Methodological report

Title: Obtaining skills in developing bioenergy projects

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PROJECT	
Project number:	101085172
Project name:	[Bioenergy innovations in waste management: European experience in implementing a circular economy]
Project acronym:	[BIOINWASTE]

Duration:	from [01/10/2022] to [30/09/2025]

This methodological report is linked to Deliverable 3, which summarizes the process and results of activities aimed at developing participants' practical skills in project development and evaluation in the field of bioenergy. As part of the Jean Monnet module, students and teachers are actively involved in studying, analyzing, and discussing the best international and European practices in the field of bioenergy development.

Content:

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1. Executive Summary

The Jean Monnet Module "Bioenergy innovations in waste management: European experience in implementing a circular economy" (BIOINWASTE) was designed to promote the study of European experience in the development and application of sustainable bioenergy technologies within the Ukrainian academic environment. The module aimed to enhance the competencies of students, academic staff, and representatives of the non-academic community in the field of bioenergy, waste recycling, and environmental safety by integrating EU best practices and policy approaches.

The module addressed several critical challenges, including the lack of practical skills for introducing bioenergy and waste recycling technologies at the local level, and the absence of introductory courses on environmental safety and renewable energy in line with EU experience. To bridge these gaps, the project introduced an interdisciplinary training approach that combined theoretical instruction with practical, project-based, and research-oriented activities.

The course *"EU Implementation of Bioenergy Technologies for Waste Recycling"* (60 academic hours) was implemented in online formats and covered a wide range of topics such as the EU bioeconomy, waste management, biomass characterization, biofuel production technologies, carbon capture and storage, and case studies of bioenergy projects in European countries. The program was complemented by open-access webinars, virtual visits to European research centers (including the Czech University of Life Sciences Prague and Linköping University in Sweden), and interactive discussions with EU experts.

Participants developed key competencies in designing bioenergy projects, conducting feasibility studies, and assessing environmental and economic performance according to European standards. Project-based assignments and teamwork activities helped students simulate real-world scenarios of local bioenergy implementation. Through this process, they gained experience in interdisciplinary collaboration and applied problem-solving.

The module also established a research and academic network between Ukrainian and European universities, facilitating knowledge exchange, joint research, and co-authored academic publications. These activities contributed to institutional capacity building in research and education on anaerobic digestion technologies and the valorization of waste by-products.

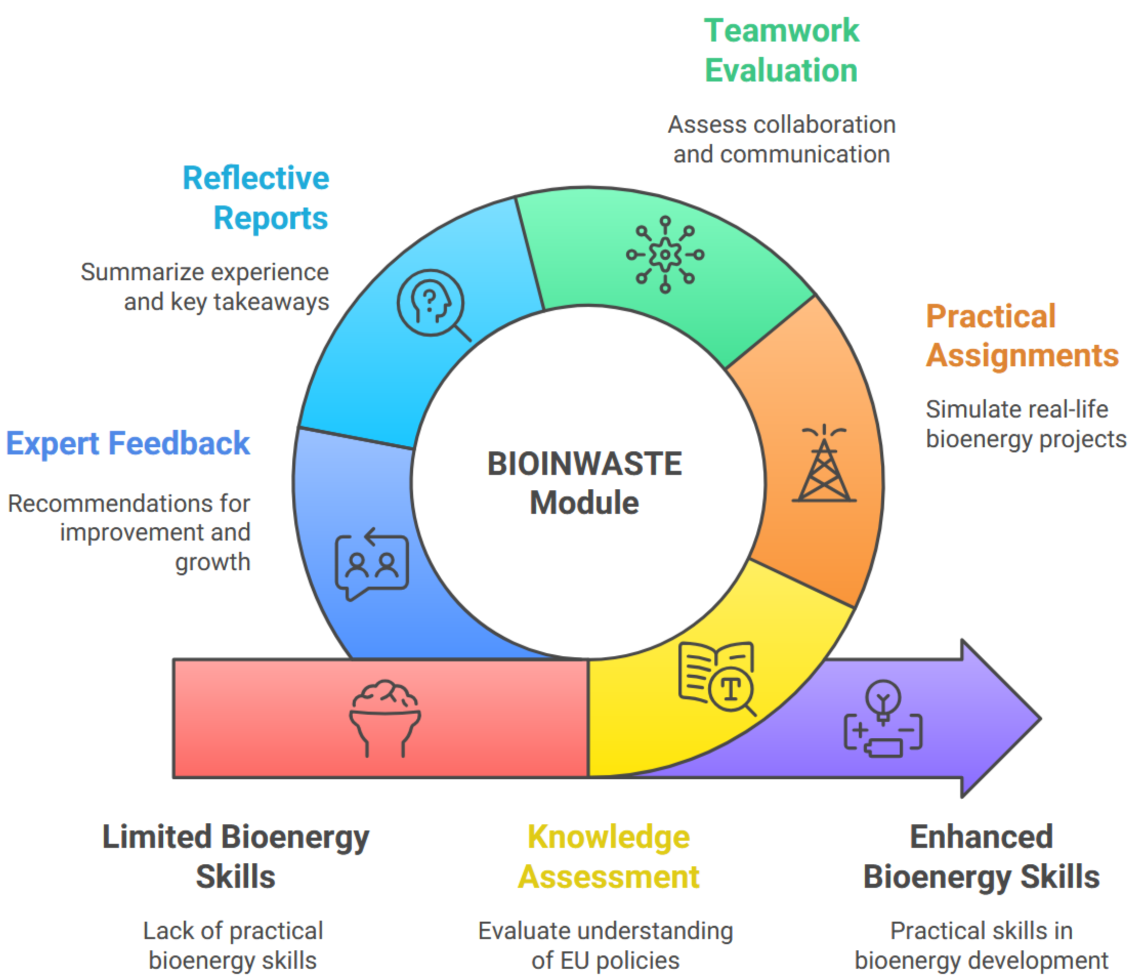
The outcomes of the module include:

- Enhanced practical and analytical skills of over 500 students and academic staff;
- Development of pilot project proposals for local bioenergy initiatives;

- Strengthened cooperation between Ukrainian and EU universities;
- Broadened public awareness of bioenergy's role in environmental protection and sustainable development;
- Integration of EU experience and methodologies into the Ukrainian higher education curriculum.

Overall, the BIOINWASTE module has successfully achieved its objectives by promoting European values of sustainability, innovation, and collaboration. It has become an integral part of multidisciplinary training in environmentally friendly biotechnologies and has laid the groundwork for continued research cooperation and curriculum modernization aligned with EU environmental and energy priorities.

Graphical Abstract



2. Training Methodology

The implementation of the deliverable 3 "Obtaining skills in developing bioenergy projects" will be based on an integrated methodological approach combining theoretical learning with practical, research-oriented, and project-based activities. The methodology aims to ensure the acquisition of specific competencies in developing bioenergy projects, drawing upon the best European practices in waste recycling and bioenergy technologies.

The training course will be organized both on-line to ensure wide accessibility for participants from academic and non-academic backgrounds. The structure of the course is designed to close the existing gaps in practical skills related to the introduction of bioenergy and waste recycling technologies at the local level, as well as to fill the curricular gap concerning introductory training in environmental safety issues and European experience in this field (Fig.1).

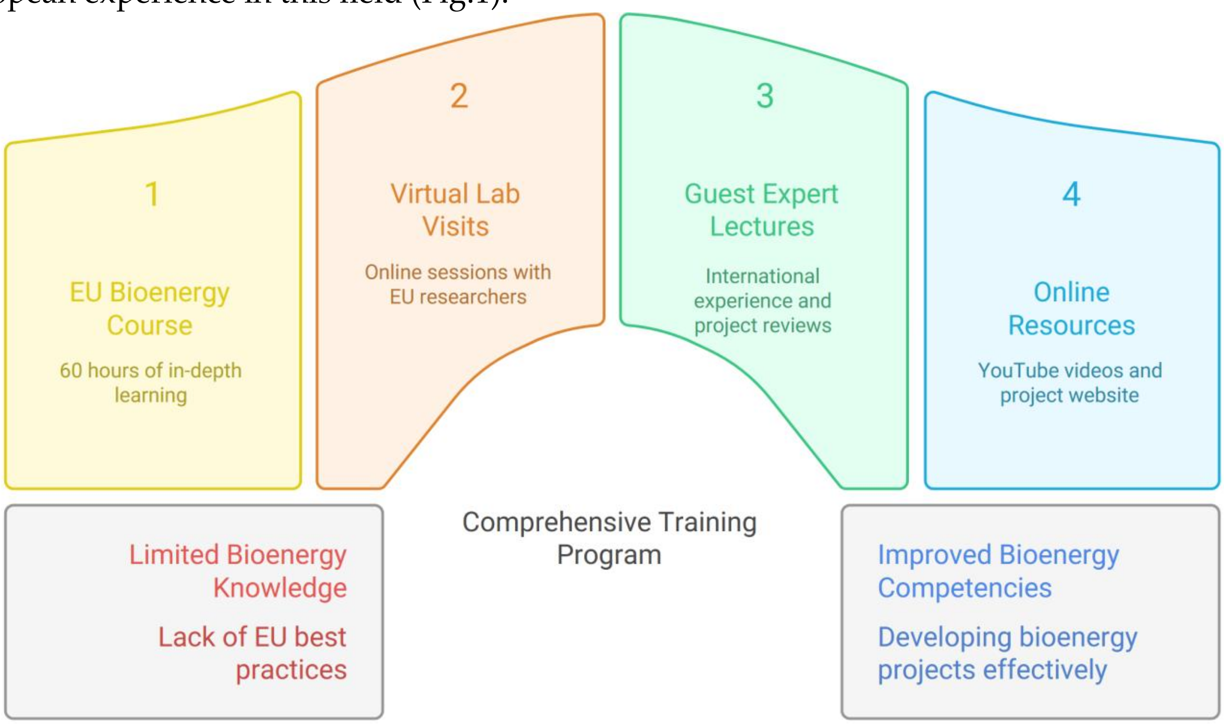


Figure 1. Methodological Approach

Key methodological elements include:

- **Competence-based learning:** Development of participants' applied skills in project design, feasibility analysis, and implementation of bioenergy initiatives based on EU models and sustainability principles.

