On the potential of Ukrainian higher educational establishments to satisfy the demand in personnel for renewable energy development

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Abstract. Green energy is a key factor for achieving global sustainable development goals. Energy safety is the basic condition for any state to function and for any economy to grow. Moreover, stable supply of energy resources is a pre-requisite for supporting adequate life quality level for the population, which is the main function of a state. In this context, the problem of training specialists in green energy has become an object of an increasing research interest in many countries, including Ukraine. Ukraine has not been experiencing any specific problems with energy security since gaining independence in 1991, except for minor issues with natural gas supply. However, in autumn and winter of 2022, the necessity to reconstruct the Ukrainian energy safety system became specifically acute. The factor having caused the problem is of a man-made nature and was brought forth by the neighboring state's military aggression. Russian military forces have been purposefully and methodically devastating the Ukrainian energy infrastructure with missile strikes over the past several months. Thanks to the technical and technological aid offered by partner countries and introducing emergency power outage schedules across the country, Ukrainian energy companies have managed to sustain the energy system in a relatively operational condition for three months by now. Nevertheless, we should envisage the future challenges and build a strategy for the post-war reconstruction of the Ukrainian energy system. Renewable energy sources have a colossal potential and may become a powerful force in the future development of Ukraine's energy industry. However, in practice, the energy industry must be supplied with a sufficient number of highly professional specialists to realize this opportunity. On the example of Ukrainian HEIs, this article offers an example and a methodology for analysing higher educational establishments' potential and preparedness to satisfy the predicted demand in personnel and to ensure sustainable development of the renewable energy market. Another finding of this research is the system of markers to measure the success of an educational programme in green energy which can be applied by educational institutions to build the programme enhancement strategy. Also, the authors define directions for perspective development of energy education in Ukraine.

1. Introduction

During the entire independence period, Ukrainian energy system has provided a stable and reliable footing for the economy. For instance, in the pre-crisis year of 2013, all areas of energy system operation collectively supplied 8.4% of the Ukrainian GDP [1]. This achievement became possible with significant natural deposits of energy minerals and fossil fuels (coal, natural gas, uranium) and the network of nuclear, thermal and hydroelectric power plants. The mentioned factors fully covered domestic consumer needs in energy resources and ensured

industrial development. In addition, a share of Ukraine's energy resources was exported, which was an added source of replenishment for the state budget. Earlier studies reported that reserves of natural energy minerals in the bowels of the earth should have been sufficient for tens and even hundreds of years, which would guarantee stable energy security for Ukraine [2]. Ukraine did experience problems with supporting the economy's need in natural gas; nonetheless, the problems had been solved every time. Also, the energy sector was fully equipped with the full professional and qualification spectrum of specialists who were trained at about two hundred higher education institutions all over the country [3], although the the facilities inherent in the country's energy infrastructure still needed to be radically modernized to comply to the current national needs and global environmental requirements. At that time, the leading specialists and energy scientists were engaged in studying this issue, as well as in improving the country's energy strategy.

Russian ongoing aggression in 2014-2021 and an unprecedented large-scale military attack in 2022-2023 brought drastic and destructive changes to Ukraine's energy security. Ukrainian territories owning the greatest potential of natural energy resources and energy extraction enterprises were either occupied or annexed by the aggressor state. Since March 2022, Zaporizhzhia nuclear power plant in Enerhodar has been under occupation. While military units of the aggressor army are located on the plant's territory, they are undertaking provocative actions that undermine radiation and nuclear security [4]. Also, in the first months of the war, Kakhovka Hydropower Plant was occupied, and Okhtyrka Thermal Power Plant was demolished. As a result of airstrikes by missiles and unmanned aerial vehicles on the Ukrainian energy infrastructure, about three quarters of the country's energy production capacity had been destroyed by mid-January 2023 [4]. The experts conclude that most of the damaged objects belonging to the country's energy infrastructure cannot be reconstructed. Quite apart from the losses caused by war and hostilities, it is considered inexpedient to restore several individual objects since they were put into operation in Soviet times and by the time they were destroyed, they had reached a critical level of moral and physical wear. In the aftermath of the above-mentioned losses in the energy system, scheduled and emergency power outages for end users have been introduced throughout the country. Such measures are temporary, and their purpose is to prevent the complete failure of the Ukrainian energy system. Thanks to implementing these measures and significant technical and technological aid from the partner countries, Ukrainian energy companies manage to support the energy system of Ukraine in a relatively operational state.

