CHAPTER 5

Universities as regional leaders for sustainable energy and climate EU-harmonized policies

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Abstract

European Green Deal envisages a wide range of goals and milestones to provide a policy framework to integrate innovative, educational, and institutional components of the input from higher educational institutions toward a green transition of their regions and countries. Since, at the initial European Commission level, the role of the university sector was not fully formulated, there's a need to create a new roadmap for their contribution. We foresee the following impact areas from the universities in the green transition of national economies: research and innovation, education, staff and infrastructure management, and public/social impact.

Keywords

University leadership, energy management system, renewable energy, energy monitoring, climate action.

5.1 Introduction

5.1.1 EU green deal and universities

In October 2023, the European University Association released a study, "A Green Deal roadmap for universities" [1]. The roadmap described universities' vital roles and outcomes in the green transition:

1. Research and innovation: universities play a crucial role in conducting research on sustainable technologies, energy solutions, climate change, and

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environmental policies. They develop innovative solutions to address the challenges of the green transition.

2. Education and training: universities provide education and training programs that equip students with the necessary knowledge and skills to address sustainability challenges. These programs include degrees in renewable energy, environmental sciences, sustainable engineering, and sustainable business practices.

3. Policy advocacy and expertise: universities contribute their expertise to policy dialogue and support policymakers in developing effective strategies for the green transition. They provide evidence-based research and analysis to shape sustainability policies at the local, national, and international levels.

4. Collaboration and partnerships: universities collaborate with industry, government agencies, and civic organizations to promote sustainable practices. They create partnerships for joint research projects, knowledge exchange, and implementing sustainable initiatives in various sectors.

5. Campus practices and operations: universities adopt sustainable practices within their campuses, aiming to reduce their carbon footprint, promote renewable energy, improve waste management, and enhance energy efficiency. They serve as living laboratories for testing and implementing green technologies and practices.

6. Community engagement: universities engage with their local communities to raise awareness about sustainability issues and contribute to the transition towards a greener society. They organize public lectures, workshops, and community-based projects to promote sustainable behaviors and empower individuals to take action.

7. Entrepreneurship and start-ups: universities support and foster entrepreneurship in sustainable industries. They provide resources, mentorship, and funding opportunities for students and faculty members to develop innovative start-ups that contribute to the green economy.

These roles and outcomes demonstrate how universities are vital partners in driving the green transition, contributing to a sustainable future for local communities and global society. Being big energy consumers in their home municipalities, universities shall become a working example of ambitious actions aimed at green transition.

5.1.2 Universities as drivers of green transition at the municipal level

Since universities typically are headquartered in relatively big towns and cities, which aligns with the stated approach, they shall contribute differently to municipal energy and climate plans. More than two-thirds (67 %) of European municipalities have adopted some form of energy and climate planning document [2], such as a sustainable energy action plan, sustainable energy, and climate adaptation plan. Based on this, it is possible to consider the leading role of universities at the municipal level far more active than at the national.

As significant energy consumers in their respective communities within the EU, universities have a distinctive role in the transition towards sustainable energy practices. Here are the critical aspects of their role:

1. Energy efficiency initiatives. Universities can implement energy efficiency measures within their facilities, considering their energy consumption. By adopting energy-saving technologies, optimizing heating and cooling systems, and maintaining efficient lighting, universities can reduce energy consumption and serve as models for sustainable community practices.

2. Collaboration with local energy providers. Universities can collaborate with local energy providers to explore sustainable energy options. By engaging in dialogue with utility companies, universities can encourage the adoption of renewable energy sources, such as solar or wind power, in their towns. This collaboration can drive the transition towards cleaner and more sustainable energy generation and consumption.

3. Research and innovation. Universities can research energy-related topics and develop innovative solutions. They can partner with local businesses, government agencies, and community organizations to address energy challenges within their home towns. Research initiatives can focus on renewable energy integration, energy storage technologies, smart grids, and energy-efficient urban planning.