- **Interdisciplinary approach:** Integration of knowledge from environmental engineering, biotechnology, economics, and public policy to form a holistic understanding of eco-friendly bioenergy systems.
- **Research-driven activities:** Capacity building in research and studies (R&S) on anaerobic digestion technology of waste recycling, with special attention to the potential use of chemical by-products, taking into account both economic and environmental aspects.
- **Network cooperation:** Formation of an academic and research network between Ukrainian and European institutions to enhance competitiveness within the European education and research area, enabling joint initiatives and experience exchange.
- **Collaborative learning:** Organization of workshops, discussions, and project simulations to promote teamwork and critical analysis of European best practices in bioenergy project management.
- **Publication and dissemination:** Cooperation in preparing co-authored academic papers and conference materials to ensure further professional and institutional collaboration.

The course will become an **integral part of advanced multidisciplinary professional training** in environmentally friendly biotechnologies. Through shared experiences, collaborative research, and interaction with EU experts, participants will develop a practical understanding of bioenergy project development processes — from idea generation to feasibility study and sustainability assessment.

3. Overview of EU Best Practices

The European Union (EU) has established several best practices for bioenergy projects, focusing on sustainability, efficiency, and regional adaptability. These practices are essential for optimizing biomass resources and ensuring that bioenergy contributes effectively to the EU's renewable energy targets. The following sections outline key aspects of these best practices.

Holistic Framework for Biomass Utilization

- A comprehensive approach is necessary for the sustainable exploitation of biomass, integrating food, energy, and other products.
- Small and medium-scale applications are emphasized for their flexibility and adaptability to local conditions, which enhances their feasibility and sustainability(Karaoglanoglou et al., 2012).

Policy and Investment Strategies

- The EU has implemented various policies to mobilize bioenergy value chains, with a focus on national approaches that address barriers to utilization(Mozaffarian et al., 2016).
- In Finland, significant investments in bioenergy projects, particularly in biorefining, have been made through structural funds, with a total budget of 64 million euros allocated for 155 projects(Ranta, 2025).
- Policies, implemented and being considered in the UK, promote the use of biogas from anaerobic digestion (AD) (Haodong Lin et al., 2024)

Future Prospects and Challenges

- Bioenergy currently accounts for about 10% of Europe's energy supply, with potential for growth, although future contributions may be moderate due to existing limitations(Kircher, 2024).
- The integration of carbon capture and utilization (CCU) and carbon capture and sequestration (CCS) is recommended to enhance the sustainability of bioenergy

After analyzing studies on life cycle assessment of organic waste management (Buratti et al., 2015; Jensen et al., 2016; Mayer et al., 2021), the following possible management scenarios were identified: undifferentiated collection; landfill disposal; mechanical and biological treatment; incineration in incinerators; combination of anaerobic digestion with incineration; anaerobic digestion accompanied by solid digestate; separate collection and production of high quality compost; combined biogas and composting production; hydrothermal carbonization. Furthermore, a crucial aspect is the processing of various types of waste, including those from the chemical industry. Specifically, this includes the integration of phosphogypsum – a byproduct of phosphate fertilizer production – into agricultural bioprocesses (Chernysh et al., 2023).

Fig. 2 illustrates the involvement of agriculture and forestry in the bioenergy sector as a supplier of stable raw materials.

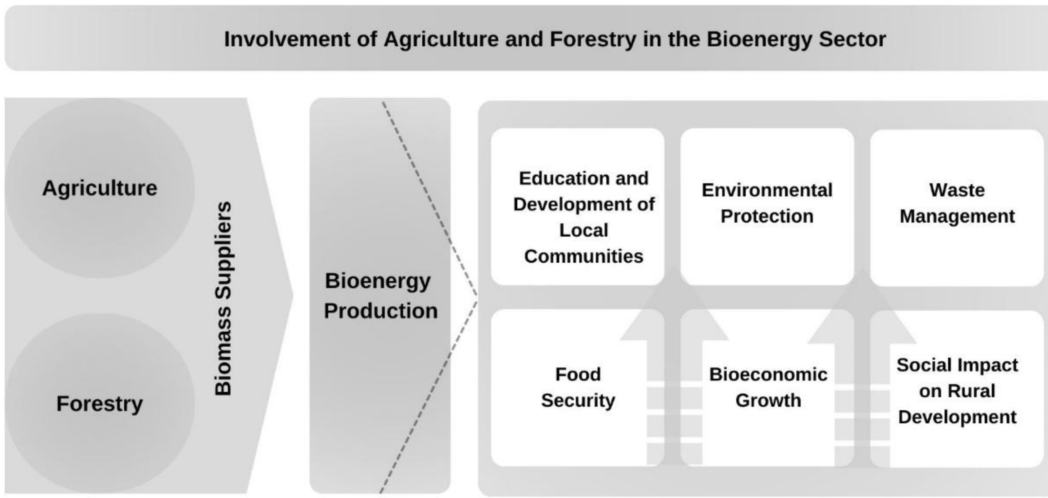


Figure 2. Involvement of Agriculture and Forestry in the Bioenergy Sector

The primary commercial challenge in biofuel production is the high cost of production, which directly affects the fuel price. In addition to reducing the cost of biofuels, technological advances play a crucial role in reducing production costs, leading to biofuels becoming a prominent source of renewable energy. Therefore, the development of advanced biodiesel and bioethanol production technologies is imperative to increasing biofuel production output (Hasan et al., 2023).

In addition, fiscal and regulatory policies to attract investors and fund research on biofuels from biomass feedstocks remain a challenge. Given the substantial costs associated with project implementation and infrastructure development, it may be challenging for the private sector to fully finance such projects. Obtaining a loan or financial support to initiate investments in the biofuel industry can be a difficult task under certain circumstances.