The situation described above has created an impetus to realize the need for technological modernization and transformation of the Ukrainian electricity generation in the post-war period.

As can be inferred from a detailed analysis of the statements articulated by the leading specialists at the Ministry of Energy of Ukraine and the goals declared by the Energy Strategy of Ukraine until 2050, it is expected that nuclear energy will remain the basic component of energy generation in Ukraine [4]. What is more, alternative energy sources should progress, and new products and innovative technological solutions should be searched for. The above prompts us to predict that the specific share of renewable energy in the structure of the overall electricity generation will grow. The roadmap for introducing and advancing renewable energy sources will create conditions for sustainable development and satisfy the principal requirements of environmental friendliness and climate neutrality, accessibility and social justice. In addition, such an action plan fully meets the goals of integrating the Ukrainian energy system into the European ENTSO-E power grid.

Renewable energy strategies can be realized in Ukraine if two interrelated conditions are met. The first condition requires implementing technical means and innovative engineering solutions to develop renewable energy in Ukraine. These tools and solutions are costly, and it will be exceedingly difficult to implement such projects in practice independently and autonomously

within a short period. Attracting grants and large-scale technical aid from developed countries together with searching for various other possibilities and sources will accelerate advancements in renewable energy.

The second mandatory condition is regular personnel supply. This condition requires from Ukraine independent and autonomous solutions. Therefore, it is urgent to assess the capacity of Ukrainian HEIs to train sufficient numbers of highly professional specialists in renewable energy on a regular basis. The success of the entire renewable energy development project in Ukraine will depend on the positive answer to this question.

Considering the above, this paper seeks to remedy these problems by analyzing the preparedness and capacity of Ukrainian HEIs to satisfy the expected demand for personnel in the growing renewable energy market.

2. Literature review

Education plays a key role in promoting environmental-friendly culture, primarily through perception and acceptance of ecological values by the youth. In recent years, this thesis has been attested by various methods and proved by scientists from such countries as the USA, China, Vietnam, Hungary, Brazil, Israel, India, Iran, Malaysia, and Nigeria [5–17]. Surveys such as those mentioned above prompted us to select the importance of educational policies in ensuring rational nature management in Ukraine as the main hypothesis of this study. In this context, growing knowledge about energy saving methods among young people and rapid transition of the economy to renewable energy sources within the framework of the practical implementation of the Sustainable Development Goals is particularly relevant.

Studies by Singh et al [8], Hoque et al [9], Friman et al [16] recommend familiarizing young people with the basics of renewable energy in primary and secondary schools through gamification, which will facilitate and promote a culture of rational energy resources use and is supposed to encourage teenagers to opt for higher education in the field of renewable energy. At the same time, Colmenares-Quintero et al [7], Kinol et al [17], and Eshiemogie et al [15] argued that significant attention should be paid to high-quality special training of energy engineering specialists by HEIs. Moreover, a study by Szeberényi et al has revealed that representatives of primary, secondary and higher schools believe that low-income families cannot afford using renewable energy sources [13]. Therefore, raising the living standard in the country is an effective factor in activating the transition to renewable energy sources. Taking into account the fact that a country's standard of living is significantly determined by the quality of higher education, sufficient attention should be paid today to improving the training quality of graduates in energy specialties at the universities. Colmenares-Quintero et al propose to improve the quality of training of energy engineers with Problem based learning and design thinking methods [7]. Ji has proved that the quality of higher education in the field of energy can be enhanced by increasing investments and strengthening the environmental component of training [11]. Saputro et al have substantiated introducing STEAM approach into the educational process that will deepen the students' comprehension of renewable energy sources [18]. Popescu et al. have indicated that introducing a pilot course on the technical, legislative and geopolitical aspects of the transition to renewable energy sources into the educational process of the university would be an advantageous approach [19]. We also fully support the conclusions made by Heffron and Foley that higher education should become the key tool for providing young people with specific knowledge and skills to prevent climate change on the planet [20]. To achieve this aim, as highlighted by Fartash et al, countries should develop a network of HEIs preparing a sufficient number of highly-qualified professionals in renewable energy and undertake in-depth research in this field [14]. It is also important for governments to foster interest and motivation among young people to obtain specific specialties in renewable energy.

