

The Fourth Industrial Revolution: Towards Energy 4.0 in Kazakhstan

Aisultan ALIMKHAN *, Adilkhan MAKHAMBAYEV *, Ikechi A. UKAEGBU *

* Electrical and Computer Engineering Department, Nazarbayev University, Astana, Kazakhstan
aisultan.alimkhan@nu.edu.kz, adilkhan.makhambayev@nu.edu.kz, ikechi.ukaegbu@nu.edu.kz

Abstract— Large-scale changes in technological advancements will lead to large scale innovations and stimulation of economic growth across the globe. Nowadays, as the leading industrialized economies move to intelligent manufacturing, called industry 4.0, there is a growing impact on the energy sector in any country. The latter may be referred to as Energy 4.0, which incorporates the period of mechanization, the gas and oil era, and the new digital revolution with renewable energy era. Generation, distribution, consumption and smart production of energy - all of these are going to experience an enormous revolutionary changes due to technologies as big data, IoT and cloud computing. This work describes the current state of art of Energy 4.0 in Kazakhstan, its future potential, benefits, challenges and the vision of government to introduce further discussions in the formation of a new technological revolution of Industry 4.0 that will have fundamental and structural nature. The article analyzes the global industrial revolutions and the relevant global energy steps implemented over the past 10 years by illustrating it through Networked Readiness Index (NRI) charts, that show the positions of Kazakhstan by different criteria established of reliable international organizations. Moreover, paper presents the experience of the Energy 4.0 strategy development in technologically advanced countries. In this work, we also offer the approaches and proposals associated with the Industry 4.0 strategy adaptation to the Kazakhstani energy sector, which can be taken as a basis for the new industry development strategy during the upcoming global technological changes.

Keywords— Industry 4.0, Energy 4.0, The four industrial revolution, Energy sector, Technological innovation.

I. INTRODUCTION

The fourth industrial revolution is significantly transforming the energy sector. One of the definitions for Energy 4.0 might be a digitization of energy industry. Energy generation issues currently experience a variety of such changes as nuclear phase-outs, progress in renewable sources of energy, innovative distribution grids and some changes due to Industry 4.0 technologies. With the changes in energy generation and distribution there are some shifts in commercial energy environment, such terms as unbundling, trading that are actual today. Currently, the energy sector is aiming to grow up to the one large and extremely complicated cyber-physical system. Energy 4.0 means by itself an introduction of such modern technologies as cloud computing, IoT, big data and others into energy generation, transmission, distribution, retail, consumption spheres. This paper is about the current and future state of Energy 4.0 in developing

country Kazakhstan, its business models and legal relations those that are relevant to Energy 4.0.

II. BACKGROUND

A. Definition of Industry 4.0 and Energy 4.0.

In order to deeper understand the concept of Energy 4.0 and its dependence on Industry 4.0 technologies, an example can be given: smart cities is intended to increase the residents' life quality by using IoT, which is helpful in reducing of energy consumption. Regarding the international experience, it is needed to be mentioned that 78 cities in Europe have signed protocols for energy industry digitalization, and their aim is work out roughly 300 cities by 2019th year [1]. One of the dreams in European cities is to have ability to self-generate the energy, and the cost of this will be the same with that if they purchase energy from local providers by 2022, in another words so-called distributed energy resources are able to revolutionize the energy sector in near future. Recently the introduction of the blockchain technologies promises a more efficient and easier electrical power delivery to customers.

III. GLOBAL READINESS OF KAZAKHSTAN TOWARDS ENERGY 4.0

A. Networked Readiness Index

The innovation in technology has taken people, countries, businesses and the overall global market place closer than ever before and this trend with no doubt will extend and speed up over time. A huge study by World Economic Forum, WEF, is used to determine the adoption of Networked Readiness Model by many countries. WEF studied various countries and recorded them. The key countries harnessing information technology in top 10, and also ranking of Kazakhstan with its neighbours can be seen from the tables 1, 2 and 3.