The advancement of the bioenergy economy requires overcoming several challenges related to competition for agricultural land, rising food prices, difficulties with technological progress, and obstacles in infrastructure development (Hasan et al., 2023). The current state of biotechnology allows for the production of environmentally friendly products while preserving the environment, significantly contributing to the development of methods for efficient and sustainable business operations.

While these best practices provide a robust framework for bioenergy development, challenges remain, particularly in achieving uniform implementation across member states and addressing the environmental impacts associated with biomass sourcing.

3.1. Sustainable Feedstock Sourcing

Adherence to Sustainability Criteria

All bioenergy projects must adhere to the EU's sustainability criteria for biofuels and bioliquids, as outlined in the Renewable Energy Directive (RED) II. This includes demonstrating greenhouse gas (GHG) emission savings compared to fossil fuels, protecting land with high biodiversity value, and ensuring sustainable agricultural practices (Fig. 3).

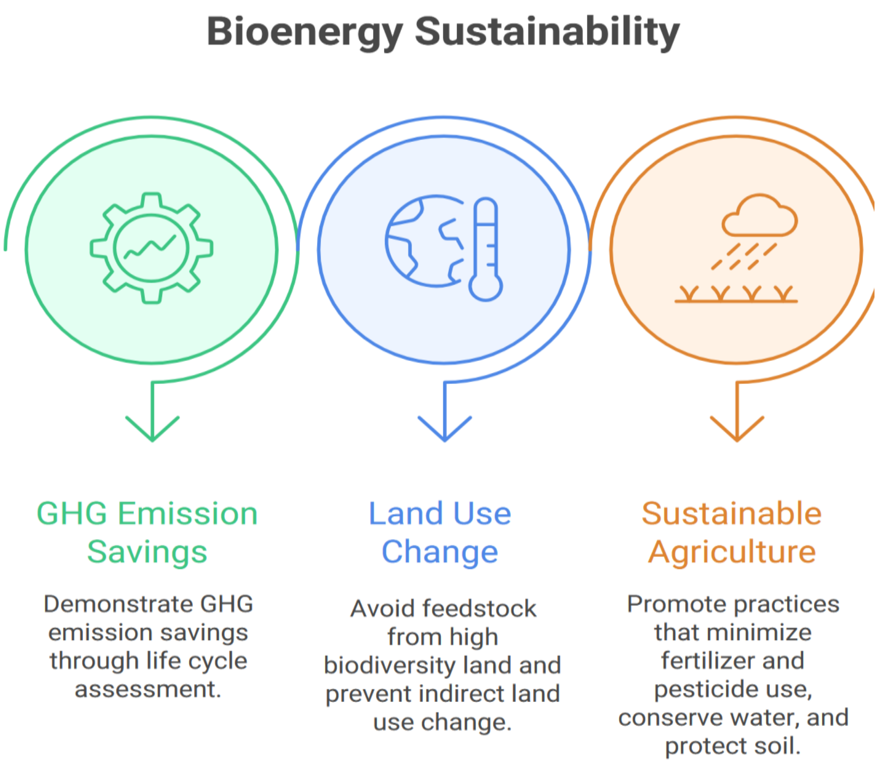


Figure 3. Sustainability criteria for biofuels

- **GHG Emission Savings:** Conduct a thorough life cycle assessment (LCA) to demonstrate that the bioenergy pathway achieves the required GHG emission savings thresholds.

- **Land Use Change:** Avoid sourcing feedstock from land with high biodiversity value, such as primary forests, wetlands, and protected areas. Implement measures to prevent indirect land use change (ILUC).
- **Sustainable Agriculture:** Promote sustainable agricultural practices that minimize the use of fertilizers and pesticides, conserve water resources, and protect soil health.

Feedstock Diversification

Diversifying feedstock sources can enhance the resilience and sustainability of bioenergy projects.

- **Residues and Wastes:** Prioritize the use of agricultural residues (e.g., straw, corn stover), forestry residues (e.g., branches, bark), and organic wastes (e.g., food waste, sewage sludge) as feedstock.
- **Energy Crops:** If energy crops are used, select species that are well-suited to the local climate and soil conditions, and that require minimal inputs of fertilizers and pesticides. Consider using marginal lands for energy crop production to avoid competition with food crops.
- **Algae:** Explore the potential of algae as a sustainable feedstock for bioenergy production, particularly in coastal regions.

Supply Chain Transparency and Traceability

Establish transparent and traceable supply chains to ensure the sustainability of feedstock sourcing.

- **Certification Schemes:** Utilize recognized certification schemes, such as the International Sustainability and Carbon Certification (ISCC) or the Roundtable on Sustainable Biomaterials (RSB), to verify the sustainability of feedstock.
- **Chain of Custody:** Implement a robust chain of custody system to track the origin and movement of feedstock throughout the supply chain.
- **Supplier Engagement:** Engage with feedstock suppliers to promote sustainable practices and ensure compliance with sustainability criteria.

3.2. Technology Selection and Efficiency

Technology Assessment

Carefully assess the available bioenergy technologies to select the most efficient and appropriate option for the specific project context.

- **Conversion Technologies:** Consider various conversion technologies, such as combustion, gasification, pyrolysis, anaerobic digestion, and fermentation, based on feedstock characteristics, energy output requirements, and environmental considerations.