3. Methods

The statistical data array analyzed in this study is drawn from five main sources.

The State Statistics Service of Ukraine has supplied data on the volume of the gross national product, the energy balance, and the number of people employed in various sectors of the economy [1]

The Unified State Electronic Database on Education in Ukraine has been used a source of information on the bachelor's and master's training programs in specialties 141 "Electrical power engineering, electrical engineering and electromechanics" and 145 "Hydropower engineering" in Ukrainian universities [3].

The normative framework has been outlined by the current legislative and regulatory acts issued by Verkhovna Rada of Ukraine and the Cabinet of Ministers of Ukraine, documents by the National Agency for Ensuring the Effective Use of Energy Resources and the International Renewable Energy Agency.

The data array obtained from the above sources served as the information base of this research. Both qualitative and quantitative methods were used in this investigation to visualize, prove and evaluate the information base:

(i) By employing the cartographic method, we attempted to visually represent the territorial distribution of Ukrainian HEIs, where training in specialty 141 "Electric power engineering, electrical engineering and electromechanics" is being delivered in the 2022-2023 academic year.

(ii) Selective and tabular methods were adopted to describe in detail the current educational programs for training bachelors and masters in the specialties 141 "Electric power engineering, electrical engineering and electromechanics" and 145 "Hydropower engineering" at Ukrainian HEIs, which focus on training professionals in renewable energy.

(iii) Logical generalization and comparative methods were used to explore and compare educational programs training specialists in renewable energy at Ukrainian HEIs with the highest contingent of students as of January 2023.

4. Results and discussion

Reducing or precluding any energy dependence of the country's economy on any other country is the basis for preserving independence, decision-making autonomy and provision for all domestic energy needs. This aspect is especially relevant if a country that owns significant reserves of energy resources pursues an overly aggressive foreign policy. The above exactly describes the situation Ukraine has recently found itself in, and one of the solutions that may be offered would be to realize the Ukraine's aspiration to autonomously provide for all the needs of the national economy in energy resources. This, among other things, can be achieved by diversifying the growing share of renewable energy in the total volume of energy generation in the country. Simultaneously, all areas of the country's life should transfer to the latest energy-efficient technologies. This will be an induced measure due to the fact that energy consumption per unit of manufactured products in the Ukrainian economy is 3-4 times higher than the similar indicators in the world's developed economies [21], whereas implementing the intended goals will allow to ensure an increase in the level of energy efficiency in Ukraine now and in the near future.

The idea of strengthening the role of renewable energy in the Ukrainian economy has been around for the past two decades and was not inspired by the war or the blackouts. In the Ukrainian legislation, the first normative documents highlighting certain aspects of developing renewable energy in the country date back to 2009. In fact, the first document discussing renewable energy in Ukraine was titled the Decree by the Cabinet of Ministers of Ukraine "On signing the Agreement on financing the program Supporting the implementation of the

Ukrainian Energy Strategy in the field of energy efficiency and renewable energy sources" No. 1524-p, dated December 16, 2009 [22]. The authority to secure the necessary financing under the 2010-2011 European Union aid program at the state level was entrusted to the National Agency for Ensuring the Effective Use of Energy Resources (now the State Agency for Energy Efficiency and Energy Saving of Ukraine [23]. In 2023, more than thirteen years after the decree was issued, the problem is still gaining momentum.

In October 2014, the Cabinet of Ministers of Ukraine approved the National Renewable Energy Action Plan for the period until 2020 [21]. Even though the deadline for implementing the plan has already passed, the document remains valid and relevant today. The document states that according to the calculations by the experts at the Institute of Renewable Energy at the National Academy of Sciences, the annual technically achievable energy potential of renewable energy sources in Ukraine is able to reach 50% of the total energy consumption in the country. In addition, the document envisaged increasing the share of renewable energy to 11.0% in the structure of Ukraine's own production. In the years preceding the war, the share of renewable energy in the structure of domestic production in Ukraine fluctuated within the range of 7.2-10.3% [24]. These data imply that it has not yet been possible to fully utilize the potential of renewable energy.