4. Knowledge dissemination and public outreach. Universities are responsible for sharing their expertise and knowledge with the local community. They can organize workshops, seminars, and public lectures to raise awareness about sustainable energy practices and promote behavioral change. By engaging with local residents, businesses, and policymakers, universities can foster a shared understanding of the benefits of sustainable energy consumption and encourage its implementation beyond their campuses.

5. Collaborative projects with local stakeholders. Universities can initiate collaborative projects with local businesses, communities, and government bodies to promote sustainable energy practices. These projects can involve joint research ventures, pilot programs for renewable energy adoption, or consultations on energy efficiency measures for local infrastructure. By working together, universities and their hometowns can create innovative solutions and drive the transition toward a sustainable energy future.

5.2 University as community leader in energy transition

The global transition to sustainable energy systems requires collective action from all sectors of society. Universities are uniquely positioned to lead this transition as centers of knowledge and innovation. Their activities demonstrate a commitment to reducing their carbon footprint and promoting sustainable energy practices in their home cities. By collaborating with local stakeholders, engaging in research and innovation, and promoting knowledge dissemination, universities are making a significant contribution to the European Union's (EU) energy transition goals and inspiring their communities to use energy more cleanly and sustainably.

Education is a cornerstone of the energy transition. Universities can contribute by developing comprehensive educational programs that address energy literacy and consumption patterns. Understanding these patterns is essential for developing strategies that support the energy transition. By incorporating energy education into their curricula, universities can raise awareness and promote responsible energy behavior.

To solve the abovementioned problems of staffing the industry, IFNTUOG launched a new bachelor's program "Renewable Energy Engineering" in the specialty 152 "Metrology and Information and Measuring Technology". The new educational program, which is consistently and meaningfully aligned with the strategies of the university, Ivano-Frankivsk region and the government of Ukraine, has emerged as a central component of the eco-system that has been formed on the basis of the Department of Energy Management and Technical Diagnostics in recent years. In the **Fig. 5.1**, ecosystem includes the Master's program in Energy Management, which has been implemented since 2016, the New Energy Science Campus (since 2016), the program for training and certification of energy auditors, experience in implementing and ongoing international projects and academic mobility programs for students and teachers with EU universities, and a significant portfolio of completed projects commissioned by Ukrainian enterprises and municipalities.

In the fall of 2019, a draft profile of the educational program was developed and published on the university's website. Within 2 months, almost 30 reviews were received from stakeholders, and most of the substantive comments were considered. The improved program was agreed upon and approved by the established procedure. At the same time, there was a significant number of needs for material and information support for the new educational program. For this purpose, an application was submitted to the USAID Energy Security Project (ESP) grant competition and was supported.

Thanks to the ESP grant support, the latest training equipment, computer hardware, and specialized software were purchased during the 2020/2021 academic year, which successfully complemented the existing material base at the department.