- **Energy Efficiency:** Prioritize technologies that maximize energy efficiency and minimize energy losses.
- **Technological Maturity:** Evaluate the technological maturity and reliability of different options, considering factors such as operational experience, maintenance requirements, and scalability.

Integration with Existing Infrastructure

Explore opportunities to integrate bioenergy projects with existing infrastructure to improve efficiency and reduce costs.

- **Combined Heat and Power (CHP):** Consider implementing CHP systems to generate both electricity and heat, maximizing the overall energy efficiency of the project.
- **District Heating Networks:** Integrate bioenergy plants with district heating networks to supply heat to residential, commercial, and industrial consumers.
- **Grid Connection:** Ensure reliable grid connection for electricity generation, and explore opportunities for grid balancing services.

Innovation and Research

Support innovation and research to develop more efficient and sustainable bioenergy technologies.

- **Pilot Projects:** Encourage the development and demonstration of innovative bioenergy technologies through pilot projects and research initiatives.
- **Collaboration:** Foster collaboration between research institutions, industry, and policymakers to accelerate the development and deployment of advanced bioenergy technologies.
- **Funding:** Provide funding for research and development activities focused on improving the efficiency, sustainability, and cost-effectiveness of bioenergy technologies.

3.3. Environmental Impact Mitigation

Air Quality

Implement measures to minimize air emissions from bioenergy plants.

- **Emission Control Technologies:** Utilize advanced emission control technologies, such as scrubbers, filters, and catalytic converters, to reduce emissions of particulate matter, nitrogen oxides, sulfur dioxide, and other pollutants.
- **Combustion Optimization:** Optimize combustion processes to minimize the formation of pollutants.
- **Air Quality Monitoring:** Conduct regular air quality monitoring to ensure compliance with emission standards.

Water Management

Implement responsible water management practices to minimize water consumption and prevent water pollution.

- **Water Efficiency:** Utilize water-efficient technologies and practices to reduce water consumption in bioenergy production processes.
- **Wastewater Treatment:** Treat wastewater from bioenergy plants to remove pollutants before discharge.
- **Water Reuse:** Explore opportunities for water reuse within the bioenergy plant or in other industrial or agricultural applications.

Waste Management

Implement a comprehensive waste management plan to minimize waste generation and promote recycling and reuse.

- **Waste Reduction:** Implement measures to reduce waste generation at all stages of the bioenergy production process.
- **Recycling and Reuse:** Recycle or reuse waste materials whenever possible.
- **Proper Disposal:** Dispose of waste materials that cannot be recycled or reused in an environmentally sound manner.

Biodiversity Protection

Protect biodiversity and minimize the impact of bioenergy projects on ecosystems.

- **Habitat Protection:** Avoid siting bioenergy plants in or near areas with high biodiversity value.
- **Ecological Corridors:** Maintain or restore ecological corridors to allow for the movement of wildlife.
- **Invasive Species Control:** Implement measures to prevent the spread of invasive species.

3.4. Community Engagement and Social Acceptance

Stakeholder Consultation

Engage with local communities and other stakeholders throughout the project development process.

- **Early Engagement:** Initiate stakeholder consultation early in the project planning phase.
- **Transparency:** Provide transparent and accessible information about the project, including its potential impacts and benefits.
- **Feedback Mechanisms:** Establish mechanisms for stakeholders to provide feedback and express concerns.

Local Benefits

Maximize the local benefits of bioenergy projects.

- **Job Creation:** Create local jobs in feedstock production, plant operation, and maintenance.
- **Economic Development:** Stimulate local economic development through increased investment and business opportunities.
- **Community Benefits Agreements:** Negotiate community benefits agreements with local communities to ensure that they receive a fair share of the project's benefits.

Public Awareness

Raise public awareness about the benefits of bioenergy and address any misconceptions or concerns.

- **Educational Programs:** Develop educational programs to inform the public about the role of bioenergy in achieving climate goals and promoting sustainable development.
- **Site Visits:** Organize site visits to bioenergy plants to allow the public to see the technology in action and learn about its environmental and social impacts.
- **Media Engagement:** Engage with the media to disseminate accurate information about bioenergy and address any misinformation.

3.5. Policy and Regulatory Framework

Supportive Policies

Advocate for supportive policies that promote the development and deployment of sustainable bioenergy projects.

- **Incentives:** Provide financial incentives, such as feed-in tariffs, tax credits, and grants, to encourage investment in bioenergy projects.
- **Regulatory Framework:** Establish a clear and predictable regulatory framework that provides certainty for project developers.
- **Streamlined Permitting:** Streamline the permitting process to reduce the time and cost of developing bioenergy projects.

Enforcement of Regulations

Ensure effective enforcement of regulations to ensure that bioenergy projects comply with sustainability criteria and environmental standards.

- **Monitoring and Auditing:** Implement monitoring and auditing programs to verify compliance with regulations.
- **Penalties:** Impose penalties for non-compliance with regulations.
- **Transparency:** Make information about compliance and enforcement publicly available.

By adhering to these best practices, the EU can promote the development of sustainable bioenergy projects that contribute to climate change mitigation, energy security, and rural development, while minimizing environmental impacts and maximizing social benefits.