We believe that one of the reasons that did not allow the Ukrainian enterprises to unlock the utmost potential of renewable energy in Ukraine is the failure to attend to one of the most important and key components, that is, failure to provide the industry with highly qualified personnel. For instance, the National Plan had mentioned issues related to the personnel supply only twice – first, to assign the Ministry of Education of Ukraine, in collaboration with other institutions, to create educational and methodological support for the activities undertaken by centers for professional development and certification of specialists who install energy equipment that works on renewable energy sources; second – to recommend to include questions regarding the prospects for producing energy carriers from renewable energy sources and alternative types of fuel in Ukraine in the programs of educational institutions of all levels for the purpose of their popularization [21]. It follows that no questions related to training highly professional specialists in renewable energy were raised in the plan.

In December 2017, Ukraine joined the Charter and in February 2018 became a full member of the International Renewable Energy Agency (IRENA), founded in January 2009 [25, 26]. Participation in IRENA enabled Ukraine to access the world-class experience and knowledge in developing and implementing technologies for utilizing renewable energy. It is also important to receive specific practical recommendations on devising national policy provisions from the Agency's specialists. IRENA also implements measures that contribute to increasing the knowledge potential of participating countries, i.e., organizes special programs for training and education, and encourages scientific and research work. It is this function that is particularly important and relevant in the context of our research topic.

Thus, we can conclude that there is a clear understanding at the governmental level that development of renewable energy sources will become an indispensable condition for ensuring Ukraine's energy independence. In addition, renewable energy will save traditional fuel resources and improve the natural environment. However, a major step has not been taken at the regulatory level, namely, no prerequisites have been created to adequately staff the prospective renewable energy development projects.

The evidence suggests that alternative energy sources and renewable energy represent a lever for successful reconstruction of Ukraine, positive outcomes of which reach out far beyond the post-war period. However, there is a question that we cannot leave unanswered, that is, if Ukraine has sufficient human resources to achieve the ambitious goals set by the authorities. To answer this question, we will analyze the current situation in training renewable energy professionals in Ukraine. Training specialists capable of being directly engaged at renewable

energy facilities in Ukraine is being delivered within two specialties: 141 Power Engineering, Electrical Engineering and Electromechanics; 145 Hydropower [3]. Specialists trained in other related specialties (142-144) can also be employed in the renewable energy sector, although after appropriate retraining.

As of January 2023, 56 institutions of higher education in Ukraine are training specialists for master and bachelor's degrees in specialty 141. The territorial distribution of educational institutions is presented in figure 1 [3].

Figure 1. Territorial distribution of educational institutions training specialists in specialty 141 "Electrical power engineering, electrical engineering and electromechanics" in the 2022-2023 academic year.

The largest number of educational institutions training students in specialty 141 are concentrated in the Ukrainian cities of Kharkiv, Kyiv and Dnipro. This distribution is natural and predictable, since these cities represent regions with a substantial number of energy infrastructure facilities and industrial enterprises that need a constant supply of personnel trained in general energy engineering. In addition, institutions of higher education in Kyiv supply specialists for the rest of Ukrainian regions, since educational degree received at one of the capital's universities is considered more prestigious.

According to our observations, training specialists in electricity is being conducted throughout Ukraine, including higher education institutions temporarily displaced due to hostilities or occupation. Examples of displaced HEIs are Volodymyr Dahl East Ukrainian National University (relocated from Luhansk to Syeverodonetsk in 2014, and later, in 2022, to Kyiv), State Higher Educational Institution "Donetsk National Technical University" (relocated from Luhansk to Pokrovsk in 2014, and to Lutsk in 2022), State Higher Educational Institution

"Pryazovskyi State Technical University" (relocated from Mariupol to Dnipro in 2022), Donbas State Machine-Building Academy (relocated from Kramatorsk to Ternopil in 2022).

Tables 1 and 2 demonstrate that only 15 Ukrainian HEIs deliver undergraduate and/or graduate educational programs specializing in renewable energy [3]. Two educational programs are not institutionally accredited. Only four HEIs offer both bachelor and master programs.

