likelihood of technical failures and emergency shutdowns.

Environmental issues are another critical concern. The dominance of coal-fired power plants makes a significant contribution to carbon dioxide emissions, air pollution, and environmental degradation. Furthermore, energy production processes generate substantial amounts of industrial waste, including ash and slag from thermal power plants. These byproducts are often unused and accumulate in landfills, posing additional environmental risks. In addition, inefficiencies in the extraction, processing, transportation, and consumption of energy resources lead to the avoidable loss of valuable materials and energy.

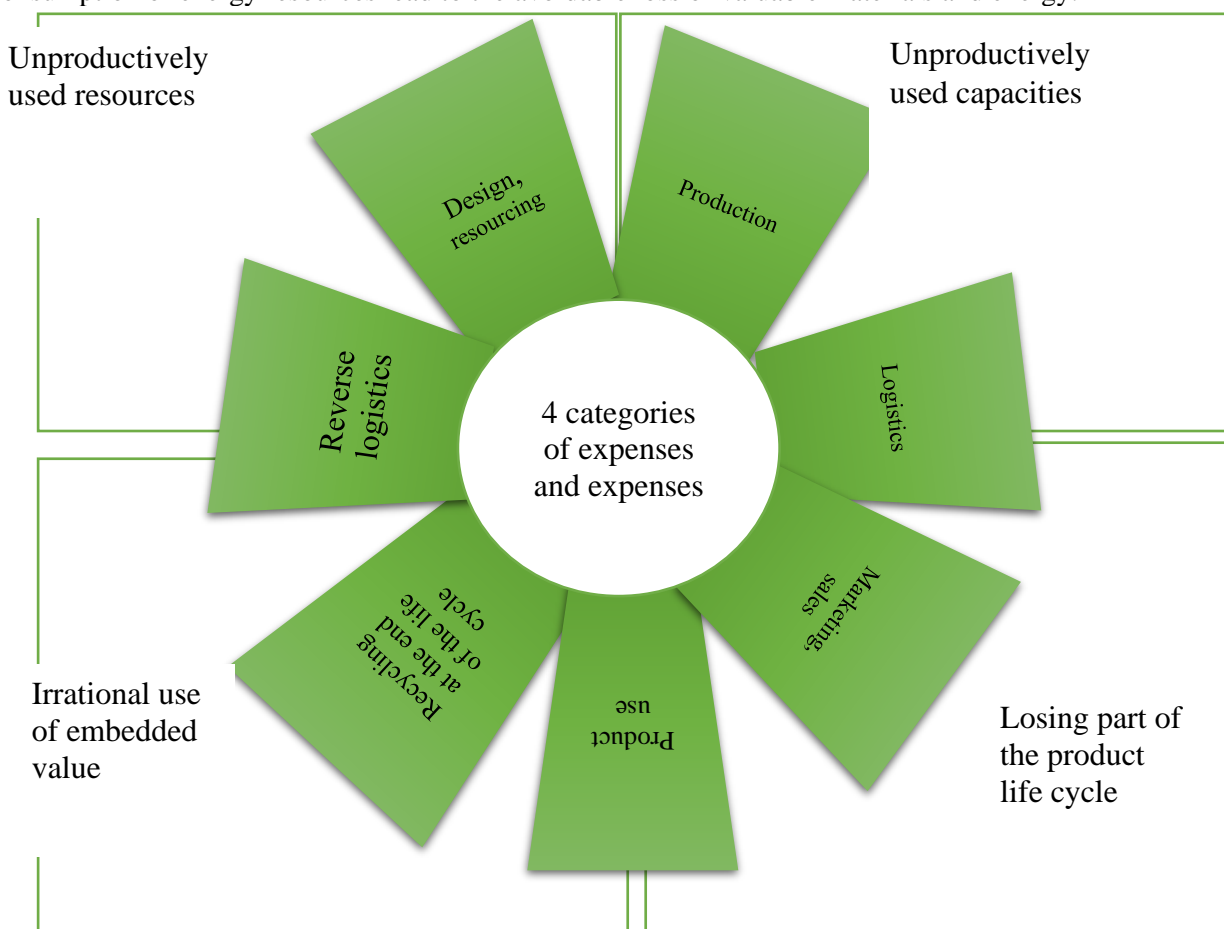


Figure – 1. **Four types of costs in a linear economy**

**Compiled by the authors based on the source [8]*

From a circular economy perspective, these issues highlight significant opportunities to improve resource efficiency and reduce waste generation. Circular approaches can promote the reuse and recycling of industrial byproducts, improve energy efficiency, extend the lifespan of infrastructure, and facilitate the integration of renewable energy. Therefore, the current state of Kazakhstan's energy sector clearly indicates a need to shift towards a more sustainable and resource-efficient development model. Introducing circular economy principles can thus be a crucial tool for enhancing the sector's economic sustainability, improving environmental performance, and long-term competitiveness. The identified structural and environmental problems indicate that the traditional linear model of resource use is becoming increasingly inefficient in Kazakhstan's energy sector. In a linear economy, resources are extracted, processed, consumed, and ultimately disposed of as waste, leading to significant economic and environmental losses. The costs primarily fall into four categories: inefficient resource use, energy loss, accumulation of industrial waste, and underutilization of assets (Figure 1).

The introduction of circular economy models in the energy sector of the Republic of Kazakhstan is currently one of the directions of strategic importance. Within the framework of the traditional linear model, four main categories of costs are formed that do not allow for maximum benefit (Figure 1): inefficient use of resources, energy losses, accumulation of industrial waste and underutilization of assets. In the case of Kazakhstan, these problems are especially pronounced in the coal-dependent power industry and the oil and gas sector. For example, since the majority of electricity is generated at coal-fired thermal power plants, energy efficiency remains low and carbon dioxide emissions remain at a high level.