4. Description of Implemented Learning Activities

Within the module, a series of educational activities combining both offline and online formats were carried out, targeting a wide audience that included students, teachers, and representatives of the public sector. The main activities included:

Course "EU Implementation of Bioenergy Technologies for Waste Recycling" (60 hours, open to all specialties) *(https://bioinwaste.ecolog.sumdu.edu.ua/)*

Course topics included:

- Introduction to the EU experience in implementing innovations in bioenergy based on waste utilization.
- Bioeconomy as a foundation for green growth.
- Characteristics of biomass (e.g., food waste, sewage sludge).
- Raw and potential feedstock for sustainable bioproducts production in EU countries.
- The role of bioenergy in carbon capture and sequestration.
- The EU research ecosystem: development of bioenergy technologies.
- Case studies: implementation of bioenergy and waste recycling technologies in EU countries.
- Environmental safety in the context of biowaste recycling in Europe.

Format: lectures, seminars, discussions, and practical assignments (offline with optional online participation).

Participants: students of various specialties, university staff, and other interested stakeholders.

Objective: to significantly improve competencies in developing bioenergy projects and performing their economic and environmental assessments based on EU best practices.

Virtual visits to European research laboratories such as:

- *Biogas Research Team*, Czech University of Life Sciences Prague (Czech Republic).
- *Biogas Solutions Research Center*, Linköping University (Sweden).

Format: online sessions with European researchers, thematic assignments, and discussions of EU practices in bioenergy from waste.
Audience: not limited to students and teachers; the webinars also involved the wider academic and non-academic community, including representatives of local communities.

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Objective: to expand access to knowledge about European bioenergy practices and foster a sustainable exchange network between Ukrainian and European institutions.

Guest experts were involved to discuss international experience in the field of bioenergy and to review example bioenergy projects and their feasibility studies based on the best practices of EU countries:

Dr. Hynek Roubik, Director of the Biogas Research Team, CZU mobiLAB, Associate Professor of Sustainable Technologies, Dean of the Faculty of Tropical Agricultural Sciences, Czech University of Natural Sciences in Prague, Czech Republic.

Dr. Joachim Venus, Leibniz Institute of Agricultural Engineering and Bioeconomics (ATB), Department of Microbiome Biotechnology, Germany

Dr. Eric Fehrhau, Technical University Bergakademie Freiberg, Institute of Heat Engineering and Thermodynamics, Department of Gas and Heat Engineering Systems, Freiberg, Germany

Dr. Alex Henrik Prast, Professor, Department of Case Studies - Environmental Change, Linköping University, Sweden

Dr. Werner Fuchs, Associate Professor, Director of the Institute of Environmental Biotechnology, Vienna University of Renewable Resources and Life Sciences, Chairman of the Strategic Board of the Austrian Competence Center "Bioenergy and Sustainable Technologies", Austria

Dr. Wolfgang Gabauer, Group Leader, Biogas Research and Consulting, Institute of Environmental Biotechnology, Vienna University of Renewable Resources and Life Sciences, Austria

Dr. Karin Tonderski, Associate Professor, Department of Management and Engineering - Environmental Technology and Management, Linköping University, Sweden

Björn Magnusson, Planning and Technology Engineer, Gasum AB, Sweden

Dr. Jan Mostedt, Research Manager, Biogas Research and Development, Tekniska verken i Linköping AB (publ.), Senior Lecturer, Department of Case Studies, Environmental Change, Linköping University, Sweden

Dr. Pierre Buffier, Professor, Head of DEEP Laboratory - Waste, Water, Environment and Pollution, National Institute of Applied Sciences of Lyon, France

Dr. Stefan Junne, Professor at Aalborg University Esbjerg, Denmark, Research Group Leader at the Technical University of Berlin, Germany

Prof. Mykola Kharytonov, Chief Research Scientist of the project of the Ministry of Education and Science of Ukraine, public position: Head of the Center for Natural Agricultural Production, Doctor of Agricultural Sciences, Professor of the Department of Ecology and Environmental Protection, Dnipro State Agro-Economic University, Dnipro

Georgii Geletukha, Doctor of Technical Sciences, Chairman of the Board of the Bioenergy Association of Ukraine"

Ivan Traksler, PhD, Director of MHP Eco Energy, member of the Bioenergy Association of Ukraine

Dr. Yevhenii Shapovalov, leading reseacher at State Scientific-Technical Library of Ukraine and National Center of Junior Acdemy of Sciences, Ass. Prof. at National Univerisity of Food Technologies, Ukraine

Videos of lectures and workshops are available on the YouTube channel (https://www.youtube.com/@bioinwaste) of the BioInWaste project.

The full presentation material for the training course ***"EU*** **implementation of bioenergy technologies for waste recycling"** is available on the project website here:

https://bioinwaste.ecolog.sumdu.edu.ua/?page_id=199

https://bioinwaste.ecolog.sumdu.edu.ua/?page_id=1040

The project's Tiktok, Instagram, and Facebook pages:

https://www.facebook.com/groups/bioinwaste

https://www.instagram.com/bioinwaste/

https://www.tiktok.com/@bioinwaste?lang=uk-UA

4.1. Project Work and Practical Assignments

Within the course and webinars, participants carried out thematic tasks simulating the stages of bioenergy project development — from feedstock analysis to economic and environmental feasibility assessment (Fig. 4).