The fact that most educational programs in renewable energy are accredited until mid-2023 or mid-2024 is of significant concern. Thus, out of 11 bachelor's level educational programs, three are accredited until July 1, 2023, and two programs are accredited until July 1, 2024. The prospects seem even gloomier for the graduate programs, since out of eight educational programs, one program is accredited until July 1, 2023, and five programs are accredited until July 1, 2024. One of the factors explaining this situation is the martial law, which has been introduced in Ukraine and which made it impossible to perform the full scope of accreditation procedures. At the same time, it cannot be guaranteed that all the existing programs will successfully renew the accreditation after the martial law expires. In other words, there is a certain risk of curtailing the currently existing educational programs.

At present, only 394 students in total are enrolled on all accredited educational programs related to renewable energy in all the four years of study. By the time the students are awarded their bachelor's diploma, it will require six months for those who are in the fourth year of study now (the nearest graduation is expected in July 2023) and up to three and a half years for those who are in the first year of study (2022 entrants are expected to graduate in July 2026). Qualified graduated bachelors will enter the labor market gradually, which will not immediately satisfy the potential demand for the number of professionals required to enable the renewable energy sector to develop intensively. In addition, some of these students will continue their studies being enrolled on graduate programs after completing the undergraduate degree, which will postpone their entry into the labor market and add another one and a half or two years to the graduation date from the undergraduate courses. At the moment, 91 students are enrolled on the existing accredited master degree educational programs in renewable energy. If these students do not choose to continue their studies at any of the postgraduate schools, they will enter the Ukrainian labor market as certified specialists in January-February 2024 and 2025.

Thus, in 2023-2026, the industry will be replenished with 485 certified professionals provided that all renewable energy education programs are successfully accredited and all students currently enrolled in education programs at the two educational levels successfully complete their studies, are awarded bachelor's and master's degrees, and join the workforce instead of joining the next educational stage.

In addition to graduates majoring in renewable energy, the Ukrainian labor market employs graduates majoring in the specialty 145 "Hydropower". Only three Ukrainian HEIs train specialists in Hydropower at undergraduate and graduate levels. These are The National University of Water and Environmental Engineering (in Rivne), Zaporizhzhia National University (in Zaporizhzhia) and National Technical University "Kharkiv Polytechnic Institute" (in Kharkiv). At all the three universities mentioned, the titles of educational programs for bachelor and master levels coincide with the name of the specialty.

Table 3 below presents the numbers of students who are pursuing an educational degree in specialty 145 "Hydropower" at Ukrainian HEIs in January 2023 [3].

The situation with accreditation seems to threaten only one educational program, which we do not consider critical. However, the number of certified specialists who will replenish the army of hydropower professionals in 2023-2026 will be only 104 specialists even under favorable conditions.

The statistical data above suggest that Ukrainian higher education institutions do not possess adequate potential to prepare more than 589 graduates in two renewable energy specialties by 2026. This number may satisfy the need in covering staff turnover and staff rejuvenation at

Table 1. The contingent of undergraduate students majoring in Electric Power Engineering, Electrical Engineering and Electromechanics studying in educational programs in renewable energy as of January 2023.

HEI	Educational program, number of undergraduate students (persons) and state accreditation validity
O.M. Beketov National University of Urban Economy in Kharkiv	Alternative and Renewable Energy Sources 91 (accreditation valid until 01.07.2028)
Lviv Polytechnic National University	Energy Systems for Sustainable Development 77 (accreditation valid until 01.07.2023)
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"	Alternative and Renewable Energy Sources 75 (accreditation valid until 01.07.2023)
Odesa National University of Technology	Alternative and Renewable Energy Sources 52 (accreditation valid until 01.07.2024)
Odessa Polytechnic National University	Renewable Energy Sources and Energy Complexes 51 (accreditation valid until 01.07.2029)
National Aerospace University "Kharkiv Aviation Institute"	Alternative and Renewable Energy Sources 33 (accreditation valid until 01.07.2024)
"Zaporizhzhia Polytechnic" National University	Renewable Energy Engineering 8 (accreditation valid until 01.07.2026)
Kyiv National University of Technologies and Design	Intelligent Systems in Renewable Energy and Electric Vehicles 7 (accreditation valid until 01.07.2023)
Ukrainian State University of Railway Transport	Alternative Energy Sources and Environmentally Friendly Transportation 0 (accreditation valid until 01.07.2027)
National University "Yuri Kondratyuk Poltava Polytechnic"	Renewable Energy and Power Supply for Electric Transport 8 (no accreditation data available)
Kyiv National University of Construction and Architecture	Alternative and Renewable Energy Sources 4 (no accreditation data available)
Total number of students pursuing the accredited educational programs	394