Networked Readiness Index (NRI) is an important indicator of how countries are well or ready to step to the next generation of digitalization. Moreover, the study of WEF presents how the drivers necessary for country possess in digital technologies, and impact of it on the economy and society. Figure 1 shows the change of ranking of Kazakhstan between 2008-2016 years in the digital revolution by NRI. Notably, Kazakhstan's rank on the Network Readiness Index in 2008 was 71. In 2016, Kazakhstan ranked 39 out of 139

TABLE 1. NRI OF TOP 10 COUNTRIES AND NEIGHBOURS OF KAZAKHSTAN IN 2010 YEAR [2]

Country	Rank
Sweden	1
Singapore	2
Finland	3
Switzerland	4
United States	5
Taiwan, China	6
Denmark	7
Canada	8
Norway	9
Korea, Rep.	10
Hong Kong SAR	12
Kazakhstan	67
Russian Federation	77
Ukraine	90
Kyrgyz Republic	116

TABLE 2. NRI OF TOP 10 COUNTRIES AND NEIGHBOURS OF KAZAKHSTAN IN 2013 YEAR [3]

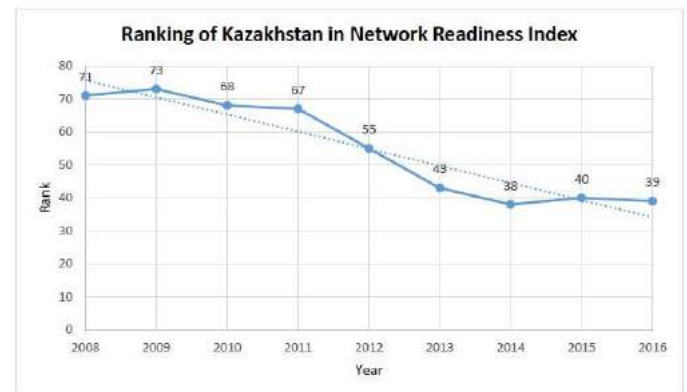
Country	Rank
Finland	1
Singapore	2
Sweden	3
Netherlands	4
Norway	5
Switzerland	6
United Kingdom	7
Denmark	8
United States	9
Taiwan, China	10
Hong Kong SAR	14
Kazakhstan	43
Russian Federation	54
Ukraine	73
Kyrgyz Republic	118

countries. At 39, Kazakhstan was ahead of its big neighbours Russian Federation (41), Kyrgyz Republic (95) and China (59). Singapore, Finland and Sweden topped the rankings. The United States was placed at 5th position, which was same position in year 2010. The top-ranked developed nations such as the U.S. and Singapore ranking is almost unchanged. But

many developing nations, especially Kazakhstan saw an increase in ranking.

TABLE 3. NRI OF TOP 10 COUNTRIES AND NEIGHBOURS OF KAZAKHSTAN IN 2016 YEAR [4]

Country	Rank
Singapore	1
Finland	2
Sweden	3
Norway	4
United States	5
Taiwan, China	6
Switzerland	7
United Kingdom	8
Luxembourg	9
Japan	10
Hong Kong SAR	12
Kazakhstan	39
Russian Federation	41
Ukraine	64
Kyrgyz Republic	95

**Figure 1.** Networked Readiness Index ranking graph of Kazakhstan during the 2008-2016 years

Tables 4, 5 and figure 2, indicates the ranking in top 10 countries and neighbours of Kazakhstan in 2018, and emphasized production of drivers and structures of Kazakhstan separately by highlighting a number of key issues such as:

- innovate technology;
- raise in digital population by businesses and companies;
- development of new types of behaviour;
- governance and leadership mechanisms and etc. [4].

According to the Future of Production Assessment study, it seems convincing that Energy 4.0 can become potentially available for Kazakhstan, however, the detailed study for “Energy 4.0 Readiness” may further do its part in this effort to

highlight the challenging milestones that many companies must still pass on the road to Energy 4.0 [5].