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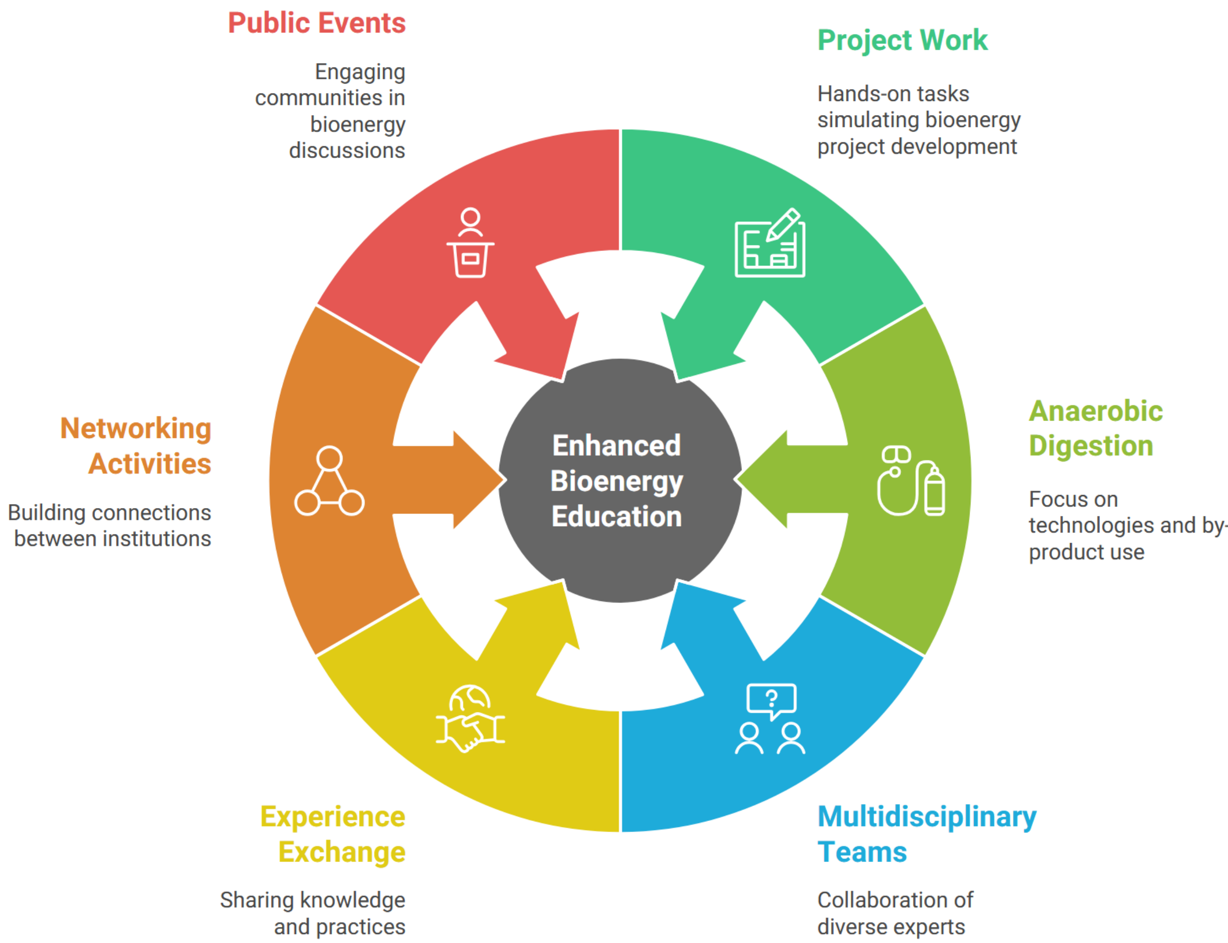

Figure 4. Project skills development

Special attention was given to **anaerobic digestion technologies** and the **potential use of chemical by-products** in these systems, taking into account both economic and environmental aspects.

Multidisciplinary student teams were formed, including environmentalists, biotechnologists, economists, and representatives of civic initiatives, to model real-world scenarios for implementing bioenergy technologies at the local level.

4.2. Networking Activities and International Cooperation

A **training and research network** was established between Ukrainian and European institutions to increase the competitiveness of Ukrainian higher education within the European educational area.

Activities included experience exchange, thematic online meetings, co-authoring scientific papers, and creating platforms for further cooperation.

Public events such as webinars and presentations were organized to engage a broader audience — including local communities — in the topics of bioenergy and waste recycling.

5. Assessment of Obtained Skills and Outcomes

The assessment of the obtained skills and learning outcomes was conducted through a combination of formative and summative evaluation methods integrated throughout the module activities. The evaluation framework was designed to measure both the acquisition of theoretical knowledge and the development of practical competences in bioenergy project design and implementation, following European approaches and sustainability principles.

5.1. Evaluation methods applied:

- **Knowledge-based assessment:** periodic quizzes, short tests, and oral discussions to evaluate understanding of EU policies, regulatory frameworks, and technological principles in bioenergy and waste recycling.
- **Practical assignments:** project-based tasks simulating real-life scenarios of bioenergy project development, including feedstock assessment, selection of anaerobic digestion technologies, and feasibility studies with environmental and economic justification.
- **Teamwork evaluation:** assessment of students' participation in interdisciplinary project groups, focusing on collaboration, communication, and problem-solving skills.
- **Reflective reports and presentations:** individual reports and presentations summarizing students' experience, key takeaways, and reflections on the applicability of EU best practices at the local level.
- **Expert feedback:** evaluation of student performance by module instructors and invited EU partners, providing recommendations for improvement and professional growth.

