4.2. ENERGY EFFICIENCY COMPONENT OF QUALITY ASSURANCE OF PROFESSIONAL TRAINING OF CONSTRUCTION INDUSTRY SPECIALISTS

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The mechanism for ensuring the quality component of professional training of construction industry specialists in the context of its focus on energy efficiency is described. This provides an opportunity for specialists to obtain fundamental energy-efficient professional knowledge, their systematization, generalization and deepening in the aspect of energy problems; the formation of skills and abilities in energy activities necessary for the formation of energy-efficient competence. The conclusion is substantiated that the training of future construction industry specialists in vocational education institutions is aimed not only at familiarizing them with traditional skills in the design and construction of structures, but also at understanding the principles of energy-efficient construction, circular economy, and the use of environmentally friendly materials. Future specialists should be prepared not only for the use of modern building materials, but also for such technologies as Building Information Modeling in construction, design automation and energy consumption management. At the same time, formation of energy-efficient competence of specialists in the construction industry is not only relevant, but also necessary step for the implementation of strategy for the balanced development of society, which involves the rational use of natural resources, reducing energy consumption, using energy-efficient technologies in construction, as well as the formation of environmental responsibility for environmental protection.

***Keywords**: construction industry, energy-efficient technologies, quality, professional training, professional education.*

In the context of active modernization of domestic vocational education, the problem of qualitative enrichment of the educational space through the integration of modern energy-efficient technologies is becoming particularly relevant, in particular for training of construction industry specialists requires careful consideration not only of the specifics of future work related to the construction and operation of energy-efficient structures, but also of creating conditions for the comprehensive professional development of graduate of VET-schools (Haiduk et al., 2021, p. 61). In the context of training construction industry specialists, the use of energy-efficient technologies also deserves special attention, the results of which, in our opinion, can quite reasonably be

attributed to the formation of an appropriate level of their energy-efficient competence (Anishchenko et al., 2018, p. 28).

It is obvious that energy-efficient competence, being complex, multifactorial and multilevel integral formation that encompasses knowledge, skills, abilities, value orientations and personal qualities, cannot be formed spontaneously or limited to passive assimilation of mainly theoretical knowledge from individual disciplines of the construction direction, but requires systematic and comprehensive implementation of various educational classroom and extracurricular pedagogical means within the framework of holistic, interconnected and continuous educational process in VET-schools (Gerliand et al., 2025, p. 31). In order for future builder to build energy-efficiently, he must: understand the principles of heat engineering; know modern materials, insulation, facade systems; possess technologies for installing energy-saving structures; work with modern tools and equipment; correctly apply manufacturers' instructions; understand the impact of his own work on the energy efficiency of the building (Yudenkova, 2023, p. 5).

Energy efficiency today is key pillar of the European Union's energy policy, aimed at reducing its impact on the environment and climate. Ukraine should also strive for the highest standards of energy efficiency. Today, this issue is one of the priorities, since according to global estimates, Ukraine ranks second in terms of energy intensity (Denysiuk, 2013, p. 8). Energy efficiency in the modern world goes far beyond simple resource conservation, transforming into strategic imperative to ensure sustainable development and national security, acting not only as means of overcoming the energy crisis, but also as fundamental element of reducing the negative impact on the environment. This understanding of energy efficiency reflects its evolution from purely technical or economic issue to broad concept that encompasses the shared responsibility and sustainability of the state.

Analysis of international experience provides an opportunity to outline key principles and effective practices of energy-efficient and environmentally friendly construction that have been widely implemented in foreign countries. In particular:

1. Reducing energy consumption. Achieved through the implementation of thermal insulation solutions, the use of modern heating and air conditioning systems, energy-saving LED-lighting and other technologies aimed at reducing energy costs.

2. Ecologically adapted design. The impact of the building on the environment is taken into account: careful selection of the development site, preservation of the landscape and natural resources.

3. Effective thermal insulation and constructive solutions. Modern materials and technologies are used that help minimize heat loss and maintain a stable internal microclimate (Nesterova et al., 2012, p. 64).

4. Rational climate comfort systems. Installation of energy-efficient heating, ventilation and air conditioning systems that optimize energy consumption.

5. Integration of renewable energy sources. Widespread use of solar panels, wind turbines and other sources of renewable energy.

6. Rational water use. Installation of rainwater collection, purification and reuse systems helps save water resources.

7. Use of environmentally friendly materials. Preference is given to materials with a low carbon footprint, recyclable or with the possibility of further processing.