Table 2. The contingent of graduate students majoring in Electric Power Engineering, Electrical Engineering and Electromechanics studying in educational programs in renewable energy as of January 2023.

HEI	Educational program, number of graduate students (persons) and state accreditation validity
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"	Alternative and Renewable Energy Sources 16 (accreditation valid until 01.07.2024)
Odesa National University of Technology	Alternative and Renewable Energy Sources 20 (accreditation valid until 01.07.2024)
Odessa Polytechnic National University	Renewable Energy Sources and Energy Complexes 15 (accreditation valid until 01.07.2025)
National Aerospace University "Kharkiv Aviation Institute"	Alternative and Renewable Energy Sources 8 (accreditation valid until 01.07.2024)
Oles Honchar Dnipro National University	Alternative and Renewable Energy Sources 15 (accreditation valid until 01.07.2023)
Kherson National Technical University	Alternative and Renewable Energy Sources 13 (accreditation valid until 01.07.2024)
National Technical University "Kharkiv Polytechnic Institute"	Sustainable and Renewable Energy: Electrical Engineering and Microelectronics 4 (accreditation valid until 01.07.2026)
Yuriy Fedkovych Chernivtsi National University	Alternative and Renewable Energy Sources 0 (accreditation valid until 01.07.2024)
Total number of students pursuing accredited educational programs	91

the existing facilities. However, ensuring the expected increase in the share of renewable energy to 25% of the total volume of electricity generation in Ukraine is unlikely to be achieved in 2035 with these numbers of graduates. In addition, we should consider that highly professional specialists in renewable energy are highly valued in the labor markets of the world's developed countries. Since the salaries in these countries considerably exceed the salaries in Ukraine, the country may face the risk of young professionals' outflow.

To diminish the migration risks and increase the applicants' interest in studying educational programs in renewable energy at Ukrainian HEIs, we recommend to introduce success markers into their content. In order to determine such markers, we have analyzed three undergraduate educational programs and three graduate educational programs in renewable energy, which had the highest contingent of students at the corresponding educational level for the time of the study. The evidence received by analyzing specified educational programs [27–32] enabled us to formulate the following markers of the program's success:

Table 3. The contingent of students majoring in Hydropower as of January 2023.

HEI	Educational program, number of undergraduate students(persons) and state accreditation validity	Educational program, number of graduate students(persons) and state accreditation validity
The National University Water and Environmental Engineering	32 (accreditation valid until 01.07.2026)	12 (accreditation valid until 01.07.2026)
Zaporizhzhia National University	29 (accreditation valid until 01.07.2028)	10 (accreditation valid until 01.07.2028)
National Technical University "Kharkiv Polytechnic Institute"	16 (accreditation valid until 01.07.2025)	5 (accreditation valid until 01.07.2025)
Total number of students pursuing the accredited educational programs	77	27

(i) highly professional teaching staff involved in delivering the educational program, their high scientific potential and practical workplace experience in the field of renewable energy, command of foreign languages at a level sufficient to teach major disciplines

(ii) providing the educational process for the educational programs with modern certified laboratories with high-tech equipment, for example, Siemens, Kinco, Hitachi-Omron, Mitsubishi Electric. This can be seen in the case of Cherkasy State Technological University, where teaching specialists in energy has been significantly enhanced with the new equipment received under USAID program. A wide range of equipment, particularly, the demonstration stands, has been deployed to deliver disciplines "Electrical and structural materials", "Energy-saving modes and technologies", "Industrial electronics", which enables students, for example, to calculate solar energy, improves their professional practical skills, increases their satisfaction with the quality of the educational services and enhances the overall efficiency of the educational process

(iii) close cooperation and the availability of double degree programs with universities in France, Great Britain, the Netherlands, Spain, Portugal, Greece within the framework of EUREC graduate programs; with the universities of the Netherlands, Denmark and Norway within the framework of the Erasmus Mundus graduate programs in wind energy, with the universities of the USA, Austria and Germany within the framework of the graduate programs in renewable energy sources and sciences in the field of solar energy, etc.