One of the effective ways to solve these problems is the transition to a circular economy, which demonstrates that a fundamentally successful transition can be achieved by implementing five business models (Figure 2) [8].

These five main models contribute to the transition from the traditional linear economy of «take-produce-dispose» to a circular economy, reducing waste or even eliminating it, and preventing environmental pollution. Three business models (recycling, product lifecycle extension, resource recovery) are focused on production, while the other two (sharing platforms and product as a service) are focused on consumption and the relationship between the product and the consumer. This model has been recognized as effective by many government agencies and commercial companies over the past five years. In order to accelerate the transition to a circular economy through the implementation of these business models, it is necessary to make a significant effort and implement all five business models together to fully exploit the opportunities of circular business models at all stages of the value chain.

Circular business models integrate production and consumption, integrating the entire value chain. Production-oriented models include circular resources, extending the product life cycle, and resource recovery. Consumption-oriented models include sharing platforms and product-as-a-service. The use of environmentally friendly and renewable materials is important in the circular resource model. This approach allows you to reduce harmful and disposable resources. Extending the product life cycle is aimed at using it for as long as possible. To do this, it is necessary to design the product so that it is easy to repair and upgrade. The sharing and product-as-a-service models allow you to use the service, not the product itself. At the end of the life cycle, materials are re-used by recovering resources. Thus, these models combine to form a waste-free and efficient economic system.

The use of renewable, recyclable, or recyclable materials in the production process reduces waste and reduces environmental damage. The circular resource model is one of the most widespread business approaches today. To implement it, it is necessary to replace the traditional linear resource use system with a closed, reuse-based system. In this model, it is important to use renewable resources, such as solar, wind or water resources. In addition, specially designed materials allow for multiple recycling. In the short and medium term, companies need to determine which resources are most cost-effective to replace. In the long term, the main goal is to move to a waste-free, closed-loop production system. This requires close cooperation with partners from various industries.

