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Advanced HRM practices and digital personnel for digital energetics based on the technologies of Industry 4.0

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Introduction

Digital energetics is the energy economy in which the digital technological mode dominates, which implies the active use of the leading digital technologies of Industry 4.0 (e.g., robots, big data and AI) and digital personnel (highly qualified employees with skills to use the leading technologies).

The Fourth Industrial Revolution, like all the previous ones, assumes that systemic changes are taking place in economic systems, which are not only technological but also social. It is advisable to consider the latter systematically from the standpoint of Stakeholder Theory. From the perspective of employees (supply in the energy segment of the labor market), deep technological shifts in the energy sector increase the risks of unemployment and cause uncertainty about the prospects for the disclosure of human potential.

In many countries, especially in large energy economies, employment in the energy sector is quite large, which makes the energy sector an important segment of the labor market. For example, according to Rosstat (2022), in 2020 in Russia the number of people employed in mining was 1,160,500 people, and in the field of electricity, gas, steam and air conditioning supply—1,568,100 people. The share of employment in the energy sector (and indicated related fields of activity) was 3.94% of the total number of employed 6,925,190 people.

From the standpoint of energy companies (demand in the energy segment of the labor market), the transition to industry 4.0 technologies is aimed at automating production and distribution processes that pose a threat to the health of workers. Many energy companies note in their corporate social responsibility reports that the introduction of advanced automation tools has allowed them to reduce industrial injuries and improve production safety. At the same time, technological modernization cannot take place without highly qualified personnel introducing "smart" innovations. Therefore, it seems that the demand for human resources and human resources management (HRM) practices is specific to each production process of energy companies, which further increases uncertainty.

In this regard, the study of the social consequences of the transition to digital energetics for people employed in the energy sector demonstrates both high relevance and scientific and practical significance. In the existing literature (Morelli et al., 2022; Zhang et al., 2022; Zhao et al., 2022), much attention is paid to the technological advantages of the transition to digital energetics, including increased productivity and production capacities of energy companies, improved safety (including environmental) of production and distribution processes in the energy sector, expanded opportunities for the development of "clean" energy.

At the same time, the social consequences of the transition to digital energetics have not been sufficiently studied, which is a gap in current scientific knowledge. This article aims to fill this gap and specify the role of digital staff in the development of digital energetics based on the technologies of Industry 4.0, as well as to review the best practices of performing this role.

The contradiction of the social consequences of the transition to digital energetics

In the existing literature, much attention is paid to the prospects of the digital development of the energy sector. Automation covers more and more economic processes and systems of energy companies (Afshari et al., 2022' Buchmayr et al., 2022; Krupnik et al., 2022). The research works (Chadwick et al., 2022; Guglielmi et al., 2022; Shidong et al., 2022) note that the transition to digital energetics based on the technologies of Industry 4.0 increases the risks for workers in this industry (Al-Haidan et al., 2022; Baur et al., 2022; Büscher, 2022).

However, in most cases, industrial robots and other "smart" technologies of industry 4.0 do not displace human resources, but transform the need for them and change the functional component of their work (Matsunaga et al., 2022; Niet et al., 2021; Shinkevich et al., 2021; Udin, 2020). At the same time, not purely cybernetic, but cyber-physical systems are being formed in the energy economy, in which the "smart" technologies of industry 4.0 (technological resources) are flexibly combined with other types of resources (natural, social, *etc.*) (Matsunaga et al., 2022; Morelli et al., 2022; Nathaniel et al., 2021a; Nathaniel et al., 2021b; Trzaska et al., 2021).

This leads, firstly, to the need for digital personnel capable of effectively using the "smart" technologies of industry 4.0 in the activities of energy companies, as well as subsequently developing new digital competencies as technological development proceeds (in accordance with the concept of lifelong learning) (Hoffmann and Thommes, 2020; Rolim and Baptista, 2021; Silamut and Sovajassatakul, 2021; Zaychenko et al., 2019).

Secondly, this results in the need to use advanced HRM practices that allow energy companies to create high-performance and knowledge-intensive jobs, introduce effective labor incentives for the fullest disclosure and development of human potential (Christina et al., 2017; Fatihudin et al., 2020; Lee, 2020; Wang, 2021).

