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Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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TRANSFORMATION OF INDUSTRIAL ENTERPRISES IN THE COUNTRIES WITH TRANSITIONAL ECONOMIES: THE DIGITAL ASPECT

Abstract. The relevance of the study is conditioned by the growing role of the fuel and energy complex of emerging markets in the economy decarbonization. Having identified sustainable development as one of the key priorities, Kazakhstan has set the goal to achieve carbon neutrality by 2060. In the context of the designated energy transition, the features of industrial enterprises transformation with the use of digital technologies are being updated as the most important tool for increasing efficiency in the face of increasing competition in the global market of mineral raw materials.

The main sources of information for the study: available statistical data of the Organization for Economic Cooperation and Development (OECD), the international energy agency IEA, audit companies PwC and KPMG, the monitoring project in the Ranking.kz ranking format, information and analytical material of the Bureau of National Statistics of the Agency for Strategic Planning and reforms of the Republic of Kazakhstan, publications in scientific journals. The well-known practices of economic analysis are applied to the assessment of the digital activity of enterprises.

The features of transformation of industrial enterprises in the context of the economy long-term decarbonization are considered. It has been shown that one of the leading areas of innovation policy in the industrial sector is digital transformation aimed at diversifying the fuel balance of the electric power industry and reducing the share of coal generation. It has been established that, despite the emerging progress in the digitalization of industry, most enterprises have a low potential for transition to a new technological paradigm. The factors hindering digitalization and the growth of innovative and investment attractiveness of enterprises have been identified. It has been substantiated that acceleration of the digital transformation of enterprises in the new energy era requires institutional transformations, coordinated cooperation between the state and business as equal partners.

The conclusions and proposals of the study can be used in the development of a digital development strategy by industrial enterprises of Kazakhstan and the adoption of measures for the scientific and technological development of industry in the countries with transitional economies.

Key words: transitional economy, Kazakhstan, decarbonization, digitalization, mining sector, industrial enterprise.

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ӨТПЕЛІ ЭКОНОМИКАСЫ БАР ЕЛДЕРДЕГІ ӨНЕРКӘСІПТІК КӘСІПОРЫНДАРДЫҢ ТРАНСФОРМАЦИЯСЫ: ЦИФРЛЫҚ АСПЕКТ

Аннотация. Зерттеудің өзектілігі экономиканы декарбонизациялаудағы дамушы нарықтардың отын-энергетикалық кешенінің рөлінің артуына байланысты. Тұрақты дамуды негізгі басымдықтардың бірі ретінде анықтай отырып, Қазақстан 2060 жылға қарай көміртегі бейтараптығына қол жеткізу мақсатын қойды, белгіленген энергетикалық көшу контекстінде минералды шикізаттың жаһандық нарығында өсіп келе жатқан бәсекелестік жағдайында тиімділікті арттырудың маңызды құралы ретінде цифрлық технологияларды қолдана отырып, өнеркәсіптік кәсіпорындарды трансформациялау ерекшеліктері өзектендіріледі.

Зерттеуге арналған ақпараттың негізгі көздері: экономикалық ынтымақтастық және даму ұйымының (ЭЫДҰ), IEA халықаралық энергетикалық агенттігінің, PwC және KPMG аудиторлық компанияларының, Ранкинг форматындағы мониторинг жөніндегі жобаның қолжетімді статистикалық деректері Ranking.kz, Қазақстан Республикасы Стратегиялық жоспарлау және реформалар агенттігінің ұлттық статистика бюросының ақпараттық-талдамалық материалы, ғылыми журналдарда жарияланымдар. Кәсіпорындардың сандық белсенділігін бағалауға Экономикалық талдаудың танымал тәжірибелері қолданылады.

Экономиканың ұзақ мерзімді декарбонизациясы аясында өнеркәсіптік кәсіпорындардың өзгеру ерекшеліктері қарастырылады. Өнеркәсіптік сектордағы инновациялық саясаттың жетекші бағыттарының бірі электр энергетикасының отын теңгерімін әртараптандыруға және көмір генерациясының үлесін төмендетуге бағытталған цифрлық трансформация болып табылатыны көрсетілген. Өнеркәсіпті цифрландыруда байқалған прогреске қарамастан, көптеген кәсіпорындардың жаңа технологиялық жолға көшу үшін әлеуеті төмен екені анықталды. Цифрландыруға және кәсіпорындардың инновациялық - инвестициялық тартымдылығының

өсуіне кедергі келтіретін факторлар анықталды. Жаңа энергетикалық дәуірдегі кәсіпорындарды цифрлық түрлендіруді жеделдету институционалды қайта құруды, тең серіктес ретінде мемлекет пен бизнестің үйлесімді ынтымақтастығын қажет етеді.

Зерттеу қорытындылары мен ұсыныстары Қазақстанның өнеркәсіптік кәсіпорындарының цифрлық даму стратегиясын әзірлеуі және өтпелі экономикасы бар елдердің өнеркәсібін ғылыми-техникалық дамыту жөнінде шаралар қабылдауы кезінде қолданылуы мүмкін.

Түйінді сөздер: өтпелі экономика, Қазақстан, декарбонизация, цифрландыру, тау-кен өндіру секторы, өнеркәсіптік кәсіпорын.