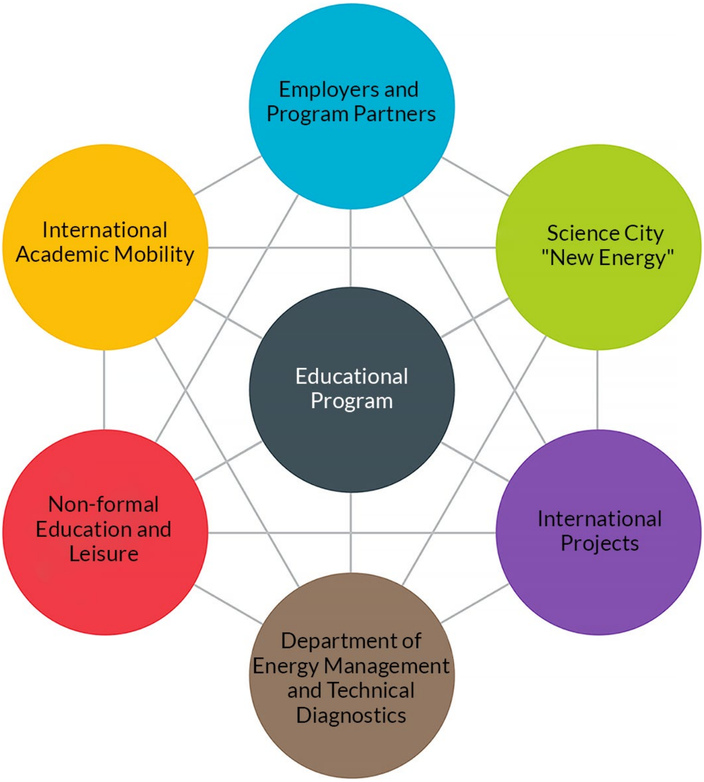

Fig. 5.1 Eco-system of the Renewable Energy Engineering study program

Additionally, external lecturers were engaged to teach specialized courses provided by the educational program. A good example of such involvement is the involvement of V. Sheremeta, Head of the Ukrainian Greek-Catholic Church Bureau of Ecology, to teach a separate module of the Philosophy and Environmental Ethics course.

Its coverage in the media and social networks is equally important for popularizing the new educational program. For this purpose, several videos were filmed, more than 100 thematic publications were created and disseminated on social networks, and more than 10 appearances in regional media were made.

One factor that hinders the development of energy efficiency and renewable energy in Ukraine is the lack of trained personnel. Specialized companies operating in the energy sector are constantly looking for additional training for their staff. As of the end of 2019, no university in Ukraine trained specialists in the renewable energy sector – there were only "adapted" educational programs that did not meet the industry's requirements and lacked proper technical and methodological support. The efforts of many stakeholders, a solid methodological and technical base, and compliance with the current requirements of the higher education system allowed to introduce an educational program that meets the challenges of the Ukrainian and global labor market.

Integrating an educational program with industry partnerships, international collaborations, and practical experiences is crucial for preparing specialists capable of addressing current and future energy challenges. Universities play a central role in this process by creating an environment that fosters learning, innovation, and engagement with the broader community. The schematic representation underscores the importance of a multifaceted approach to education in driving the energy transition forward.

The outbreak of the war in Ukraine exacerbated existing problems in the energy production and transmission sector. Critical infrastructure was damaged, leading to frequent power outages. In this context, the role of universities becomes even more important. Alumni and current students are contributing to solving these pressing problems, using their experience to find innovative solutions in difficult circumstances.

Universities, as centers of learning and research, can catalyze community energy initiatives by establishing partnerships and promoting the sharing of energy resources. Student initiatives can play a crucial role in bridging the gap between universities and local communities. By engaging students in community projects, universities can educate a new generation of environmentally conscious citizens and contribute to a sustainable future.

In a series of projects mainly co-funded by the EU, the authors showcased an approach to how universities can become local drivers of the energy-green transition in Ivano-Frankivsk, Ukraine. The university played a central role in promoting sustainable energy practices by collaborating with local stakeholders – including government agencies, businesses, and community groups.

The projects involved installing shared photovoltaic facilities, conducting energy literacy workshops, and developing community-driven energy plans. These initiatives reduced the university's carbon footprint and inspired the local community to embrace cleaner energy consumption. Importantly, 100 % of the university's alumni involved in these projects emerged as competent specialists, well-prepared to address their community's energy challenges.

5.2.1 Energy management system at the university as a public institution

The ISO 50001 standard is a powerful tool for organizations to improve energy performance. It has been estimated that the ISO 50001 Energy Management Standard could positively impact 60 % of the world's energy use by providing public and private sector organizations with management strategies to increase energy efficiency, reduce costs, and improve energy performance. Effective energy management is a priority focus because of the potential to save energy and reduce greenhouse gas (GHG) emissions [3].