TABLE 4. READINESS OF TOP 10 COUNTRIES AND NEIGHBOURS OF KAZAKHSTAN FOR THE STRUCTURE OF PRODUCTION ASSESSMENT IN 2018 [5]

Structure of Production		
Country	Score	Rank
Japan	8.99	1
Korea Republic	8.85	2
Germany	8.68	3
Switzerland	8.39	4
China	8.25	5
Czech Republic	7.95	6
United States	7.78	7
Sweden	7.46	8
Austria	7.46	9
Ireland	7.34	10
Singapore	7.28	11
Russian Federation	5.71	35
Ukraine	5.17	43
Kazakhstan	4.19	62
Kyrgyz Republic	3.73	76

TABLE 5. READINESS OF TOP 10 COUNTRIES AND NEIGHBOURS OF KAZAKHSTAN FOR THE DRIVERS OF PRODUCTION ASSESSMENT IN 2018 [5]

Drivers of Production		
Country	Score	Rank
United States	8.16	1
Singapore	7.96	2
Switzerland	7.92	3
United Kingdom	7.84	4
Netherlands	7.75	5
Germany	7.56	6
Canada	7.54	7
Hong Kong SAR	7.45	8
Sweden	7.4	9
Denmark	7.2	10
China	6.14	25
Russian Federation	5.3	43
Kazakhstan	4.74	61
Ukraine	4.47	67
Kyrgyz Republic	3.43	96

B. Government's perspective

According to the Zh. Kassymbek [6], the minister for investments and development of Kazakhstan, the technological modernization of the economy of country will be popularized within the President's address "Global Competitiveness of Kazakhstan - Third Modernization". Moreover, he analyzed that Energy 4.0, according to the calculations of international experts, will allow to increase the annual GDP growth by an average of 1.5% through the large-scale use of advanced info communication technologies such as autonomous robotic systems, the analysis of massive data (Big Data), 3D printing technologies, industrial Internet, and etc. [6].

Drivers of Production	Weighting	Rank	Score /10
Technology & Innovation 	20%	58 th	4.1
Human Capital 	20%	43 rd	5.4
Global Trade & Investment 	20%	63 rd	4.9
Institutional Framework 	20%	68 th	4.6
Sustainable Resources 	5%	91 st	4.4
Demand Environment 	20%	49 th	4.9
Structure of Production	Weighting	Rank	Score /10
Complexity 	60%	63 rd	4.6
Scale 	40%	64 th	3.5

Figure 2. Readiness of Kazakhstan for the Future of Production Assessment according to all Drivers and Structures [6], 2018

C. Importance of Energy 4.0 for Kazakhstani automotive areas

The Ministry of Investment and Development of Kazakhstan analyzed more than 600 enterprises together with experts from the European Fraunhofer Institute for Applied Research and specialists from the advanced mining cluster of Sweden and company Nokia. All of them were from the manufacturing, mining and smelting complex sector. According to the results, it was revealed that in the manufacturing industry about 20% have sufficient technological, organizational and personnel base for the implementation of technologies of Energy 4.0. In the mining sector, the situation was somewhat better, about 40%. As a result, they made up a "long" list of those most prepared companies for technological transformation, and then, based

on additional criteria, reduced it to seven only. These enterprises were Altynalmas JSC, JSC Kentau Transformer Plant, JSC Eurasian Foods, Himfarm JSC, Ball Tekstil LLP, Karlskrona LLP, and Almaty Fan Plant LLP. At the same time, along with the transition to the use of digital technologies, such as stand-alone robotic systems and 3D printing, the decrease in the number of manual labor is expected. Alik Aidarbayev, first Vice-Minister for Investment and Development of the Republic of Kazakhstan, stated that some monotonous hard work will be automated, but the people who replaced by machines will remain at the same enterprises and new jobs will be created for them [7].