At the same time, the consequences of the transition to digital energetics for human resources are poorly studied and ambiguous, and therefore represent a research gap. In particular, despite a large number of the existing publications, it is still unclear to which extent human resources are required in EnergyTech and what their significance/technological resources (high technologies of Industry 4.0) ratio is. Uncertainty of the social factors of digital energetics leads to incomplete scientific view of it.

Unjustified (due to the absence of the scientific and methodological support) personnel cuts by energy companies, in their striving for digital competitiveness could lead to unpredictable consequences. In particular, contrary to their expectations, this may lead to the loss of their competitive advantages (which are based on corporate knowledge). From the society's point of view, uncertainty of the future employment in the energy economy destabilizes the labor market and aggravates the social tension.

That is why, at the current stage of the development of EnergyTech, it is important to reveal and substantiate scientifically its needs for human resources (including digital personnel) in the long-term. This will be a signal for managing the social risks of EnergyTech for universities (e.g., the change of educational programs) and applicants (e.g., preferring alternative professions instead of energetics) and for the current energy personnel in the labor market (e.g., retraining or advanced training).

This research gap slows down the development of EnergyTech due to the contradiction and obscureness of social consequences (chances for employment, character of labor, possibility of human potential development) of the transition to digital energetics. In this article, the identified research gap is filled through a review of international experience and a case study of Russia's experience in implementing advanced HRM practices, training digital personnel in the education system and their distribution in the labor market in digital energetics based on the technologies of Industry 4.0.

International experience of the contribution of advanced HRM practices and digital personnel to the development of digital energetics based on the technologies of Industry 4.0

To study international best practices, this article provides a sample of the top 10 countries by the value of the Energy Trilemma index prepared by the World Energy Council

TABLE 1 Advanced HRM practices, digital personnel, high technologies of Industry 4.0 and energy sustainability in the top 10 digital energy economies of the world in 2021, score 0–100.

Top 10 digital energy economies of the world	Energy trilemma index	The knowledge index, reflecting the level of training and availability of digital personnel	Knowledge-intensive employment	High-tech manufacturing
Switzerland	84.2	86.929	83.1	89.8
Sweden	83.8	86.485	88.9	62.8
Denmark	83.0	81.415	79.2	63.4
Finland	81.7	77.181	79.2	52.3
Great Britain	81.7	76.031	82.3	58.2
Austria	81.0	77.166	67.4	59.0
France	81.1	68.044	75.0	66.9
Canada	80.6	81.795	70.4	48.5
Germany	80.4	75.854	74.6	74.6
Norway	79.6	73.499	84.3	42.2

(2022) in 2021, which are also the leaders of The IMD World Digital Competitiveness (WDC) rating (2022) in 2021. This makes it possible to characterize the sample countries as developed digital energy economies in terms of the use of high technologies, energy security and sustainability (environmental friendliness) of the energy sector, which makes their experience especially valuable for research.

The selection of the Energy Trilemma Index as an empirical basis of the research is due to the following: first, it is one of the most reliable and authoritative sources of statistics on energetics. Second, the advantage of the Energy Trilemma Index is that it fully (systemically) reflects the achieved progress in the implementation of SDG 7, covering 1) energy security (affordability of energy and absence of its deficit); 2) energy (general equal accessibility of energy); 3) environmental sustainability of energy systems (reduction of production waste, distribution and consumption of energy, and decarbonization of economy).

The choice of such a sample of countries is explained by the following: first, it includes the leading digital economies of the world according to IMD Business School (2022). Thus, the sample precisely characterizes the modern practice of the development of digital energetics based on the technologies of Industry 4.0 (EnergyTech). Second, the sample is optimal for this research, because it allows studying the experience of countries that reached the biggest success in the practical implementation of SDG 7.

Third, countries of the sample are known for their progressive HRM practices, which are based on a high level of corporate social responsibility and knowledge-intensive and highly-efficient jobs. Due to these reasons, the sample fits the research of advanced HRM practices and digital personnel for digital energetics based on the technologies of Industry 4.0. Experience of countries of the sample, which is systematized and reconsidered in this paper, will be useful for other countries, for it will allow world dissemination of advanced HRM practices of digital personnel management in digital energetics based on the technologies of Industry 4.0, thus supporting the development of EnergyTech and the practical implementation of SDG 7 at the scale of the world energy economy.