The structure of ISO 50001:2020 is designed according to other ISO management system standards, ISO 9001:2015 (Quality Management Systems) and ISO 14001:2015 (Environmental Management Systems). Since all three management systems are based on the Plan-Do-Check Act (PDCA) cycle (**Fig. 5.2**), ISO 50001:2020 can be integrated easily into these systems [4].

The ISO 50001:2020 standard is grounded in the Plan-Do-Check-Act (PDCA) cycle, providing a structured approach for continuous improvement in energy performance. In the context of a university's energy management [5], this cycle enables the institution to effectively control energy use, identify opportunities for enhancement, and implement strategies to achieve energy efficiency goals.

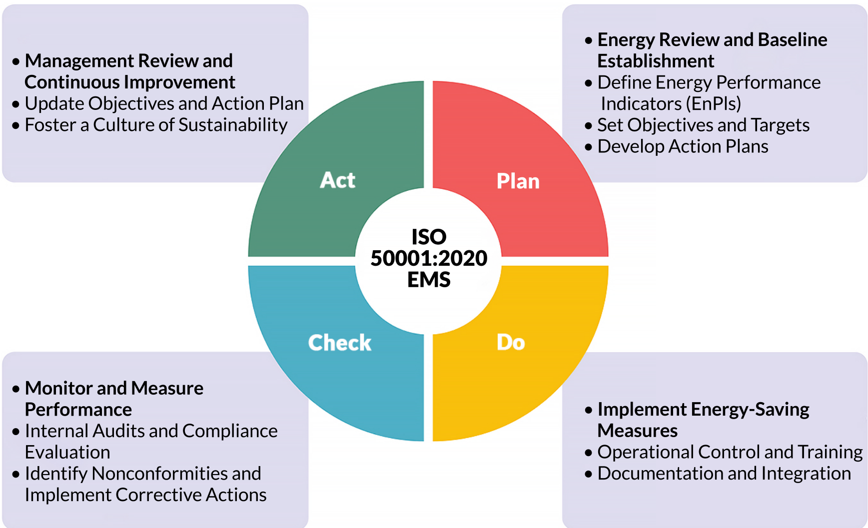

Fig. 5.2 Plan-Do-Check-Act (PDCA) cycle of ISO 50001:2020 for IFNTUOG

In the **planning phase**, the university begins by conducting a comprehensive energy review to analyze current energy consumption across all facilities, including classrooms, laboratories, offices, and dormitories. This review helps establish a baseline against which future improvements can be measured, considering factors like seasonal variations and occupancy rates. The institution then defines energy performance indicators such as energy consumption per square meter or per student, facilitating the monitoring of progress toward energy objectives. Clear and achievable energy objectives and targets are set, aligning with the university's energy policy and sustainability commitments. Detailed action plans outline necessary actions, responsibilities, timelines, and resources to meet these objectives.

During the **implementation phase**, the university puts the planned actions into practice. This may involve executing strategies like retrofitting buildings with energy-efficient lighting, installing solar panels, optimizing heating and cooling systems, and promoting energy-saving practices among students and staff. Operational control ensures daily operations align with energy performance objectives, such as scheduling equipment use during off-peak hours and ensuring equipment is properly maintained for optimal efficiency. Communication and training are essential components, as educating faculty, staff, and students about energy management initiatives fosters a culture of sustainability and encourages active participation. All relevant records and documentation are maintained to support the Energy Management System (EMS) and demonstrate compliance with ISO 50001 requirements.

In the **checking phase**, the university monitors and measures key aspects of operations that determine energy performance. Regular tracking of energy performance indicators and energy consumption data allows assessment of performance against the baseline and objectives. Internal audits are conducted to verify that the EMS conforms to planned arrangements and ISO 50001 requirements, helping identify areas of non-compliance and opportunities for improvement. Compliance with legal and other requirements related to energy use is evaluated, ensuring adherence to local regulations, building codes, and environmental standards. When deviations from expected performance are identified, corrective measures are implemented to address nonconformities.