D. Large companies of Kazakhstan

According to the Ministry of Investment and Development of the Republic of Kazakhstan, currently such large companies as ERG, Kazakhmys, ArcelorMittal, Kazatomprom and KazZinc are already introducing individual elements on the digitization of Energy 4.0 in enterprises. To date, these companies have developed their own digital modernization plans and are embarking on the implementation of such programs as "smart factory", where massive data analysis technologies, advanced detectors and sensors, integrated information systems and robotic operations will be introduced. As an example, KazZinc, the mining company, is implementing seven digitalization projects at once. Another company Kazatomprom, the national atomic company, started developing 3D printing technologies in 2016. With the help of 3D printers, they plan to launch the release of implants from tantalum, which is well compatible with the human body. In addition, these technologies will allow printing equipment parts for uranium production. As a result of the introduction of technologies by 2020, an economic effect of 2 billion tenge is expected [8].

IV. CURRENT STATE OF ART IN KAZAKHSTAN

Talking about the sources of electrical energy, 70 percent of generated energy comes from coal plants, nearly 15 percent from hydroelectric power plants, about 11 percent from gas, and there many companies who provides energy services [9]. The problem of implementing the Energy 4.0 is in lack of concernment, for example, in one of the largest electrical power company KEGOC (Kazakhstan Electricity Grid Operating Company), there was a competition among engineers, who must suggest innovative ideas. The best ideas were the installation of space dampers in order to prevent wires convergence or installation of extra zeolite column in order to increase the lifetime of oil moisture meter. As seen from previous example, there are improvement in electrical generation and distribution, but not related to technologies of Industry 4.0. Yet there is a strongly funded research and development program in KEGOC, the aims of this department are balance regulation of active and reactive power to keep the operating voltage and frequency levels, also the improvement of the national power grid. However, the information about by what methods they will achieve it is not available [10].

V. ENERGY 4.0 - OPTIMAL SOLUTION FOR KAZAKHSTAN

A. Advantages of Energy 4.0 for Kazakhstan

Digitalization increases production flexibility, reduces the time to launch a new product to the market, which allows implementing new business models. All this greatly increases the efficiency and competitiveness of all enterprises:

- labor productivity increases by an average of 10-20% due to the optimization of processes;
- the ability to quickly analyze data in real time;
- reduces emergencies and downtime;
- improves the interaction of staff and equipment;
- labor safety is ensured by minimizing human labor in particularly dangerous zones and places with a high level of injury. For example, to check the hazardous areas in the mine and data that excludes injuries to personnel. It also allows operators to move from underground to safer and more comfortable working environments in control rooms;
- the timing of new products on the market will be reduced by 20% due to digital engineering technologies and rapid prototyping.

In addition, enterprises can strengthen their market positions and develop new markets by more accurately identifying customer needs and market forecasts, as well as production for specific needs.

B. Challenges in Energy 4.0

Constraints for the implementation of Energy 4.0:

- lack of understanding of the business of the economic benefits of digitalization;
- weak development of domestic developments and competencies in automation and digitalization;
- lack of qualified personnel;
- limited financial resources, as well as infrastructure constraints;
- the need to rethink management procedures and overcome resistance to changes in the production culture [11].

VI. ENERGY 4.0 IN GERMANY, LESSONS FOR KAZAKHSTAN

After a conducted survey among 559 industrial companies, such countries as USA, Germany and Japan can be regarded as leading nations in utilizing the technologies of Industry 4.0. In addition to these earlier listed countries are also frontrunners in renewable energy and efficient generation of energy. These countries already experience the advantages from digitization in energy sector. For example, Germany reached 30% of energy efficiency in car manufacturing due to robotics optimization. The technologies of Industry 4.0 like smart grid enable automation flexibility, stabilization of energy systems and more efficient energy storing. One of examples is also that, there is a NEW 4.0 project in Northern Germany, which provides renewable energy for 4.5 million residents [12].