8. Integrated waste management. Strategies for reducing construction waste and its reuse are being implemented.

9. Ensuring a healthy environment. “Green” buildings are designed taking into account the comfort of users: high-quality natural lighting, ventilation, and a favorable microclimate are provided.

10. Environmental certification. To confirm compliance with the principles of sustainable development, buildings can receive international certificates, such as LEED (Leadership in Energy and Environmental Design) or BREEAM (Building Research Establishment Environmental Assessment Method) LEED and others, which certify the level of their energy efficiency and environmental friendliness.

In developed countries of the world, such as the USA, Canada, Japan, European Union, etc., energy efficiency issues in construction have been in the focus of state policy for several decades. These countries have made significant progress in developing and implementing advanced technologies, promoting the use of renewable energy sources and creating effective regulatory frameworks.

International experience also confirms the importance of renewable energy sources (RES) in the construction industry. In particular, the use of solar, wind and geothermal energy in building design has reduced dependence on traditional energy resources. Global practice in the construction industry is increasingly demonstrating the significant potential of integrating RES to ensure energy sustainability and reduce environmental impact. Various RES technologies are used at different stages of the life cycle of buildings and infrastructure facilities, offering effective solutions to cover a significant part of their energy needs.

The main trends observed at the international level are:

- passive design principles: the use of strategies that optimize building orientation, insulation, and cladding systems to maximize natural light and ventilation while minimizing heat loss;
- modern materials and technologies: the development and implementation of innovative building materials play crucial role in the energy efficiency of building, such as high-performance insulation (vacuum insulation panels provide excellent thermal efficiency, significantly reducing heating and cooling needs); electrochromic glass, which adjusts its tint depending on the intensity of sunlight, helps control solar heat and glare; green concrete (the use of recycled aggregates and alternative cement substitutes reduces the carbon footprint);
- building information modeling (BIM) allows architects and engineers to virtually model the characteristics of building before construction begins, determine potential energy efficiency, and optimize designs to achieve maximum efficiency;
- integration of renewable energy sources, such as solar photovoltaic panels and geothermal systems directly into buildings, dramatically reduces dependence on fossil fuels;
- SMART-building technologies: advanced control systems can monitor and optimize energy consumption depending on the number of people, weather conditions and other factors (intelligent thermostats, automatic lighting control, energy management systems, etc.).

As we can see, in Ukraine, energy efficiency issues in construction have begun to develop actively in recent years, especially after the signing of the Association Agreement with the European Union and the adoption of a number of legislative acts aimed at implementing European norms and standards. The introduction of energy-efficient technologies into modern construction and architectural practice in Ukraine is a multifaceted process that covers various areas of application: from the modernization of the existing housing and commercial stock to the integration of innovative solutions in new buildings and reconstruction projects.

Today, the training of future construction industry specialists in vocational education institutions is carried out on the basis of relevant standards, the structuring of the content of which is based on competency-based approach, which involves the formation and development of key and professional competencies in students. Key competencies enable an individual to understand the situation, achieve success in personal and professional life, acquire social independence and ensure effective professional and interpersonal interaction (Stopina et al., 2018, p. 6). Professional competencies determine the ability of a person, within the limits of authority, to apply special knowledge, skills and abilities, to demonstrate appropriate moral and business qualities for the proper

performance of established tasks and responsibilities, training, professional and personal development. At the same time, one of the key competencies is environmental and energy-efficient, which include knowledge: of the basics of energy efficiency; regulatory and legal acts in the field of energy conservation, ecology; methods of energy-efficient use of materials, resources, and energy-saving equipment in professional activities and everyday life; methods of energy saving at the enterprise; rules for sorting garbage, waste disposal; basics of rational use, reproduction and conservation of natural resources; methods of preserving and protecting the environment in professional activities and everyday life, as well as the ability to: rationally use energy resources, consumables in professional activities and everyday life; use energy-efficient equipment; comply with environmental standards in professional activities and everyday life.

Ecological and energy-efficient competence is formed throughout the educational program depending on the learning outcomes. The formation of energy-efficient competence in students has a number of important aspects, in particular: practical significance (most professions acquired in vocational education institutions are somehow related to energy consumption (construction, electricity, technological processes, etc.). Therefore, knowledge of the principles of energy saving is not an additional skill, but a mandatory component of professional training); formation of environmental awareness (energy-efficient behavior in everyday life is becoming the norm in many countries of the world. Raising a responsible attitude towards resources in young people contributes to the formation of a culture of sustainable development); demand in the labor market (the modern market requires specialists who not only perform technical tasks, but are also able to assess the energy efficiency of processes, offer optimization competitiveness of graduates); integration into the European educational space (the development of energy-efficient competence meets the requirements of international standards and contributes to the harmonization of Ukrainian vocational education with European educational models) (Haiduk et al., 2021, pp. 11–12).