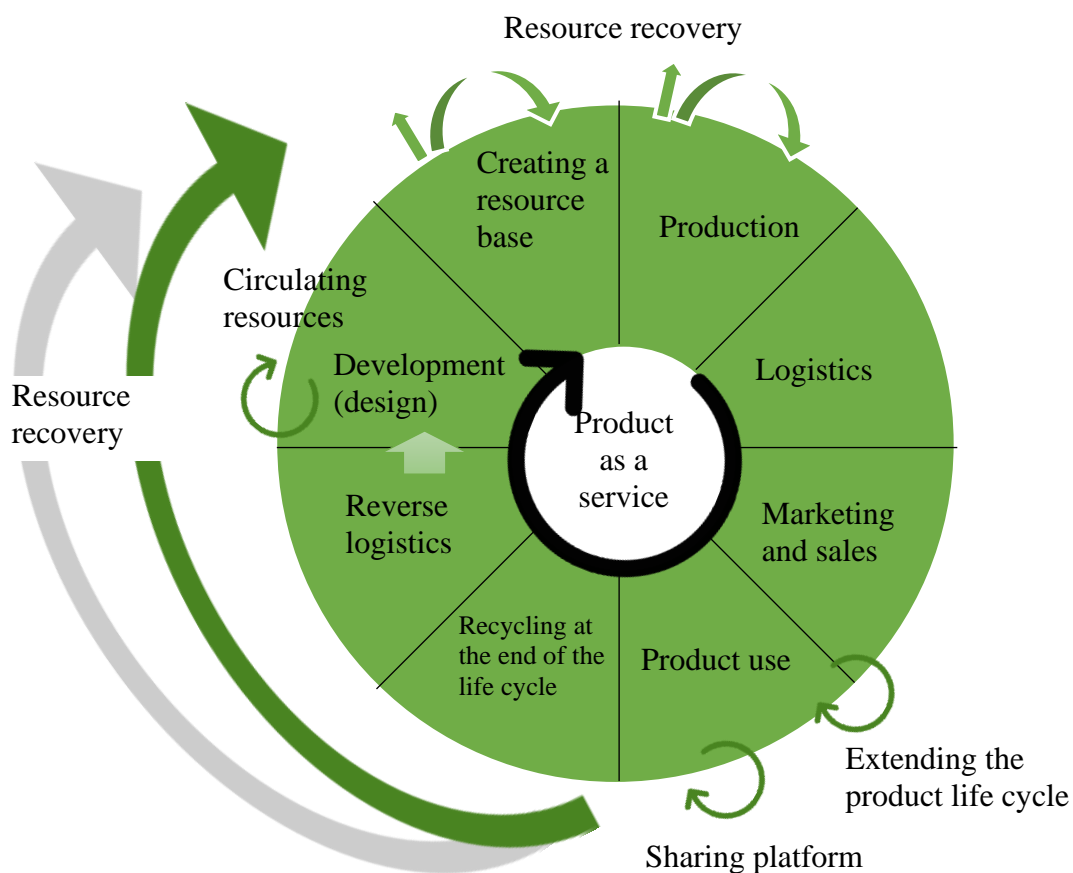


Figure – 2. Value chain and five business models
 *Compiled by the authors based on the source [8]

The model of revolving resources can be implemented in the energy sector of Kazakhstan through the development of renewable energy sources. Since the main part of electricity in the republic is currently produced at traditional coal-fired power plants, it is important to increase the share of wind and solar energy. The natural and climatic features of Kazakhstan, especially the high wind potential in regions such as the Dzungarian Gate and the Shelek corridor, as well as the high level of solar radiation, create favorable conditions for the development of this direction [9]. However, there are obstacles to the introduction of renewable energy sources, such as insufficient development of infrastructure, the high cost of energy storage technologies, and investment risks. The model of extending the life cycle of products is of particular importance in the power sector of Kazakhstan. Many thermal power plants and energy infrastructure facilities in the country have been used for a long time and are physically and morally worn out. As of January 1, 2024, the wear and tear of major equipment at power plants reached 56.8%, with more than a third of the plants being worn out within 70-90%. The highest level of wear and tear is observed at CHP and MAES. At 14 power plants, more than 80% wear and tear was recorded, and at 21 power plants, the wear rate varied from 60% to 80%. This is directly related to the high accident rate, since most accidents occur at plants with wear and tear exceeding 80% [10]. In this regard, it is necessary to extend the service life of equipment by modernizing it, introducing digital monitoring systems, and systematically carrying out repairs. In addition, the introduction of modular and repairable technologies increases the efficiency of this model.

The resource recovery model is aimed at obtaining raw materials or energy from it again at the end of the product's life cycle. For this, waste collection, sorting, and recycling technologies are used. The main goal is to preserve the value of materials for as long as possible. This model has great potential in the oil and gas sector of Kazakhstan.