The term NEW 4.0 means the transition of industry to intelligent system networks. The project itself demonstrates the significant transformation of the whole energy sector. The

project NEW 4.0 is illustrating that even in regions with imbalances in production and consumption of electrical energy can be easily overcome, if all terms of energy sector such as production, distribution, consumption and storage run by intelligent network technologies. The project is supported by Federal Ministry for Economic Affairs and state governments of Hamburg. The enormous budget of 90 million EUR is aimed to support the 100 individual projects related to the project NEW 4.0. The technologies like mechatronics, cyber physical systems, data mining enable the smart and more efficient processes, improved utilization grids, smart market, flexible consumption, innovative system management, reactive power management, virtual inertia, smart balancing [13], [14].

The power generated by wind turbines has a big potential, there are three parts of Kazakhstan with different indicators of wind speed and its availability. The highest wind speed over than 8.0 and 0.9 of availability is observed in Erementau, Shelek and fort Shevchenko. Such locations as Astana, Arkalyk, Karabatan have little lower indicators, where speed is 7.0 and 0.8 of availability. And third part with high potential includes Kordai and Karakary. Such wind characteristics allow commercial-scale wind farms [15].

The plants of renewable energy, which are enhanced with Industry 4.0 technologies, can profoundly help a numerous number of cities in Kazakhstan with high air pollution, such cities as Astana, Ust-Kamenogorsk, Almaty, Qaraghandy. The example in Northern Germany clearly shows that it is possible to create such sustainable energy generation for several million residents. Since the implementation of Industry 4.0 technologies is not widely spread, the lack of experience around the world, it all requires hundreds individual projects aimed to develop intelligent energy systems for generation, distribution and consumption of electrical energy.

VII. NEW MARKET DESIGN FOR KAZAKHSTAN DUE TO TECHNOLOGIES OF INDUSTRY 4.0

It is predicted that the energy consumption will reach 123 billion kWh in Kazakhstan by 2050 year. Due to wear out of old plants and finishing of fuel fossils, there is a forecasted shortage of generated energy. In order to compensate the consumption demand, the new electricity markets are highly useful. Such market models as peer-to-peer, single buyer will make electricity market participants face the demand [16].

The new technologies like blockchain, smart grid, load aggregators allow earlier mentioned markets to exist. These technologies allow people to have auctions, when any buyer bid their own price for electricity, the price is updated in real time. Such electricity markets have many advantages because each market participant can generate the energy and sell it. Due to personal solar panels or air turbine they generate energy and arrange the auctions among buyers [17], [18].

Even if the Energy 4.0 is not highly developed in Kazakhstan, the future demand of electrical energy will require the new electricity market models, which require the implementation of Industry 4.0 technologies.

VIII. CONCLUSION

To conclude, this research paper has had analyzed the measures that been taken to stimulate the transition of Kazakhstan's production sector to Industry 4.0 and Energy 4.0. Work proposed that it will have a positive impact on productivity growth and improvement of labor safety, competitiveness of domestic industry and the economy as a whole in accordance with the instruction of the Head of State. The implementation of elements of Energy 4.0 introduce not only challenges for Kazakhstan, but also new openings, namely, a considerable increase in efficiency, the formation of a new business and export-oriented industries. One may realize that in many "digital undertakings" Kazakhstan is one of the pioneers, offering the world its own unique know-how and non-standard solutions in the use of cyber technologies.