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ТРАНСФОРМАЦИЯ ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЙ В СТРАНАХ С ПЕРЕХОДНОЙ ЭКОНОМИКОЙ: ЦИФРОВОЙ АСПЕКТ

Аннотация. Актуальность исследования обусловлена возрастающей ролью топливно-энергетического комплекса развивающихся рынков в декарбонизации экономики. Определив устойчивое развитие как один из ключевых приоритетов, Казахстан поставил цель достичь углеродной нейтральности к 2060 г. В контексте обозначенного энергетического перехода актуализируются особенности трансформации промышленных предприятий с применением цифровых технологий как важнейшего инструмента роста эффективности в условиях нарастающей конкуренции на глобальном рынке минерального сырья.

Основные источники информации для исследования: доступные статистические данные Организации экономического сотрудничества и развития (ОЭСР), международного энергетического агентства IEA, аудиторских компаний PwC и KPMG, проекта по мониторингу в формате рэнкингов Ranking.kz, информационно-аналитический материал Бюро национальной статистики Агентства по стратегическому планированию и реформам Республики Казахстан, публикации в научных журналах. К оценке цифровой активности предприятий применены общеизвестные практики экономического анализа.

Рассмотрены особенности трансформации промышленных предприятий в контексте обозначенной на долгосрочный период декарбонизации экономики. Показано, что одним из ведущих направлений инновационной политики в промышленном секторе является цифровая трансформация, нацеленная на диверсификацию топливного баланса электроэнергетики и снижение доли

угольной генерации. Установлено, что, несмотря на наметившийся прогресс в цифровизации промышленности, большинство предприятий имеют низкий потенциал для перехода на новый технологический уклад. Выявлены факторы, препятствующие цифровизации и росту инновационно - инвестиционной привлекательности предприятий. Обосновано, что ускорение цифровой трансформации предприятий в новой эпохе энергетики требует институциональных преобразований, координированного сотрудничества государства и бизнеса как равноправных партнеров.

Заклучения и предложения исследования могут найти применение при разработке промышленными предприятиями Казахстана стратегии цифрового развития и принятия мер по научно-техническому развитию промышленности стран с переходной экономикой.

Ключевые слова: переходная экономика, Казахстан, декарбонизация, цифровизация, горнодобывающий сектор, промышленное предприятие.

Introduction. The world's leading mining and energy companies are actively investing in digital solutions and have now reached a new level of transformation. Kazakhstan that takes the 10th place in the world in terms of energy intensity of production, a significant part of which falls on the mining complex, also participates in the formation of global demand for fossil energy resources (Environmental Code, 2021; Decree of the Government of the Republic of Kazakhstan, 2020; Association KAZENERGY, 2020), supports the policy of developing countries seeking to contribute to achieving sustainability (*Tienhaara*, 2006:6; *Kasatuka and Minnitt*, 2006:12; *Nilsson et al.*, 2018; *Campbell*, 2012).

The Kazakhstan course towards carbon neutrality involves accelerated modernization and construction of new capacities of the fuel and energy complex, the digital transformation of which is the key tool for increasing efficiency in the face of growing competition and tightening environmental requirements. The mining sector plays the key role in Kazakhstan adaptation of the CRIRSCO principles and the transition from the economic model based on carbon-intensive export products, environmentally negative and energy-intensive processes to an inclusive, “human-centric” economic model. The progress of the extractive industries requires, on the one hand, effective measures of state support, and, on the other hand, involvement in the implementation of the national strategy for low-carbon business development, which should become the main driver of digitalization.

The state is focused on developing a long-term comprehensive program of the energy industries development. It is necessary to develop high-level information technology platforms for the mining and metallurgical complex, to improve investment conditions in the energy sector in order to ensure the flow of private investment throughout the entire period of energy transition. The geological exploration program is being updated that is aimed at finding new oil and gas fields with the involvement of investors and provision of the necessary fiscal and non-fiscal measures of state support (Decree of the Government of the Republic of Kazakhstan, 2020; State Program “Digital Kazakhstan”,

2017). In the designated documents, the central place is given to modernization of industrial enterprises using digital technologies and taking into account ESG (Environmental, Social, and Corporate Governance) factors, building an infrastructure for digital interaction of all the subjects of industrial production at the intersectoral level. In the future, digital transformation should increase the investment attractiveness of backbone enterprises, develop flexible and highly efficient network production based on digital platforms that unite all the participants in the value chain into a single ecosystem.

Taking into account the desire of industrial enterprises for digitalization that determines the scenarios for their competitiveness in the global market of mineral raw materials, the growing role of the mining and energy sectors in the economy of Kazakhstan decarbonization, the authors set the goal to identify the features of the mining and energy sectors of the economy of Kazakhstan enterprise transformation in the context of the ongoing processes of their digital transformation.

Literature review. In this study there are used the key provisions of the concept of innovation systems used in studying industrial technological development (Malerba, 2002; *Arjune et al.*, 2021).

At the moment, the extensive world experience has been accumulated that reveals the relationship between the new technological order, the transformation of the labor market (Ghobakhloo and Fathi, 2020:1), the growing role of man in the innovation process (Campbell et al., 2012:3; Amrin and Nurlanova, 2020:2). Relevant studies reveal the impact of digitalization on newly created jobs (Arntz et al., 2017; Lahera Sánchez, 2019:2), the impact of robots on the final results of enterprises and the importance of unmanned technologies (David, 2015:3).

The OECD studies that summarize the effectiveness of the digital transformation of enterprises and confirm the need for an integrated approach to considering the features of digitalization of business processes are of greatest interest now. The analysis of the intensity of introducing digital technologies in various regions of the world shows that most industries are characterized by the average and high level of their distribution (OECD, 2019).