(iv) introducing a practice-oriented approach to education. This can be illustrated by a positive example of collaboration between the Department of Electric Power Engineering and Control Systems (Lviv Polytechnic National University), LLC "Sambir Solar Station" and PE "Art-Energo". The laboratory of "Renewable Electricity" was equipped with modern equipment [28]. Another example is provided by the Renewable Energy Sources department (National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute") who initiated the Ukrainian-Polish Center for the Improvement of Renewable Energy Sources and Energy Efficiency Technologies, thanks to which both teachers and students have been acquainted with the leading experience of Polish universities and companies who are engaged in developing renewable energy and energy efficiency [29]

(v) opening possibilities for the students enrolled on the educational programs in renewable energy to participate in international mobility programs initiated by universities in the UK, Germany, Poland, Spain, etc. (with 1-2 semesters mobility period)

Replication or targeting the previously listed markers should spur demand for the educational programs in renewable energy among young people, as well as demand for the graduates among the potential employers. Implementing high-quality educational programs in renewable energy will build an effective ecosystem of electric car service in Ukraine, which will become an additional factor in improving the quality of life for the population and improve the environmental situation in the country [33]. A high-quality education will also encourage graduates to launch their own business in the field of renewable energy.

5. Conclusions

In summary, the results of this research show that in the near future, if the current situation in the specialist training in renewable energy persists, it will not facilitate achieving the goals of intensive development of renewable energy announced by the Ukrainian government. On this basis, this study formulates the most effective directions for increasing the number of highly qualified specialists in renewable energy on the Ukrainian labor market in the post-war period:

(i) increasing the level of remuneration in the renewable energy sector in Ukraine

(ii) securing more investments into the development of human capital, satisfactory working conditions and sufficient social package at renewable energy enterprises in Ukraine. Special attention should be paid to the social protection of young professionals and the development of their talents

(iii) expanding opportunities for professional development and retraining for specialists from the primary and secondary labor markets trained in specialties referred to specialism 14 to match the operational specifics related to the field of renewable energy. In this context, it is important to deploy the experience of both international renewable energy organizations and Ukrainian experience in the field of professional retraining for energy engineers

(iv) enhancing the activities performed by the HEI representatives in compliance with the requirements for successful accreditation of all current educational programs in renewable energy. In this context, it is important to focus on the best practices of the world's leading universities in specialized courses and educational programs.

(v) enriching curricula with the disciplines that acquaint students with the leading global experience in the field of renewable energy, the basics of international energy standards, and sustainable development management. It would also be beneficial to design educational programs so as to ensure the possibility of academic mobility for students, their practical training at leading renewable energy companies

(vi) launching existing educational programs at all educational levels for those HEIs where exclusively bachelors or exclusively masters in renewable energy are being trained at the moment. This will significantly expand the contingent and improve the quality of educational services

(vii) launching new educational programs in renewable energy at both undergraduate and graduate levels in Ukrainian HEIs within the scope of specialty 141. In this context, it is important to increase the level of productive cooperation between Ukrainian HEIs where specialized educational programs can launch in collaboration with the enterprises that operate in the industry

(viii) increasing the professional and qualification level of lecturers and teachers participating in delivering renewable energy educational programs. It is also important to continuously update the methodological base of the courses taught within the educational programs

(ix) increasing the prestige of the entire spectrum of professions related to renewable energy in public opinion. Regional and local authorities should play a key role in the implementation of this direction.

Implementing the above measures and the directions listed above within a short period of time will fetch a significant socio-economic and ecological effect. The social component will be ensured by reducing the number of the unemployed population and increasing the level and quality of life in Ukraine. The economic effect will manifest itself in a different way, that is, from a reduction in the Ukrainian economy's need for external energy resources to an increase in the share of energy in the gross domestic product. The country will be able to obtain an ecological effect through reducing negative consequences for the environment, which will be achievable due to a reduction in the production of the traditional energy resources.

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