REFERENCES

- [1] —, "Energy 4.0: Digital transformation in energy & utilities industry." [Online]. Available: <https://mobidev.biz/blog/digital-transformation-energy-utilities-sector>, 2018.
- [2] S. Dutta and I. Mia, "Networked readiness index in 2010-2011," The Global Information Technology Report 2010-2011, pp. 21–22, 2011.
- [3] S. D. B. Bilbao-Osorio and B. Lanvin, "Networked readiness index in 2013," The Global Information Technology Report 2013, pp. 23–24, 2013.
- [4] S. D. S. Baller and B. Lanvin, "Networked readiness index for the future of production," The Global Information Technology Report 2016, pp. 18–20, 2016.
- [5] A. Kearney, "Networked readiness index for the future of production," Readiness for the Future of Production Report 2018, p. 24, 2018.
- [6] —, "Kazakhstan," Readiness for the Future of Production Report 2018, pp. 150–151, 2018.
- [7] Z. Kassymbek, "Analysis of the readiness of the production sector of Kazakhstan," Primeminister.kz, 2017.
- [8] A. Kasymova, "Energy 4.0: Experts have rated Kazakhstan enterprises readiness," Kazinform, 2017.
- [9] —, "Kazakhstan - Electrical Power Generation", 17th Kazakhstan International Energy, Electrical Equipment and Machine Building Exhibition and Forum of KazInterPower, [Online]. Available: <https://www.export.gov/article?id=Kazakhstan-Electrical-Power-Generation>, 2018.
- [10] —, "KEGOC's development strategy for 2018-2028", Kazakhstan Electricity Grid Operating Company, pp. 6-22, 2018.
- [11] Y. Masanov, "Energy 4.0 in Kazakhstan: state plans or reality?" Inform-buro, 2018.
- [12] E. Boucher, "Industry 4.0 in Kazakhstan: expert advice," Mining & Metals Guide, 2017.
- [13] P. D. W. B. Jenny Capel, "Innovation alliance of hamburg and schleswig-holstein for the energy system of the future," NEW 4.0, Norddeutsche Energiewende, 2017.
- [14] T. Nagasawa, "Accelerating clean energy through industry 4.0 manufacturing the next revolution," United nations industrial development organization, 2017.
- [15] A. Akhmetov, "Wind Power Development in Kazakhstan: Potential and Obstacles.," Creative Commons, 2018.
- [16] —, "Electricity consumption in Kazakhstan will increase by 50 percent by 2050." [Online]. Available: <http://novoetv.kz/2017/06/na-50-procentov-uvlechitsya-k-2050-godu-potreblenie-elektroenergii-v-kazaxstane/>, 2017.
- [17] S. Moura, "Blockchains for decentralized optimization of energy resources in microgrid networks," 2017 IEEE Conference on Control Technology and Applications (CCTA), 2017.
- [18] K. B. Rakhimov, "A comparative analysis on the electricity sector of Kazakhstan to create a sustainable market model." Creative Commons, 2015.



Aisultan Alimkhan Almatuly is currently receiving the B.Sc. degree in electrical and computer engineering at the Nazarbayev University, Kazakhstan, Astana, and will graduate in 2019. Presently, he is working as an electrical engineer assistant in the Kazakhstan Paramount Engineering (KPE), Astana, Kazakhstan. His research interests include power system protection, distributed energy resources, smart grid, industry 4.0 and AI applications in power industry.



Adilkhan Makhambayev is currently receiving the [B.Sc.](#) degree in electrical and computer engineering at the Nazarbayev University, Kazakhstan, Astana, and will graduate in 2019. His research interests include power generation and distribution, PV systems, industry 4.0 in power industry. Intern in car manufacturing company AziaAvto, and in power distribution company TATEK.



Ikechi Ukaegbu received his B.Sc. in Electrical Engineering, Electro mechanics and Electro-technology at Moscow Power Engineering Institute (Technical University), Moscow, Russia in 2004 and M.Sc. in Electronics and Microelectronics at the same university in 2006. He obtained his Ph.D. at Korea Advanced Institute of Science and Technology (KAIST) in 2012. He has worked as a Post-Doctoral researcher in Electrical Engineering Department at KAIST from 2012 to 2013. He held R&D positions at Electronics and Telecommunications Research Institute (ETRI), Korea, from 2008 to 2009 and at Lightron Fiber-Optics Inc., Korea in 2013. He also worked as a senior engineer with the design technology team at Samsung Electronics Co. Ltd, Korea from 2013 to 2016. He co-founded a startup company where is served as the CTO from 2016 to 2017. He joined Nazarbayev University School of Engineering in 2018 and he is currently an assistant professor with Electrical and Computer Engineering Department. His research interests include 5G Technologies, Electronics & Nanophotonics, Signal & Power Integrity, Channel Modeling, and Terahertz Chip-to-chip links. More information can be found at www.idslab.info.