The advantages of systemic digital transformation of the leading countries is demonstrated by studying the specifics of industrial decarbonization (Adeyemi et al., 2020), the effectiveness of using current energy management systems (Di Vaio et al., 2021; Menzel and Teubner, 2021:15), the rationale for the need for systemic assessments of the digital technologies impact on the power engineering development (IEA, 2020).

The attention of scientists is drawn to the features of transformation of the mining sector to the new digital conditions in emerging markets and the assessment of risks that enterprises take on when developing the possibilities of autonomous control, digital infrastructure and new technologies. The possibilities of developing a database using high technologies including all the elements of an integrated chain from geological exploration to logistics are being explored (Gellweiler and Krishnamurthi, 2020:1; Li et al., 2021; Yang et al., 2020). It is discussed how digitalization changes the existing industry architecture of interaction between participants in various segments of the fuel and energy complex (Setiawan et al., 2019:2; Young and Rogers, 2019). From the

viewpoint of entering the stage of the fourth energy transition to the widespread use of renewable energy sources, digital transformation of the oil and gas sector and the coal industry is being studied, and optimization of the production chain from extraction to supply of resources to the consumer is evaluated (*Barnewold and Lottermoser, 2020:6*).

Unfortunately, the scientific community has not yet developed a common understanding of transformation of industrial enterprises specifics, the use of the digitalization potential they have accumulated to increase efficiency along the entire value chain. There are no empirical models for transformation of industrial enterprises in Kazakhstan in the context of transition to a higher level of innovation. The foregoing confirms the relevance and necessity of a comprehensive study of the identified problem for countries with transitional economies and Kazakhstan in particular.

Materials and basic methods. The main sources of information for the study were the available statistical data of the OECD, the International Energy Agency IEA, the PwC and KPMG audit companies, the monitoring project in the ranking format Ranking.kz, the information and analytical materials of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, publications on the designated topics in scientific journals, the authors' own research. Despite an acute lack of empirical data, well-known practices of economic analysis were applied to assess the digital activity of industrial enterprises in Kazakhstan.

Current state of industrial enterprises digitalization in Kazakhstan. The backlog of Kazakhstan from the leading countries in the development of technologies that form a new industrial revolution remains critical. Given a high level of state presence in the basic sectors of the economy, the technological transformation of state-owned enterprises and the transformation of large enterprises with state participation into the determining force of the new technological revolution, their transformation into competitive international companies are being updated. The export-oriented nature of the economy, the predominant share of the raw materials sector and high prices for mineral resources constrain digitalization, since a part of the mining enterprises' income from exports belongs to foreign investors who finance them.

The scientific and technological paradigm supported by the state is called upon to rebuild the economy on the basis of new technological solutions. As part of the technological re-equipment of basic industries until 2025 and the development of new approaches to the extraction of solid minerals, a set of regulatory and incentive measures has been developed to modernize industries based on scaling up new technologies and developing markets for a high-tech economy. In particular, it provides for 40% increasing the amount of reimbursement of costs for IT solutions; industrial grants for technological modernization of production by co-financing; tax preferences that encourage enterprises to digitalize, especially with the use of domestic digital technologies that allow transforming the activities of an enterprise through new business models, increasing the value of products and strengthening competitive positions.

However, state regulation of the information technology promotion does not solve the problem of technological transformation of industrial sectors in full. Despite the numerous tools of state policy, it should be stated that the effectiveness of the

management system for scientific and technological development remains a challenge for the country. According to the authors, there is a lack of concentration on the removal of regulatory barriers, providing domestic enterprises with access to relevant markets and demanded initial data, high-quality organizational and economic mechanisms that stimulate the development of digital solutions, taking into account the industry specifics of enterprises.

Since industrial enterprises of Kazakhstan include industries with different parameters (business models, place in the value chain, technological level, readiness for change, infrastructure, features of the formation and use of data), a differentiated approach is required from the state to stimulate their innovative growth. It is to be followed from the sequence of passing through certain stages of introducing digital technologies in order to achieve full-fledged “digital maturity”, reducing the capital intensity of production and accelerating the adaptation to changing market conditions. The situation is exacerbated by the need to introduce simultaneously interconnected digital technologies, such as PLM, MES and ERP systems, into production with a large number of conversions and multiple integration of the final product.

For enterprises, the infrastructure availability for embedding new technologies into the existing processes is important, especially given the limited development of digital technologies and the growing need for them with the start of mining operations. The emphasis is on specific IT-technologies designed to solve problems for a given type of mineral deposit, methods of its development, geotechnical problems, and complexities of rock massifs.

The approach to evaluating the effectiveness of digital transformation deserves special attention, which involves comparing costs across all the technological chains of production, transport, transformation and consumption of resources in each industry. This is, firstly, the calculation of the capital and operating costs of an enterprise for the creation of new technologies that expand the technical potential of their application (for example, technologies for the development of hard-to-reach mineral deposits); secondly, capital costs for the digitalization of production and technological process control objects, their achievement of high levels of complexity, the technical equipment of the infrastructure, the costs of end users of resources (mainly electricity and gas).

As a result, there should be developed regulatory, market, and tax mechanisms for managing the system of support for new innovation and investment areas, taking into account, on the one hand, losses for both enterprises and consumers, and, on the other hand, justifying the effect for the fuel and energy complex and the economy of the country as a whole.