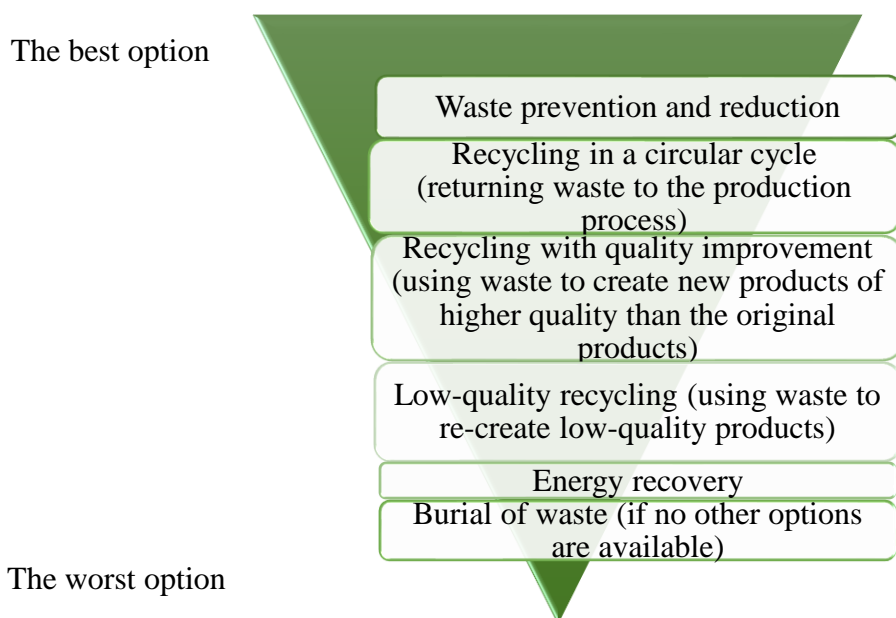


Figure – 3. **Waste hierarchy in a circular economy**

**compiled by the authors*

This is especially evident in the oil and gas sector, since the volume of associated petroleum gas in large fields is quite high. In particular, in large fields such as Tengiz, Kashagan and Karachaganak, associated gas generated during production was previously often flared or released into the atmosphere, causing environmental and economic losses [11], but now a significant part of it is injected back into the reservoir and used to increase the efficiency of oil production. This approach allows you to avoid wasting resources and increase production efficiency. In 2022, about 1.1 billion m³ of gas was lost due to flares and release into the atmosphere, which is about 2% of Kazakhstan's gas production [12].

In addition, the introduction of carbon capture and storage (CCUS) technologies will allow reducing carbon emissions. Many companies are already implementing the process of extracting useful resources from waste (Figure 3). This does not require major changes, so it is relatively easy to implement. However, the issues of increasing the volume and improving the quality of recycling are still relevant. In addition, the lack of waste sorting and infrastructure development hinders. In general, this model allows saving resources and increasing environmental sustainability. Sharing platforms allow increasing the efficiency of products and assets by sharing them. This model is often implemented using digital technologies and provides affordable and convenient services to consumers.

The sharing platform model can be implemented in the conditions of Kazakhstan mainly through the joint use of production and energy infrastructure. For example, in industrial zones (Atyrau, Mangistau), the development of the practice of using shared energy facilities by several enterprises allows for the efficient allocation of resources and cost reduction. This model is especially beneficial for small and medium-sized businesses, as they can access the necessary resources without investing separately in expensive energy equipment. In addition, the development of the sharing economy in the country is being studied at a scientific level, for example, studies conducted at the D. Serikbayev East Kazakhstan Technical University show that this model is considered an important tool for achieving sustainable development goals, contributing to efficient use of resources and decarbonization [13]. Some elements of this model are also observed in the energy sector. The electricity market in Kazakhstan has a decentralized structure, where many private companies are engaged in the production of electricity, and consumers can choose from different suppliers [14]. Such a market structure allows for the sharing of resources and the efficient

distribution of energy between different participants, which is consistent with the principles of the sharing economy.

The Product-as-a-Service model can be introduced in the energy sector through energy service companies (ESCO). In this case, companies provide services to improve energy efficiency and earn income from the savings received. Although this direction is still developing in Kazakhstan, its potential is high, and there is real institutional support. For example, the United Nations Development Programme has implemented projects to introduce ESCO mechanisms and develop financing instruments in Kazakhstan. In particular, one of the first factoring transactions was carried out to finance energy service contracts, which gave impetus to the development of this market [15].

