The impact of war on human capital development in the renewable energy sector of Ukraine: challenges and adaptation

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The war in Ukraine has had a significant impact on the renewable energy sector, especially on human capital, which is a key element for the development of the industry. The challenges include four areas: physical insecurity, migration, employee psychological health, and the demographic crisis.

The **physical danger** to employees has increased due to the hostilities. Between 22 March and 31 August 2024, Russian carried out nine large-scale waves of coordinated attacks on Ukraine's energy infrastructure. According to the UN, these attacks resulted in the loss of about 9 gigawatts of production capacity [United Nations, 2025].

Migration of skilled workers to safer regions or abroad has also increased. It is estimated that between 5 t0 9 million Ukrainians have moved abroad, 3 million of which are of working age. In addition, a significant number of people are in the temporarily occupied territories [DW, 2025]. According to a survey by the Ministry of Economy, 19% of employers have lost up to 20% of their staff, 17% - 20-50%, and 15% - more than 50%

There is a deterioration in the mental health of employees due to stress, uncertainty and post-traumatic effects. According to a study by 4Service Holding, 71% of Ukrainians admit that the deterioration of employees' mental health significantly affects their professional performance. This is most often manifested in reduced productivity, inattention, and mistakes [Krasina O., 2023].

Among other areas, the demographic crisis, which is deepening due to population decline and male mobilisation, has a significant impact on human capital. In 2022, only about 195,000 children were born, the lowest number in the country's history, and this trend has intensified since 2022 due to the war. The mobilisation became more intense, the conscription age was lowered from 27 to 25, combined with losses at the front, led to an acute shortage of working-age people.

These challenges have an impact on the economic model of enterprises in the renewable energy sector in particular:

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1. Increased costs for staff adaptation and infrastructure restoration. The direct losses of Ukraine's energy sector due to Russia's full-scale invasion are estimated at more than $16.1 billion, and indirect losses are almost $40.4 billion [KSE, 2024].
2. Reduced efficiency due to a shortage of qualified personnel. Also, the available personnel face the problem of lack of reservation for renewable energy workers in Ukraine. Renewable energy (RES) workers are not included in the list of critical professions defined by the Ministry of Energy.
3. Difficulties in implementing innovative projects due to a lack of resources and human capacity. Due to the loss of control over some territories and the destruction of infrastructure after 2022, 75% of the country's wind and more than 20% of its solar generation remained in the occupied territories [BDO Ukraine, 2024]. This limits the opportunities for introducing new technologies and innovative projects in the sector.

The issue of human capital shortages in the renewable energy sector during the war is currently being studied at the analytical level by academic institutions:

1. **The economic context of the war:**

1.1. Studies by the National Academy of Sciences of Ukraine indicate a loss of 20% of engineers in the nuclear power sector due to migration and lack of staff renewal. For example, Zaporizhzhia NPP experienced a 15% reduction in staff after 2022.

1.2. The work of the Ptukha Institute records an increase in the share of women in technical professions from 23% to 34% (2014-2024), which is due to the mobilisation of men.

2. **Adaptation strategies of enterprises:**

2.1. Studies of productive forces show an increase in economic activity in western Ukraine (Lviv and Ivano-Frankivsk regions) by 12-18% after the relocation of enterprises from the frontline areas.

3. **3. Innovative approaches:**

3.1. Digital technologies, such as the AI system for monitoring the condition of NPP equipment (project of the National Academy of Sciences of Ukraine in 2023), demonstrate the effectiveness of digital solutions to compensate for the shortage of personnel.

3.2. Flexible business models with a focus on resilience. Research by the Ptucha Institute suggests integrating resilience indicators into human development assessment.

At the time of this study, the war is ongoing and these challenges remain relevant, and thus their monitoring, evaluation and analysis continue.In particular, the analysis of 6 expert interviews (management) with representatives of the sector between 1 January and 30 March 2025, indicates that, given the significant shortage of qualified personnel, human

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capital development is critical for the growth of the industry. Without adequate staffing, opportunities for innovation, project scaling and integration into the European energy system will be limited. Further research will clarify the soft and hard skills that the Ukrainian renewable energy sector expects from its workforce.

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