Within 2016-2020 the real GDP growth in Kazakhstan amounted to 49.3%, while the share of the mining and oil and gas industries that occupy almost 50% of the total industry, decreased by 3% in the GDP. The volume of the enterprises production increased by 24.9%. In 2020, the mining industry formed 12.2% of the country’s GDP, about 50% was allocated to it in the industrial structure, the annual economic effect from the use of digital technologies was estimated at \$ 9 billion. The dynamics of industry is directly related to changes in prices for oil and metals, the level of demand for energy resources. Currently,

almost all the mining productions have a 10-15% potential for increasing efficiency and reducing the cost of mining operations (Information agency Strategy2050.kz, 2021).

In order for digital transformation to accelerate the fuel and energy complex decarbonization, to develop decentralized energy systems and to improve the infrastructure in related industries, it is necessary, first of all, to increase the innovative activity of enterprises that is currently extremely low: 41.7% of innovative products are new in the market products, 58.3% are new for enterprises (Fig 1).

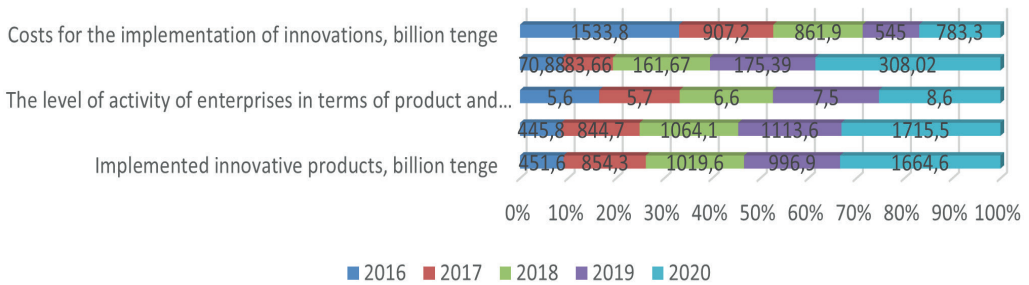


Fig. 1 – Indicators of the enterprise innovation activities

Source: compiled by the authors based on (Bureau of National Statistics, 2021; Project Ranking.kz, 2021).

The studies have established that depletion of the studied resource base and the non-replenishment of the mineral resource base remain the most important problems for the mining industry against the backdrop of the absence of new technological innovations, difficulties in adapting borrowed technologies to local conditions, and, in general, critical dependence on foreign digital solutions.

Environmental factors significantly affect the country's economy decarbonization and acquisition of long-term competitive advantage by enterprises. Improving the environmental performance of the sectors of the fuel and energy complex is a direct consequence of changing such performance indicators as, for example, reducing accidental emissions or specific consumption of carbon-containing fuel and energy resources.

According to the data, the environmental pressure on the industry tends to increase, the amount of pollutants emissions into the air that negatively affect the ecosystem stability, is increasingly dependent on enterprises.

The growth of waste processing actualizes the introduction of “green” technologies, searching for new technical solutions for the use of recycled products and reducing the cost of production. In order to attract the attention of investors within the framework of sustainable development, the mode of environmental regulation and regulation of the activities of nature users is being improved, the principles of the best available technologies (BAT) and ESG are being introduced, the tools for financing green projects in accordance with the Green Bond Principles (GBP) of the International Capital Markets Association (ICMA), ISO 14001 and ISO 50001 standards (Environmental Code, 2021; Decree of the Government of the Republic of Kazakhstan, 2020).

Building a new development model by enterprises based on scientific knowledge

and innovative technologies, is largely determined by technical readiness calculated by the basic level of production automation including the availability of process control systems, PDM and ERP systems, financial stability and management understanding of the need to invest in new technologies.

At the system level, technological modernization should be reflected in the growth of investments in fixed capital that is not observed in Kazakhstan. The share of investments in fixed assets of enterprises decreased by 1.6%, which was caused by decreasing the investment activity in the segment of crude oil and natural gas production. They cover the needs for fixed assets of the enterprise almost independently (Fig. 2).

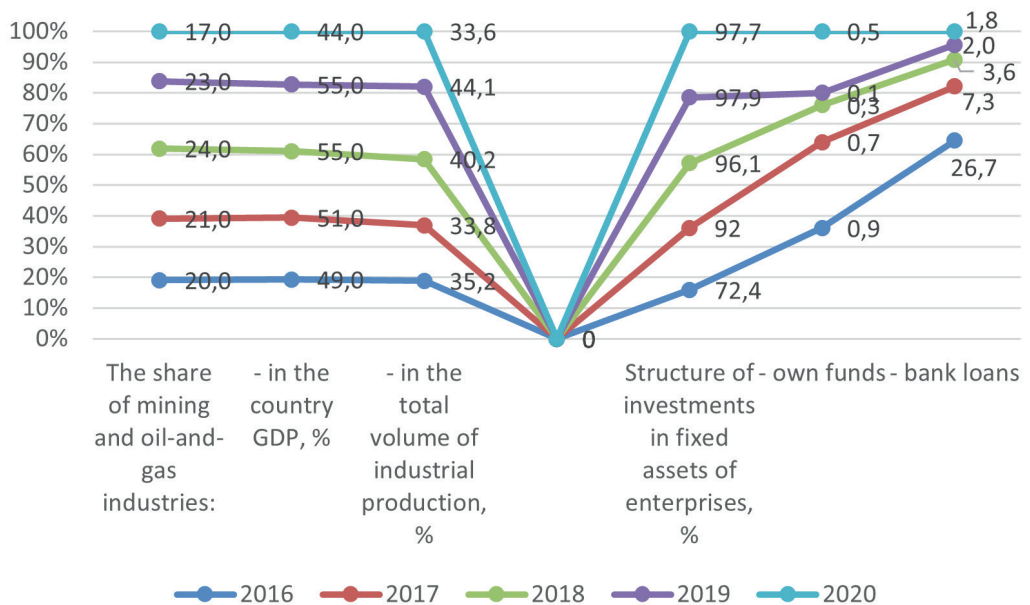


Fig. 2 – Indicators of mining and oil-and-gas industries
Source: calculated based on (Bureau of National Statistics, 2021)