The process of transition to a circular economy in the Republic of Kazakhstan is closely related to technological factors. If in 2015 10 key technologies were considered for the development of a circular economy, now their number has increased to 27, which indicates the rapid development of digital and industrial transformation. Among the 27 technologies, there are artificial intelligence, machine learning, cloud computing, machine vision, Big Data, IoT, machine-to-machine communication, mobile devices, blockchain, digital anchors, digital twins, 3D printing, robotics, energy storage and use, energy harvesting and conversion, nanotechnologies, spectroscopy, physical markers, AR/VR, carbon capture and storage, material science, bioenergy, bio-based materials, genetic engineering, DNA markers, cell and tissue engineering, hydroponics and aeroponics. In the case of Kazakhstan, among these technologies, the Internet of Things (IoT), Big Data, artificial intelligence and digital twins are of particular importance, as they allow for the modernization of energy infrastructure and efficient resource management.

Table 1 shows that the five circular economy models are not uniformly applied across all energy sectors. In the oil and gas industry, the greatest potential lies in resource extraction through the use of relevant oil and gas and carbon capture technologies, while shared platforms facilitate more efficient use of transportation and storage infrastructure. In the power sector, the extension of circular resource and product lifespan is particularly important due to the need to introduce renewable energy and modernize aging power generation assets. Product-as-a-service models and shared platforms can be implemented in both sectors through energy service companies and infrastructure cooperation agreements. Therefore, each energy sector is characterized by different combinations of circular business models that reflect its technological and operational characteristics.

Table – 1

Industries and focuses of circular transformation in energy

№	Industry	Description	Rotating transformation focus
1	Oil and Gas Industry	Resource Recovery	Utilization of associated petroleum gas, gas injection into reservoirs, waste recovery, and CCUS technology.
2	Oil and Gas Industry	Sharing Platform	Shared use of pipelines, warehousing facilities, logistics and industrial infrastructure
3	Oil and Gas Industry	Product-as-a-Service	Energy service contracts, industrial energy management services
4	Electric Power Industry	Circular Resources	Develop renewable energy sources (wind, solar, hydropower)
5	Electric Power Industry	Product Life Extension	Centre for Health Protection factory modernization, predictive maintenance, digital monitoring system
6	Electric Power Industry	Sharing Platform	Shared energy infrastructure, decentralized electricity market
7	Electric Power Industry	Product-as-a-Service	ESCO Project, Energy Efficiency Services
8	Electric Power Industry	Resource Recovery	Recycling industrial waste and recovering materials from decommissioned equipment

**Compiled by the authors*

For example, the introduction of sensors and automated systems in energy facilities will increase the ability to monitor energy consumption in real time and reduce costs. In addition, blockchain and RFID

technologies will provide transparency in monitoring oil, gas and electricity flows, creating conditions for effective monitoring of resource movements.

In Kazakhstan, the circular economy is developing unevenly in different sectors, but the energy sector is one of the strategic priorities (Table 1).

The oil and gas industry, forming the basis of the national economy, includes the stages of exploration, production, transportation and processing, and at each of these stages the issue of efficient use of resources is relevant. The main focus of the circular transformation in this sector is related to the energy transition, that is, the gradual reduction of dependence on hydrocarbons, the efficient use of associated gas and the reduction of carbon emissions. In the power sector, the main focus is on increasing the efficiency of energy production and supply, as well as the widespread introduction of renewable energy sources. Since the majority of electricity in Kazakhstan is generated at coal-fired power plants, the energy transition is a very important strategic task for this sector.

The circular economy opens up new financial opportunities for companies and offers three main ways to create value: increasing profits, reducing costs and migrating value. Reducing costs is the most common and effective approach, as it allows you to save resources and increase production efficiency. And creating new sources of income is more difficult, since consumers are not always ready to pay extra for circular products and the competition in the market is high. Value migration refers to the transfer of profits from one company or industry to another, and in some cases, it blurs the boundaries between industries. Circular initiatives are implemented in seven main areas: pricing, brand development, new business models, product redesign, resource provision, forecasting, and production optimization. The first three areas are aimed at increasing profits, while the rest help reduce costs. By changing product design, less raw materials are consumed, and the right use of resources increases production efficiency. Forecasting and logistics reduce excess inventory and waste, and energy and water conservation in production play an important role.