So, it is energy-efficient competence that is an important element of the training of a modern specialist. Its formation in vocational education institutions is a strategically important step towards modernization, improving its quality and practical value, and contributes to the formation of responsible specialists capable of working in accordance with environmental standards.

For example, future specialists in the construction industry must not only possess traditional professional skills, but also have developed energy-efficient competence, which allows them to make rational technical decisions in the process of designing, constructing and modernizing buildings (Gerliand et al., 2025, p. 33). The main areas of formation of such competence include: mastering modern construction technologies,

understanding regulatory requirements, practical application of energy efficiency principles, formation of environmental and professional responsibility.

In addition, it is important to integrate interdisciplinary modules into curricula that combine knowledge of natural sciences, labor protection – this is allows you to create a holistic vision of environmental friendliness and energy efficiency as comprehensive professional skill.

The implementation of energy-efficient technologies in vocational education institutions in the construction industry covers wide range of technical solutions aimed at optimizing energy consumption and creating comfortable learning environment. One of the most common and effective areas is the thermal modernization of buildings. It includes set of measures, such as insulation of roofs, facades, installation of energy-efficient windows and doors, as well as thermal insulation of pipes. This may include replacing window structures with modern energy-efficient ones, demonstrating the practical application of these approaches, which has become part of the educational process. Heating and ventilation systems are also subject to modernization. This involves converting boiler rooms to alternative, more economical energy sources and installing modern room temperature control systems to optimize heat consumption.

The emphasis on both passive (insulation, daylighting) and active (smart systems, renewable energy sources) energy efficiency technologies reflects a comprehensive approach to the energy efficiency of buildings. This approach goes beyond simple fixes and aims for integrated, data-driven solutions. The combination of these approaches demonstrates that modern practices do not favor one approach over another, but rather advocate their synergistic integration. Such holistic strategy maximizes energy savings and operational efficiency, which, in turn, requires diverse and complex set of skills for implementation, maintenance and optimization, which directly affects the curricula and training needs for the construction industry in vocational education institutions.

Therefore, the formation of energy-saving behavior among vocational education students and staff is key. This includes simple but effective actions such as turning off the lights, unplugging electrical appliances after use (even computer that is turned off and plugged in continues to consume energy), and closing doors tightly. These seemingly insignificant habits can save impressive amounts of money on an educational institution scale per year. Increasing the culture of energy consumption is achieved through active educational work. This includes the production and placement of leaflets, stands, posters, drawings on energy-saving topics in educational institutions. The goal is to popularize the economic, environmental and social benefits of energy saving, as well as to increase the educational level of all participants in the educational process in this area. Monitoring and accounting for energy consumption is also an important aspect. Implementation of

the principle The establishment of energy consumption limits in physical terms and the transition to the application of basic level of fuel and energy consumption based on compliance with sanitary norms and rules is an important step. However, there is a need to improve the monitoring of energy consumption, as there is often a lack of accounting data, insufficient observations of weather and other factors that significantly affect the volume of consumption, as well as the lack of multi-year databases for qualitative analysis.

Behavioral and organizational changes are recognized as crucial, cost-effective components of energy efficiency, complementing technological upgrades and emphasizing the importance of the human factor in sustainable energy management. Educational programs should be aimed at developing both technical skills and important Soft-skills related to awareness, responsibility and effective energy management.

To implement these provisions, an online survey was conducted using the Google Forms web service using a specially designed questionnaire. In total, 285 teachers of various qualification categories, teaching titles and work experience from 17 regions of Ukraine and the city of Kyiv were surveyed.

By their professional experience, the respondents were distributed as follows: 46.0% − have been working in a vocational education institution for over 20 years; 12.6% −15-20 years; 11.6% − from 10 to 15 years; 11.2% − from 5 to 10 years; 18.6% − from 1 to 5 years.

The institutions that participated in the survey represented wide regional spectrum of Ukraine, most of all − Kharkiv, Kyiv, Vinnytsia, Sumy and Khmelnytskyi regions.