Finally, in the **action phase**, the university takes steps to continually improve energy performance and the effectiveness of the EMS. Top management reviews the system to assess its suitability, adequacy, and effectiveness, making decisions regarding resource allocation, policy adjustments, and strategic direction. Changes and enhancements identified during reviews or as a result of monitoring and audits are implemented, embracing new technologies and practices that can further reduce energy consumption. Objectives, targets, and action plans are updated based on performance data and changing circumstances, ensuring the EMS remains dynamic and responsive to evolving energy needs.

By integrating the PDCA cycle into its EMS, a university creates a system that adapts to technological advancements and changing energy demands [6]. For example, if the institution sets a goal to reduce energy consumption in campus buildings by 15 % over the next two years, it would implement energy-saving measures such as installing energy-efficient windows, upgrading to LED lighting, and encouraging energy-conscious behaviors. Progress would be monitored monthly using EnPIs, and strategies would be adjusted based on the findings as needed.

Implementing the PDCA cycle in university energy management offers numerous benefits. It provides a systematic approach to managing energy performance across diverse campus facilities and encourages continuous improvement of energy efficiency measures. Engaging the entire campus community fosters a culture of sustainability, while compliance with regulatory requirements can qualify the university for grants and recognition programs. Additionally, optimizing resource use leads to significant cost savings, allowing the institution to allocate funds to other critical areas such as research and education.Building upon the principles of the ISO 50001 standard and the Plan-Do-Check-Act (PDCA) cycle, scientists at Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG) have developed and prepared an Energy Management System (EnMS) for certification. This initiative demonstrates the university's dedication to enhancing energy efficiency, reducing operational costs, and contributing to environmental sustainability.

The development process involved creating a comprehensive set of documents aligned with the national standard DSTU ISO 50001 requirements. University scientists meticulously prepared key documents, including the implementation order of the EMS, which formalizes the initiation and scope of the energy management system within the institution. They established regulations for the working group on the EMS, defining the roles and responsibilities of the team overseeing its implementation and maintenance.

An integral part of the documentation is the Energy Policy, outlining the university's commitment to energy efficiency and setting strategic objectives and guiding principles for energy management. Additionally, they prepared a questionnaire for the management system certification body, providing essential information required for the certification assessment. Procedures for documentation management were established to ensure consistency and accessibility of all EMS-related documents.

The team also developed protocols for internal audits and corrective and preventive actions to facilitate regular assessments and continuous system improvement. Guidelines for record management were specified to maintain and safeguard records pertinent to energy performance and EMS activities. General guidelines offering overarching instructions for effective energy management within the university context were included to support the implementation process.

To establish a baseline for energy consumption, a methodology for calculating the basic level of consumption of fuel and energy resources was created. This provided a systematic approach to tracking consumption patterns and identifying areas for improvement. An in-depth analysis of energy consumption was conducted to pinpoint significant energy uses and uncover opportunities for enhancement.

Upon completion, the university's leadership reviewed and approved these documents, ensuring they met the specific conditions and requirements of IFNTUOG. The formal approval of the Energy Policy and accompanying regulatory documentation signifies a strong institutional commitment to energy efficiency and adherence to DSTU ISO 50001 standards.

As a result, Ivano-Frankivsk National Technical University of Oil and Gas has developed a comprehensive Energy Policy that underscores the institution's commitment to energy efficiency and sustainability. This policy serves as a guiding framework for all energy-related activities within the university, reflecting a dedication to reducing environmental impact and promoting responsible energy use.

A central focus of the Energy Policy is the reduction of fuel and energy consumption, aiming to minimize unnecessary costs and promote the rational use of resources. The university actively seeks to enhance energy efficiency by implementing energy-saving measures, ensuring that every aspect of its operations contributes to this goal.