The analysis of the leading mining enterprises technical condition carried out in 2017 with assistance of experts from the Fraunhofer Institute of Applied Research, specialists from the Swedish mining cluster and the Nokia Company, showed a low level of digitalization. It was revealed that most industries were not ready for the full transition to Industry 4.0: more than 56% of enterprises corresponded only to the level of Industry 2.0; 23% of enterprises required complete replacement of equipment, only 21% of the fields were equipped with updated equipment and developed communication networks (Business weekly Kursiv, 2020; Business portal Kapital.kz, 2021). Due to the low technological equipment (only 40% of enterprises were equipped with the technological, organizational and human resources that allowed moving to the next stage of digitalization), the mining industry had low labor productivity and competitiveness compared to the world leaders.

For the most part, digitalization was reduced to the technical re-equipment of the

production base (acquisition of computer technology and communication equipment, software adaptation), which is typical for the initial stage of digital transformation. By 2022, due to digitalization, the share of medium and large enterprises using digital technologies was planned to be increased to 11% (Business weekly Kursiv, 2020).

In 2019, about 95% of all the information products used at mining and metallurgical enterprises were imported, and the development of imported information and technical systems covered mainly the lower technical levels of modernization (operational and intermediate). The analytical groups formed at some enterprises did not cover the main technological processes, the effectiveness of the use of information technologies was average, information and technical products were fragmented and poorly adapted to the business processes of enterprises. Automated management decision support systems were developed slowly (Tables 1 and Fig. 3).

Table 1 – Indicators of enterprises digitalization in 2019

Indicator	Industry/number of enterprises examined					
	Mining /13	Mechanical engineering /27	Metallurgy /9	Oil-and-gas /13	Power engineering /4	Chemical /5
Number of automated business processes	24	21	6	23	8	13
Number of enterprises where there is a service responsible for automation	10	13	6	7	2	2
Number of systems implemented / software maintenance	15	19	11	17	6	6
Number of enterprises providing for the cost of	7	11	3	5	0	3

Source: (Kazakhstan Center for Industry and Export “Qazindustry”, 2020)

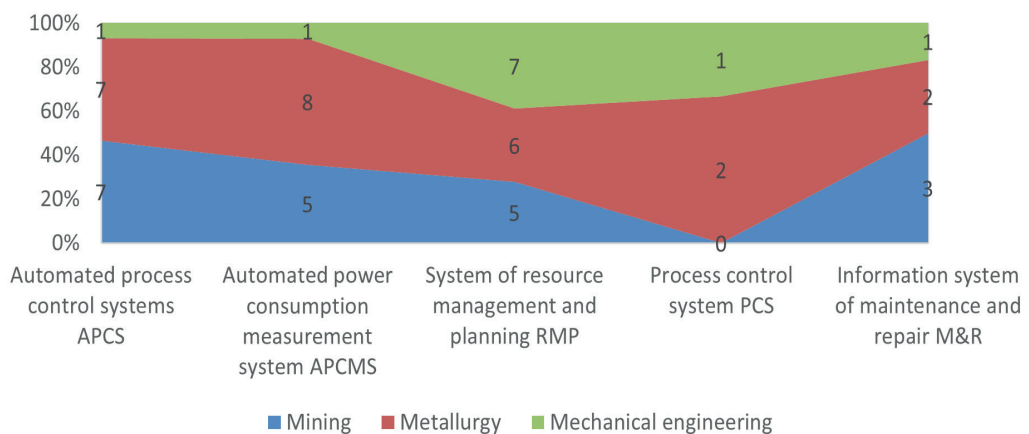


Fig. 3 – Information systems introduced by enterprises in 2019

Source: (Kazakhstan Center for Industry and Export “Qazindustry”, 2020)

Taking into account the trajectory of technological development of enterprises, their digital transformation is based on modernization of production including that through transferring the best technologies; generating an information array of data and based on it automated output of various indicators and criteria that demonstrate the efficiency and condition of the equipment. When implementing large projects related to the infrastructural changes of enterprises, high-cost equipment was used. With the development of digital communications and the Internet of Things technologies, enterprises were able to form a digital production model and to introduce new automation tools replacing old methods of technological optimization with new ones based on software platforms for analyzing all the data coming from an object.

Digital twins were introduced as models in which both data and systems were present, the enterprise could be managed in real time, remotely. At mining enterprises, there are still separate cases, a prototype of the enterprise is created with connected equipment. Through VR glasses it is possible to “move” around the enterprise changing business models based on new technological opportunities.

In 2019, thirteen large mining enterprises implemented 27 projects out of the planned 53 projects for 283 billion tenge, 39 out of 112 enterprises implemented digital solutions (Business weekly Kursiv, 2021). In accordance with the plans of the strategic vision and indicators for decarbonization, the projects were implemented using deep automation, the Internet of things, artificial intelligence and machine learning. These are enterprises with a high market share and geographical diversification, which stimulate the development of related industries and form the basis for the growth of the country’s economy. To achieve long-term competitive advantage in the Fourth Industrial Revolution, these enterprises will need to focus on strategic value innovation and business model transformation. The emphasis should be put on investing in research and development, introducing new technical solutions, searching for new partners in innovation, developing highly competitive markets.