Table – 2

Value intensity map of circular initiatives across 2 sectors and areas in energy

№		Circular initiatives	Oil and gas industry	Electric power industry
1	Income	A roundabout approach to premiumizing products – pricing power		
2		Turnover as brand value – market share		
3		Resale, restoration, repair, recycling of revolving business models		
4	Costs	Circular development – using fewer resources		
5		Circular forecast – undersupply		
6		Circulating resources – more efficient purchasing		
7		«Smart» operations - more efficient execution		
		Not significant impact		
		Low: less than 10 percent of total impact		
		Medium: 10-20 percent of total impact		
		High: more than 20 percent of total impact		

**compiled by the authors*

In the case of Kazakhstan, especially in the energy sector, the greatest potential is in the direction of cost reduction. High production costs in the oil and gas and electricity sectors allow for significant economic efficiency through resource conservation, increased energy efficiency, and waste recycling. However, initiatives aimed at increasing profits, such as premium pricing for «green» energy, are still limited in Kazakhstan, due to the incomplete formation of consumer solvency and market mechanisms. The data presented in Table 2 show that the impact of circular economy initiatives on value creation in the energy sector is uneven, and their main impact is often through cost reduction rather than revenue enhancement. In comparison with the oil and gas and power sectors, it is noticeable that the impact of areas that affect revenue is limited, while the impact of measures aimed at increasing operational efficiency is much higher. Among the initiatives aimed at increasing revenue, circular approaches to premiumizing products are less effective in the oil and gas sector, since products in this sector are standardized and their prices are determined by the international market. In the power sector, on the other hand, consumer demand for environmentally friendly products, especially electricity generated from renewable energy sources, is increasing, allowing for a certain level of price premium.

In general, the analysis conducted shows that the introduction of circular economy models in the energy sector of Kazakhstan should be carried out in a systematic and comprehensive manner, and not in a fragmented or individual way. This means that the circular transformation should not be limited to the introduction of individual technologies or the initiatives of individual enterprises, but rather should be considered as a set of interconnected and coordinated changes that include all stages of the value chain.

Conclusion. The introduction of circular economy models in the energy sector of the Republic of Kazakhstan is currently one of the strategically important directions. In the conditions of a traditional linear economy, four main categories of losses are observed: inefficient use of resources, energy losses, accumulation of industrial waste and underutilization of assets. These problems are especially pronounced in the coal-dependent power industry and the oil and gas sector. For example, since the majority of electricity in the country is generated at coal-fired thermal power plants, energy efficiency and carbon dioxide emissions remain at a high level. Such conditions clearly indicate the need to transition to a circular economy.

The circular economy includes five main business models: circular resources, extending the product life cycle, resource recovery, sharing platforms and providing products as a service. These models cover production and consumption, allowing for efficient use of resources and waste reduction at all stages of the value chain. Production-oriented models (recycling, extending the life cycle of products, resource recovery) ensure environmental sustainability by saving energy and materials, extending the service life of equipment, and recycling waste. Consumption-oriented models (sharing platforms, providing products as a service) are aimed at the most efficient allocation of resources and providing convenient services to consumers.

The implementation of these models is of great practical importance for the energy sector in Kazakhstan. The use of associated gas processing and carbon capture technologies in the oil and gas sector reduces production costs and reduces environmental damage. The widespread introduction of renewable energy sources and infrastructure modernization in the power industry will increase energy efficiency. In addition, digital technologies - IoT, Big Data, artificial intelligence and digital twins - are effective tools for the optimal allocation of resources and cost reduction in energy infrastructure management.

In general, the transition to a circular economy in Kazakhstan should be implemented systematically. This should not be limited to the introduction of individual technologies or individual initiatives of enterprises, but should be considered as a coordinated transformation that includes all stages of the value chain. Only this approach will allow us to save resources, increase production efficiency, ensure environmental sustainability, and achieve long-term economic efficiency.