To determine the role played by digital personnel in the development of digital energy based on the technologies of Industry 4.0, a factor analysis of the Energy Trilemma Index is carried out (let us introduce the notation DE). The Knowledge Index calculated by IMD Business School (2022) (let us introduce the notation Hrm_1) acts as a factor of the level of training and availability of digital personnel (2022) (let us introduce the notation Hrm_2) acts as a factor of advanced HRM practices. For comparison with the noted social factors, a technological factor is also used—High-tech manufacturing according to the World Bank (2022) (let us introduce the notation Hrm_3). The values of the indicators selected for research in the sample of countries are systematized in Table 1.

The data were obtained from references to IMD Business School (2022), the World Bank (2022), the World Energy Council (2022).

Based on the data from Table 1, the following model of multiple linear regression is obtained:

$$DE = 63,27 + 0,13{*}Hrm_1 + 0,07{*}Hrm_2 + 0,05\,Hrm_3$$

In the resulting model, F-value was 0.02116 (the model is reliable at the significance level of 0.05 and therefore is characterized by high accuracy and reliability). The R-squared was 0.7804, therefore, the change in energy stability (energy trilemma index) by 78.04% is explained by the influence of the considered factor variables. The factor of the level of training and availability of digital personnel proved to be the most significant: an increase in the Knowledge Index by 1 point leads to an increase in energy sustainability (energy trilemma index) by 0.13 points.

The factor of advanced HRM practices was in second place in significance–an increase in knowledge-intensive employment by one point leads to an increase in energy sustainability (energy trilemma index) by 0.07 points. Technological factor - when increasing high-tech manufacturing by one point, it leads to an increase in energy sustainability (energy trilemma index) by 0.05 points. It was also found that with the maximum (100 points) values of all the factors under consideration, energy sustainability will increase by 7.39% from 81.71 points on average in the sample of countries in 2021 to 87.75 points.

This indicates an important positive role of digital personnel in the development of sustainable digital energy, and also indicates a much greater importance of social factors compared to technological factors (high technologies of Industry 4.0).

Advanced HRM practices: Case experience in training and managing digital personnel for digital energetics based on the technologies of Industry 4.0 in Russia

To clarify the quantitative results obtained, we will supplement them with a qualitative analysis of the case experience of training and managing digital personnel for digital energetics based on the technologies of Industry 4.0 on the example of Russia. Russia's experience is also advanced, as it is among the top 30 countries in the world for energy sustainability (energy trilemma index) and is included in the ranking of the world's leading digital economies (IMD business school, 2022). Consequently, a progressive digital energy economy has been formed in Russia, the practical experience of which is useful for other countries. The advantage of studying Russia's experience in this paper is that this allows covering not only the practice of developed countries (which was considered above) but also the practice of developing countries, expanding the specter of the applied use of the authors' conclusions.

In 2019, the Government of the Russian Federation adopted the national program "Digital economy of the Russian Federation," which is planned until 2024. The goals of the Program are the provision of wide accessibility of the Internet, coverage of all largest cities with 5G, protection of the information of citizens, business and the government, growth of the effectiveness of the main spheres of the economy (including energetics), and training of personnel for the work in the digital environment. Training and management of digital personnel is distinguished as a separate direction of the Program, which emphasizes its high priority.

In Russia, the development of digital energetics based on the technologies of Industry 4.0 takes place in accordance with the departmental project "Digital Energy" of The Ministry of Energy of Russia (2022), developed with the active participation of energy companies. In this regard, the broad involvement of private business in the normative legal regulation (creation of "rules of the game") of digital energetics is a feature and advantage of modern Russian practice.

One of the four objectives of the Project is "to ensure the training of highly qualified personnel for digital energetics," which involves "the development of sectoral educational programs and retraining programs for digital energetics," as well as "the creation and launch of sectoral educational centers based on universities" (Ministry of Energy of Russia, 2022).

In the period up to 2024, it is planned to implement the following sectoral measures of state support for the training and disclosure of the human potential of digital personnel in the digital energy industry of Russia (Digital Energy Association, 2022):

→ Provision of certificates for the development of digital competencies by employees of the energy sector;
→ State approval of the official competence map of digital personnel in the energy sector;
→ Organization of an independent assessment of the competence of digital personnel in the energy sector (personnel audit of energy companies).

One of the first government initiatives was supported by Kazan State Energy University (2022), which organized the work of a unique educational and research laboratory "Digital Switchgear" for training personnel in digital energetics.