The responses received demonstrate that teachers are clearly aware of the key principles of energy efficiency: role of modern technologies in increasing energy efficiency (41.8%) and the importance of building insulation and modernization of heating systems (43.9%) were identified as priorities.

The most important modern technological solutions were recognized as: the use of energy-efficient equipment (47.4%), SMART-management systems (24.6%) and building automation systems (28.0%). The absolute majority of respondents support the integration of renewable energy sources into construction, primarily solar energy (62.1%).

Teachers also highly appreciated the importance of thermal insulation materials and innovative design solutions that should ensure the energy efficiency of buildings. In their opinion, the educational programs of vocational education institutions should include such topics as “Fundamentals of Energy Efficiency” (28.4%), “Methods of Increasing Energy Efficiency” (27.4%) and “Practical Skills and Cases in Energy Efficiency” (25.3%).

Most teachers (83.5%) note that their vocational education institutions teach subjects aimed at developing energy-efficient competence in students, but they mostly rate the level of knowledge and practical skills of graduates as average (over 77.5%). This indicates the need to improve the content and teaching methods.

The most effective teaching methods are identified by respondents as practical workshops (41.8%) and interactive trainings (31.2%), which indicates the need for a practice-oriented approach in developing energy-efficient skills in students. At the same time, cooperation with specialized organizations (65.6%); development of continuous training programs (12.3%); motivation to learn energy efficiency (16.8%).

Despite significant efforts by vocational education institutions, only 22.5% of teachers believe that educational programs fully meet the labor market requirements for energy efficiency, while 70.8% assess them as partially adapted. Similarly, the quality of educational materials is mostly rated as satisfactory, which confirms the need for updating resource provision.

Participation in real projects (65.3%), an increase in the number of practical classes (50.9%) and cooperation with employers are the main factors that, according to teachers, can significantly increase the motivation and effectiveness of training for vocational education applicants.

In general, the survey demonstrated a high level of awareness among teachers of the importance of energy-efficient training for future construction workers, but indicates the need for systematic updating of educational programs, increasing the practical component of vocational education, developing partnerships with business and introducing modern technologies and materials into the process of vocational training.

Analysis of the results obtained showed an average level of formation of energy-efficient competence of future construction industry specialists in four components.

The highest percentage has an average level of formation of the informational-cognitive component (77.6%), in second place is the organizational-activity component (75.4%), in third place is the personal-reflective component (75.1%), and in the last place is the motivational-value component (69.8%). Therefore, there is a need for the formation of energy-efficient competence of vocational education applicants, which should be implemented in the form of a comprehensive methodology, the gradual introduction of interdisciplinary, professionally oriented projects, a case method, etc.

The results of the study of the state of the problem of training future qualified workers in the construction industry to use energy-efficient technologies in professional activities made it possible to form the following conclusions:

- energy-efficient technologies are an integral part of the modern construction industry, and their application is considered a key factor in improving the quality of

construction and installation works, reducing energy consumption, ensuring environmental safety and competitiveness of enterprises;

- the level of integration of energy-efficient technologies into the vocational education system ranges from fragmentary to systemic, depending on the region, educational institution and the availability of a modern material and technical base. Most vocational training programs require updating the content taking into account innovative construction technologies;
- domestic educational and methodological support on the topic of energy efficiency is insufficiently didactically structured: limited number of training manuals, methodological developments and practice-oriented materials aimed at forming energy-efficient competence of future builders were identified.

Thus, the survey demonstrates high level of awareness of the importance of energy-efficient training of future construction industry specialists, but indicates: insufficient number of educational materials and equipment; lack of special training in the field of energy efficiency for proportion of teachers; fragmentation of interdisciplinary connections; limited experience of vocational education applicants in the practical application of energy-efficient technologies.

The development of energy efficiency in Ukraine will allow to compensate for the shortage of personnel engaged in the restoration of destroyed facilities, to become a stable sector of the economy and one of the types of long-term activity. We consider the implementation of innovative approaches to energy efficiency management in vocational education institutions to be particularly relevant in the context of the state policy of energy independence and Ukraine's integration into the European educational and energy space. Today, it is important not only to use modern energy saving technologies, but also to form energy-efficient competence of future specialists, which is an important component for the effective implementation of policies in the areas of energy efficiency and energy conservation.

Thus, the implementation of the energy component of professional training of construction industry specialists is impossible without taking into account modern practices of implementing energy-efficient policies in vocational education institutions, which is an important and timely step on the path to sustainable development, energy independence and modernization of the education system of modern Ukraine.