Within the frameworks of geological exploration work digitalization and in accordance with the strategic plan until 2040, the Kazakhmys Corporation LLP plans to develop the existing and to design new production facilities with the prospect of increasing ore production in the amount of 6906 thousand tons with the average copper grade of 1.08%. The enterprise was the first in the country to apply digital control in remote areas outside the coverage area of telecom operators; it carried out 3D seismic surveys and 3D scanning of mine workings using unmanned aerial vehicles to simulate mined-out underground spaces; it mastered digital technologies in surface electrical surveys (the use of the method of ground geophysics using Canadian technologies OreVision IP, InfiniTEM doubled the depth of the study).

It is assumed to assess the effectiveness of exploration and operation of deposits as a result of the digital transformation of production and business processes, by the following indicators:

- increasing the volume of recoverable mineral reserves, the effect will be expressed in increasing the volume of proceeds from sales;
- increasing the productivity of the selected method of mining the deposit, the effect will be reflected in the dynamics of capital costs.

- increasing the ore recovery factor, the effect will be expressed in increasing the volume of proceeds from sales;
- decreasing the number of employees due to increasing the share of automated or remote production and management operations, the effect will be reflected in the dynamics of fixed costs.

Kazakhstan, one of the world's key producers of uranium, mines it using environmentally friendly technologies at a relatively low cost. Over four-fifths of the country's uranium reserves can be developed using the most economically viable and least environmentally hazardous mining technology: in-situ leaching. The Kazatomprom National Atomic JSC, within the framework of the digitalization strategy developed till 2028, implements VR technologies, drones to ensure industrial safety at uranium enterprises, masters augmented reality projects, and introduces geological information systems.

The Sokolov-Sarbai Mining and Processing Production Association implemented the Smart Quarry project, which makes it possible to increase the transport equipment productivity by 10%. In 2019, elements of artificial intelligence and a special system to improve processing efficiency were introduced into the iron ore processing. Due to the system, the analysis of raw materials on the conveyor was automatically carried out, the optimal characteristics of the operation of mills for grinding ore were calculated with their subsequent transfer to the operator. A BTS structure was developed that introduced robots to automate business processes.

In 2020-2021 the situation with energy efficiency was not improved significantly: enterprises were not fully engaged in it limiting themselves to energy saving measures and, as practice showed, often to the detriment of the efficiency of mining and transport operations.

In general, mining enterprises are ready to invest in the growth of technological competencies of all the departments including the IT service, and in technologies that provide high operational efficiency, reduce the risk of industrial injuries and minimize the impact of the human factor.

The main difficulty consists in the fact that, firstly, not all the managers are aware of the possibilities of digital tools and their relationship with business efficiency, which affects their readiness to master new technical solutions, the ability to independently generate knowledge, to develop new technologies or products and to commercialize them. Secondly, in the medium term, enterprises will have to produce and service the developed traditional products within the framework of digitalization roadmaps without adapting to consumers but shaping their needs, which will complicate the organizational structure. Many enterprises cannot afford high-quality automation or spend only small amounts for it getting poor results. Thus, the development of industrial robotics, which is extremely relevant for the extractive industries, is constrained by a high cost of implementation, which only large enterprises can afford.

The problem of the qualified IT specialists shortage who know specifics of production is planned to be partially solved at the enterprises by attracting external experts through outsourcing and/or by developing centralized operator stations in large cities to manage

remote assets. Thanks to cloud services and fast data links, the location of staff is no longer a big deal, which simplifies recruitment.

The main focus of the company is put on:

- providing digital technologies for increasing productivity, reducing operating and investment costs: the most important factors in the enterprise competitiveness;
- achieving an effect from digital solutions covering processes, equipment and personnel;
- paying back of digitization projects and their real value, high operational efficiency for business;
- extending the life cycle of automation systems by updating the software of controllers, reducing costs and preserving intellectual property;
- using digital technologies for personnel training.

The effect of the enterprise from the use of new technologies can be assessed by indicators characterizing their impact on the final technical and economic indicators. These are, for example, the efficiency of use and the accident rate of equipment (load factor and useful output / production, volume and cost of emergency and repair work); the resource use efficiency (specific costs for the most important types of resources); dynamics of employed workers (release); the level of environmental impact and loss of energy resources along the technological chain. It is advisable to assess the economic effect by the dynamics of fixed operating costs and variable costs; changing capital investments in production capacities; the amount of additional income from the sale of products in the foreign and domestic markets, when the growth in output is accompanied by the development of new digital solutions. The effect can be local in nature, when the introduction of digital solutions contributes to changing the parameters of specific equipment and complex, in the case of distribution along the technological chain adjusting the parameters of other objects.

The desire of Kazakhstan to strengthen its position among developed countries-exporters of clean energy actualizes the task of the energy industry digitalization. Despite the growth in electricity generation in 2021 compared to 2020 by 6%, the electricity deficit in the country amounted to 1.7 billion kWh, by 2030 it is planned to increase it by 25-30 billion kWh. By 2030, production is projected at the level of 80 billion kW/h, the level of energy consumption will reach 130 billion kW/h.