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ЭКОНОМИКАНЫҢ АЙНАЛМАЛЫ МОДЕЛЬДЕРІ НЕГІЗІНДЕ ҚАЗАҚСТАН РЕСПУБЛИКАСЫНДА ТҰРАҚТЫ ЭНЕРГЕТИКАНЫ ДАМУ

Аңдатпа

Мақалада Қазақстанның энергетикалық секторында тұрақты даму үшін айналмалы экономика моделін енгізудің теориялық және практикалық аспектілері қарастырылады. Зерттеудің өзектілігі елдің қазба отынына жоғары тәуелділігімен, энергетикалық инфрақұрылымның ескіруімен, қоршаған ортаға әсердің артуымен және декарбонизация мен ресурстарды тиімді пайдалануға жаһандық көшуімен анықталады. Осы тұрғыда дәстүрлі сызықтық экономикалық модельдер ұзақмерзімді тұрақтылықты кепілдендірмейді, бұл айналмалы тәсілге көшуді стратегиялық басымдыққа айналдырады. Зерттеудің әдіснамалық негізі жүйелі, салыстырмалы және аналитикалық тәсілдерге негізделген. Айналмалы экономиканың теориялық негіздері және энергетикалық көшудегі халықаралық тәжірибе бойынша әдебиеттерге шолу жүргізіледі. Қазба отынына жоғары тәуелділікпен, инфрақұрылымның тозуымен және қоршаған ортаға әсер ететін қысыммен сипатталатын Қазақстанның энергетикалық жүйесінің қазіргі жағдайына салалық талдау да ұсынылады. Сондай-ақ, бес айналмалы экономика бизнес моделінің салыстырмалы талдауы жүргізіледі: тұйықталған циклді ресурстарды пайдалану, өнімнің өмірлік циклін ұзарту, ресурстарды қайта өңдеу, ортақ платформалар және өнім қызмет ретінде. Құрылымдық үрдістерді анықтау үшін ұлттық және халықаралық көздерден алынған қайталама статистикалық деректер талданды. Бұл синтетикалық әдіс айналмалы экономикаға көшудің стратегиялық бағытын қалыптастыру үшін қолданылды. Айналмалы экономикаға көшу ресурстарды тиімді пайдалануды жақсарту алатыны, қоршаған ортаға әсерді азайта алатыны және энергетика секторының бәсекеге қабілеттілігін арттыра алатыны анықталды. Тиімді енгізу энергетика жүйесінің барлық деңгейлерінде кешенді тәсілді қажет етеді.

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**РАЗВИТИЕ УСТОЙЧИВОЙ ЭНЕРГЕТИКИ В РЕСПУБЛИКЕ КАЗАХСТАН НА ОСНОВЕ
МОДЕЛЕЙ ЦИРКУЛЯРНОЙ ЭКОНОМИКИ**

Аннотация

В статье рассмотрены теоретические и практические аспекты внедрения модели циркулярной экономики для устойчивого развития в энергетическом секторе Казахстана. Актуальность исследования обусловлена высокой зависимостью страны от ископаемого топлива, старением энергетической инфраструктуры, растущим экологическим давлением и глобальным переходом к декарбонизации и ресурсоэффективности. В этом контексте традиционные линейные экономические модели больше не гарантируют долгосрочной устойчивости, что делает переход к циркулярному подходу стратегическим приоритетом. Методологическая основа исследования базируется на систематическом, сравнительном и аналитическом подходах. Проведен обзор литературы по теоретическим основам циркулярной экономики и международному опыту энергетического перехода. Также проведен отраслевой анализ текущего состояния энергетической системы Казахстана, характеризующейся высокой зависимостью от ископаемого топлива, деградацией инфраструктуры и экологическим давлением. Проведен сравнительный анализ пяти бизнес-моделей циркулярной экономики: замкнутый цикл использования ресурсов, продление жизненного цикла продукта, переработка ресурсов, общие платформы и продукт как услуга. Для выявления структурных тенденций проанализированы вторичные статистические данные из национальных и международных источников. Данный синтетический метод применен для формулирования стратегического направления перехода к циркулярной экономике. Установлено, что переход к циркулярной экономике может повысить эффективность использования ресурсов, снизить воздействие на окружающую среду и повысить конкурентоспособность энергетического сектора. Эффективная реализация требует комплексного подхода на всех уровнях энергетической системы.