5.2. Key skills and competences obtained: As a result of participation in the course and related activities, students and academic staff significantly improved their:

- **Practical skills in bioenergy project development**, including project design, feasibility assessment, and evaluation of sustainability indicators.
- **Understanding of EU strategies and regulatory frameworks** in renewable energy, waste recycling, and environmental protection.
- **Analytical and research competences** in assessing biomass potential, technology selection, and impact analysis (economic, ecological, and social dimensions).

- **Collaborative and communication skills** through teamwork in multidisciplinary and international groups.
- **Capacity for academic and professional networking**, co-authoring papers, and participating in joint research within the European educational and research area.

5.3. Learning outcomes achieved:

- Over **500 students and university staff** gained practical knowledge and skills applicable to bioenergy and waste recycling projects.
- Enhanced institutional capacity in **R&D on bioenergy technologies** and valorization of by-products.
- Strengthened cooperation and academic exchange between **Ukrainian and European universities** through joint webinars, virtual visits, and collaborative research outputs.
- Created a foundation for **further integration of EU environmental and energy practices** into the Ukrainian higher education curriculum.

5.4. Overall impact: The learning outcomes demonstrate a substantial contribution to building professional competences in sustainable bioenergy development and environmental management. The module provided participants with the ability to critically apply European experience, fostering innovation, interdisciplinary collaboration, and the advancement of green technologies in Ukraine's academic and practical contexts.

To strengthen practical skills in developing bioenergy projects, students and lecturers from Sumy State University took part in preparing joint project proposals for interdisciplinary research teams within the **AgriSci-UA Platform**.

Within the framework of the **Jean Monnet Module BIOINWASTE**, Associate Professor Yelizaveta Chernysh, the module coordinator and lecturer, provided participants with training sessions and webinars focused on the structure and requirements of scientific project proposals supported by this platform.

This collaboration enabled students to engage in project development activities and secure financial support to advance their research in the field of **anaerobic digestion of waste**. It serves as a clear example of synergy between the **Jean Monnet BIOINWASTE Module** and the **AgriSci-UA Platform**.

The experience and project-writing skills gained within the **BIOINWASTE** module create real opportunities for participants to apply for further grant funding under other initiatives, such as **"Strengthening AgriSciences in Ukraine: AgriSci-UA"**, implemented under the initiative *"AgriSci-UA Platform: Strengthening Research Capacities and Deepening*

Collaboration Among Ukrainian Universities in Agricultural Sciences", funded by the **Czech Development Agency**.

For more details, please visit: https://agrisci-ua.com/combined-use-of-pre-treatment-methods-under-anaerobic-digestion/

6. Conclusions and Recommendations

The implementation of the Jean Monnet module *BIOINWASTE* has demonstrated significant progress in integrating European approaches to sustainable bioenergy development within Ukrainian higher education. The activities carried out under the module — including lectures, webinars, project work, and networking — effectively enhanced both theoretical knowledge and practical skills among students, academic staff, and representatives of non-academic communities.

Participants developed a solid understanding of EU best practices in bioenergy, waste recycling, and environmental safety, gaining competencies in project design, feasibility analysis, and sustainability assessment. The interdisciplinary and research-oriented structure of the course encouraged collaboration across fields such as environmental engineering, biotechnology, and economics, creating a strong foundation for future innovation in green technologies.

The module also contributed to strengthening academic and institutional cooperation between Ukrainian and European universities. Through joint activities, virtual laboratory visits, and co-authored research outputs, it fostered long-term academic partnerships and knowledge exchange. The established network of cooperation serves as a valuable platform for future projects, joint publications, and curriculum modernization in line with EU environmental and energy priorities.

Recommendations

1. **Curriculum integration:** The experience and materials developed during the module should be institutionalized as a regular component of environmental and biotechnology study programs to ensure sustainability and continuity of EU-related education.
2. **Expansion of interdisciplinary cooperation:** Further collaboration between departments (ecology, biotechnology, economics, and engineering) should be encouraged to strengthen the multidisciplinary dimension of bioenergy education and research.
3. **Practical application and stakeholder involvement:** Strengthen cooperation with local authorities, businesses, and environmental NGOs to apply the acquired knowledge in real-life bioenergy and waste management projects at the regional and municipal levels.

4. **Research development:** Continue building research capacity in the field of anaerobic digestion and waste-to-energy technologies, with a focus on economic and environmental efficiency, and encourage participation in EU-funded research programs such as Erasmus+ KA2.
5. **Dissemination and networking:** Maintain and expand the academic network created under the module, supporting open-access webinars, public events, and co-authored publications to enhance visibility and share outcomes across the European Higher Education Area.
6. **Sustainability and policy impact:** Use the outcomes of the module to contribute to national and regional strategies on renewable energy and environmental safety, aligning educational and policy efforts with the European Green Deal and circular economy principles.

Overall, the module has successfully achieved its objectives, contributing to capacity building, innovation, and Europeanization of higher education in the field of bioenergy and waste recycling in Ukraine. The experience gained provides a strong foundation for further educational, research, and institutional development in alignment with EU standards of sustainability and excellence.

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