Increasing coal generation is caused by implementation of projects at coal-fired power plants, thanks to which it is possible to cover the observed increase in electricity consumption. In 2020, the share generated by coal-fired power plants was 69% (74.5 billion kWh), out of 108 billion kWh of electricity generated, gas generated 20%, hydroelectric power plants 8%. Currently, electricity generation from 134 renewable energy facilities is 3.3%, by 2030 it is planned to increase it to 15%.

Given the duration of the construction of basic power sources, it is necessary to develop coal-fired generation in the medium term, taking into account replacing with alternative energy sources. It is planned to build 4 and 5 power units of GRES-2 simultaneously, this will add over 1000 MW to the energy system in the next five years. By 2035, to meet the growing demand for electricity and capacity, it is planned

to develop about 12 GW of generating capacity including that from alternative energy sources.

Taking into account the commissioning of new coal capacities covering the energy gap, the peak of greenhouse gas emissions is expected by 2030-2032. To reduce emissions and to increase reliability of the national electricity grid, the outdated coal-fired generation will be replaced by new sources based on alternative fuels using the SMART GRID technology.

Gasification of power sources is one of the most promising and environmentally friendly trends. The main consumers of thermal coal are combined heat and power plants (CHP), which in 2020 generated more than 26% of electricity (28.2 billion kWh). Today, there are no alternative technologies that allow generating thermal energy in large volumes. Replacing coal-fired CHP plants with gas-fired CHP plants would be capital-intensive and would entail increasing the tariffs for both electricity and heat, so it is not possible to replace coal-fired CHP plants in the near future. At the moment, the existing stations are being reconstructed, which allows increasing the installed capacity, ensuring a maneuverable mode, and reducing the amount of harmful emissions into the environment. Thermal power plants should remain as the main sources of thermal energy.

Despite the fact that with the expansion of the gas power industry and the growth of the use of renewable energy sources, the share of coal in the energy balance of Kazakhstan will decrease from 57% in 2020 to 36% in 2050, coal is expected to remain the most important energy resource in the power industry.

In the coal industry, the task is to optimize the production chain from mining to supplying resources to the consumer. Thus, for exploration of various types of fossil energy resources, there are used technologies of virtual prospecting and exploration, remote sensing of the earth and new geographic information systems based on 3D modeling. Due to the use of a fundamentally new cyclic-flow technology of coal mining, waste is minimized when coal is burned at power plants. Given the global trend in the development of clean coal technologies and large coal reserves in Kazakhstan, it is planned to diversify the production of clean coal technologies. In addition, when the cost of carbon dioxide capture technologies becomes much cheaper, there will be no barriers in front of coal plants, and coal will be the main source of energy. To date, the main task is modernization of coal plants using the BAT.

From the position of Kazakhstan transition to the low-carbon economy, and taking into account the gradual abandonment of coal, enterprises will have to work on gas and alternative sources, there arises the problem of gas production, availability and price of its sale in the next decade, since it will be necessary to cover domestic needs and industry, and population. In this regard, it will be necessary to develop projects for the extraction of associated gas (collection and combustion of methane in mines) using innovative technologies.

Reducing greenhouse emissions of carbon into the atmosphere actualizes the problems associated with selecting the method of burning coal, increasing the demand for coal, taking into account new environmental requirements at thermal power plants,

and the possibility of reducing the ash content of coal. The foregoing will require constructing a new economic model for the development of the coal industry including transformation of energy blocks for carbon capture, the development of new technologies for manufacturing chemical and petrochemical products using coal, the opening of coal processing enterprises.

Introducing digital technologies in the oil and gas industry will help maintaining the level of resource extraction and focusing on hard-to-recover reserves, increasing marginality and reducing the costs in the processing of raw materials, and improving management of the value chain.

The development of promising oil projects in the next decade: the Kalamkas-Sea and Khazar fields with the cost of \$4.5 billion will allow producing 4 million tons of oil starting from 2028. Implementing the large oil and gas projects of the Karachaganak, Kashagan and Tengiz that are drivers in oil production making a significant contribution to the country's economic growth, will increase the production of raw gas by 2030 to 87.1 billion m³. Increasing commercial gas production to 42.2 billion cubic meters by 2030 is planned through the development of seven new fields and construction of gas processing plants, which will provide increasing the production of marketable gas by 2030.

An important element of the industry of Kazakhstan providing the needs of all the types of transport and energy facilities with fuel, are oil refineries. The three largest plants that are part of the KazMunayGas national oil company, which completed their modernization in 2017-2018, transferred to fully automated production (APC advanced process control systems were introduced), increased the efficiency and safety of oil refining. In 2020, thanks to the piloting of the APC system at the primary oil processing unit (AT-2) of the Atyrau refinery, the yield of gasoline and diesel fuel increased by 0.32-0.36%, and 350 million tenge of profit was received. In 2021-2022 it is planned to replicate the system at the Shymkent oil refinery.

Mastering the SAP, 1C, IBM information systems by the KazMunayGas allowed optimizing in-house business processes. In 2020, the ABAI system was introduced that consolidated the data from the oil exploration and production unit in one information space using Big Data technology. With its help, it is planned to use artificial intelligence to solve complex production problems.

The analysis of the current state of digitalization of industrial enterprises made it possible to draw some conclusions.

1. Digital transformation is relevant for a relatively small number of enterprises. At the moment, digital transformations are the privilege of large enterprises: not only the target model of innovative behavior, production processes and organizational foundations of work are being transformed but new competencies are being formed, and business culture is improving. At medium-sized enterprises, digital transformation is mainly focused on the highest possible level of development of new technologies, subject to their economic feasibility, the generation of a large information array, the automated output of indicators and criteria based on it, evaluating the effectiveness of equipment. Despite the development of analytical groups by enterprises, the main

technological processes and regulations are not fully covered, the effectiveness of using information technologies is not high, information technology products are fragmented and poorly adapted to business processes; in general, the production processes digitalization is characterized by unevenness. The development of foreign information and technical systems occurs mainly at the lower technical levels of modernization, automated systems for supporting management decisions are poorly developed.