The following innovative practices in digital energetics based on the technologies of Industry 4.0 are being implemented in Russia by Russian oil and gas companies (Oil and Gas Vertical, 2022):

– Automation of AI-based equipment maintenance: reduction of the staff of repair crews with their gradual replacement with digital sensors for collecting data on the operation of equipment;
– The transition of consulting analysts to remote work based on the Internet of Things: continuous remote monitoring of complex technological processes in remote fields;
– Development of human potential of employees using AR/VR technologies: training of personnel reserve with the help of simulators that accurately reproduce production processes in the field without the need to travel to remote areas;
– Professional corporate training using 3D printers: young employees improve their skills by practicing on 3D models of equipment that is not available for transportation to training centers;
– Intellectual support for managerial decision-making based on Big Data: risk assessment is partially automated to increase the productivity of managerial personnel;

– Creation of knowledge-intensive jobs in energy logistics using mobile applications: intra-corporate logistics and work with large clients is carried out through linear programming.

Discussion

The results obtained contribute to the literature on the topic of digital energy economy. In contrast to (Chadwick et al., 2022; Guglielmi et al., 2022; Shidong et al., 2022), the authors' conclusions of this article indicate that the transition to digital energetics based on the technologies of Industry 4.0 causes not so much new risks as new opportunities for workers in this industry. A quantitative analysis of the international experience of the contribution of advanced HRM practices and digital personnel to the development of digital energetics revealed the primary role of digital personnel in the sustainable development of energy with the secondary role of high technologies of Industry 4.0.

The qualitative review and analysis of advanced HRM practices of case experience in training and managing digital personnel for digital energetics based on the technologies of Industry 4.0 in Russia showed that digital technologies displace employees only from those few business processes that cannot be effectively performed by people or are unsafe for them. At the same time, most business processes (which are not subject to automation) are accompanied by increased employee participation and support for knowledge-intensive and high-performance employment, which contributing to the full development of human potential.

The practical significance of the findings is that the illustrated best practices are useful for other countries. The article offered a new way of looking at human resource management of energy companies, which should attract digital personnel and improve their management practices in order to support high-tech and sustainable digital energetics. This makes it possible to resolve the contradiction of the social consequences of the transition to digital energetics in favor of digital personnel as its key subjects.

Conclusion

The results obtained allow for the following conclusions. First, the key role of digital personnel and HRM practices in the development of digital energetics based on the technologies of Industry 4.0 is substantiated. This opens a new unique view of the Fourth Industrial Revolution, which is presented for the first time not through the lens of technical progress but the lens of social progress. This essentially new and original view shows the in-depth—social—nature of EnergyTech.

Due to this, the paper contributes to the new body of knowledge in the forming, but perspective, a sphere of human resource management in digital energetics. This conclusion allows bridging the gap between digital personnel and leading technologies, which leads to their systemic and highly-effective use in digital energetics. The substantiated high knowledge intensity of EnergyTech assigns it with previously unknown and leading ability to form cyber-socio-technical systems, facilitating the transition from Industry 4.0 to Industry 5.0.

Second, it is demonstrated that EnergyTech is accessible and develops successfully in developed and developing countries. The authors described a wide range of advanced HRM practices of digital personnel management in digital energetics (increase in labor safety, creation of knowledge-intensive jobs, training of personnel, and stimulation of efficiency growth) based on the technologies of Industry 4.0, which include AI, IoT, AR/VR, 3D printers and 3D models, Big Data, mobile applications, and linear programming. Management implications of this paper consist in the following: systematization and scientific analysis of the empirical and case experience of the implementation of advanced HRM practices of digital personnel management in digital energetics based on the technologies of Industry 4.0 allows energy companies around the world to perform a transition to EnergyTech and improve the results in the sphere of implementing SDG 7, using the practices that are described in this paper.

It should be concluded that a limitation of this research is its focus on the achieved results (implemented practices), while the process of their launch remained outside the scope of this paper. It seems that the process of implementing advanced HRM practices of digital personnel management in digital energetics based on the technologies of Industry 4.0 in the activities of energy companies is complex and rather long and must take into account the specifics of each company (e.g., its corporate culture and organizational structure). In it proposed that further studies pay attention to the scientific elaboration of the issues of implementing the described advanced HRM practices of digital personnel management in digital energetics based on the technologies of Industry 4.0 in the activities of energy companies.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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