2. Barriers to digital transformation of the fuel and energy complex are as follows: the absence of opportunities for intra-industry and inter-industry data collection and transmission; complex procedures for attracting public investment and the absence of incentives for private investment in digitalization, difficulties in interacting with counterparties. The key barriers for enterprises are the lack of financial resources, a high cost of innovative projects, and the absence of digital competencies of the staff. Preference is given to simple technical solutions, since high-cost technologies require complex preliminary calculations of the effect of introducing innovative projects into the production process. Some software products do not have a Russian-language interface and positive examples of their adaptation by Kazakhstan enterprises. The depreciation policy that has such strategic functions as investment and innovation designed to stimulate technological modernization is practically not used by enterprises, is not supported or developed at the state level.

3. The most significant factors that limit the activities of enterprises include external exacerbating information security risks, prevention of leakage of geological and production information, investment and innovative risks of sustainable development: the level of competition, the availability of technology and capital, the development of legislation, the uncertainty of the economic situation. Internal factors include the difficulties of changing transformable internal production processes and the low technical level of production expressed in insufficient digital maturity of current processes and the low level of automated process control systems development, the difficulty of integrating new technologies into internal production and organizational processes, low return on investment, limited liquidity. There is a lack of new competencies in mastering digital technologies, managing innovative projects, building partnerships, and strengthening international positions. Despite the introduction of new technologies and means to ensure their safety, geodynamic risks in mining continue increasing. Factors that activate the innovation activity include intensity of investments in research and development, introduction of new technologies with the emphasis on technological innovation, mutually beneficial partnerships, entering international markets with new products.

4. The coverage of enterprises in the mining sector by digitalization, as a phased revolution with elements of change management, is not yet so deep, although progress is quite obvious. It is clear that digital technologies will not solve all the increasingly complicated investment and innovation tasks of enterprises. At the same time, they make it possible to justify selecting the enterprise promotion strategy with maximum efficiency in the use of production capacities and mobilization of new algorithms in all the areas of its activity. In general, the trends of developing industrial enterprises

correspond to global trends, however, the lag in the development of digital technologies from the leading countries, according to various estimates, is about 5-10 years (Lufin and Soto-Díaz, 2022). This is largely caused by the focus on foreign scientific and technical potential, which aggravates the situation with industrial and economic security and increases the gap between the links in a single chain of the process of technological modernization.

These problems are relevant not only for Kazakhstan. Despite the fact that mining and metallurgy enterprises of the EAEU countries have increased production by 10-20% due to digitalization and reduced emissions by 15-30%, in terms of the pace of implementing digital technologies, there is a lag in the stages of transition from research to implementation of solutions in production and subsequent scaling from the banking and telecommunications sectors (Portal Profit.kz, 2022). 90% of enterprises in Kazakhstan and Central Asia consider the search for qualified personnel the main difficulty in implementation of digital projects, 77% plan to increase digitalization costs in the near future (KPMG, 2021).

Conclusion. For city-forming enterprises present day scientific and technological development is a fundamental challenge that if not overcome, is tantamount to losing competitive positions in the world market. The role of Kazakhstan as a major player in the world energy markets predetermines the importance of transformational processes on the scale of the country's fuel and energy complex. Mining and metallurgical enterprises should focus on decarbonizing operations, developing decarbonization strategies, and stimulating implementation of projects according to ESG standards.

In the coming years, the introduction of digital technologies will worsen the financial stability of enterprises due to the growing financial burden on the BAT introduction, deteriorating mining and geological conditions, and increasing production costs. Therefore, in the short term, for digital transformation, enterprises may not radically update their fixed assets of production. Technical and economic indicators can be improved through the gradual growth of the "digital connectivity" of the technology used and the introduction of business processes based on the data analysis.

In the medium term, it is necessary to solve systemic problems affecting optimization of operational procedures, the adjustment of the existing formats of interaction between participants in value chains, and the promotion of "local" digitalization. To use the accumulated potential that increases the efficiency of geotechnological complexes and reduces the cost of production, mining enterprises need step-by-step digitalization, especially since cyclic and cyclic-flow technologies are preserved, combined open-pit and underground mining options are used. Complementary investments in the growth of competencies of both IT personnel and users of IT products will be required.

In the foreseeable future, to capitalize on the potential to reduce their carbon footprint and to move towards carbon neutrality, enterprises will need to build the long-term asset value as investors move away from the short-term profit model in favor of the long-term value.

If the first stage of digitalization of enterprises is associated with the development of functional areas, then in the future it is planned to introduce end-to-end digital

solutions along the entire technological chain, to develop new technologies that allow increasing production capacity, reducing emissions into the atmosphere, scaling digital ideas and creating a flexible agile culture (Galiyev et al., 2020:1). Using the practice of the developed countries, where digital transformation is aimed at developing customer-oriented energy systems, autonomous energy supply models will be designed that are adapted to a specific consumer without significant increasing the cost of supplied energy products.

It should be noted that the approach to assessing the trends in the technological transformation of enterprises outlined in the article will deepen the understanding of various aspects related to the practice of introducing digital technologies in the countries with transitional economies.

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