Compliance with Ukraine's current legislation, international agreements, and established standards in the field of energy conservation and efficiency is a fundamental aspect of the policy. By adhering to these regulations, IFNTUOG aligns its practices with both national and international expectations, fostering a culture of accountability and excellence in energy management.

The Energy Policy emphasizes establishing and continuously analyzing energy goals, objectives, and programs designed for their implementation. Regular monitoring and analysis of energy efficiency indicators enable the university to track progress, identify areas for improvement, and adjust strategies accordingly. This dynamic approach ensures that energy performance is maintained and consistently enhanced over time.

Transparency and the availability of information regarding activities in energy efficiency are also key components of the policy. IFNTUOG is committed to providing the necessary resources to achieve its energy objectives, ensuring that all stakeholders are informed and engaged in the process. Raising awareness and motivation among staff about energy efficiency and the functioning of the EnMS is essential. By fostering an environment where employees are knowledgeable and proactive, the university enhances the effectiveness of its energy initiatives.

With over a decade of experience in energy efficiency and the rational use of energy resources, IFNTUOG has leveraged this expertise to develop and prepare for certification in an energy management system. The adoption of the ISO 50001 standard has been instrumental in this endeavor. Recognized as a powerful tool for organizations to improve energy performance, ISO 50001 provides a structured framework that enables the university to systematically manage and reduce energy consumption.

By embracing the ISO 50001 standard, IFNTUOG improves its energy performance and sets a benchmark for other institutions. The university's efforts demonstrate how public institutions can lead by example in the global pursuit of sustainability and energy efficiency. Through dedicated policy, strategic planning, and active engagement of its community, IFNTUOG continues to contribute significantly to the energy transition, both within Ukraine and in the broader international context.

5.2.2 Demonstration installations on renewable energy sources

Renewable energy installations, particularly solar power systems, are increasingly pivotal in the global energy mix. According to the International Energy Agency (IEA) [7], solar energy is projected to become the world's second-largest renewable energy source after hydropower by the end of this decade. Solar power plants (SPPs) are expected to become the most significant energy source in Europe by 2025. This rapid expansion can be attributed to the steady decline in the cost of generating power from SPPs. Over the past ten years, global prices of solar panels have decreased dramatically, while their efficiency has nearly doubled. These technological advancements have made electricity generated from SPPs commercially attractive for businesses.

Businesses are adopting SPP projects through several prevalent approaches. One method involves generating electricity and selling it to the grid at a special "green" tariff, incentivizing renewable energy production. Another strategy is generating energy for the company's own consumption, reducing dependence on external energy sources, and lowering operational costs. Additionally, a combined mode of operation is often employed, where businesses both consume the generated energy and sell any excess back to the grid. This hybrid approach allows for the optimization of energy use and the maximization of financial benefits.

As for installing SPPs for operation under the "green" tariff, due to its significant reduction and the situation that has arisen with delays in payments from the state for the generated energy, such projects are becoming less attractive for investment. Unlike working under the "green" tariff, when installing an SPP for its consumption, the enterprise can replace part of the electricity from the grid with electricity from the SPP.

According to the International Finance Corporation (IFC), Ukraine has a vast potential for developing the solar energy self-consumption segment. Experts predict that by 2030, the potential for the installation of solar power plants (SPPs) for self-consumption by enterprises in Ukraine will be from 2 to 3 GW, and the required investment volume for the implementation of these projects will be from 1.5 to 2 billion USD [8].

The simplicity of installation also helps to minimize capital costs. In most cases, SPPs do not require the allocation of particular additional space – they are installed on the roofs of industrial buildings or empty land areas on the enterprise's territory. Another factor in reducing the cost side is that there is no need to connect to the network and obtain many permits. As a result, the quick installation and ease of registration allow the solar power plant to be operated in just a few months. The operating costs of SPPs are minimal compared to other renewable energy sources. SPP equipment is reliable and durable (the service life of photovoltaic panels is 25 years or more, inverters – up to 10 years), requiring minimal maintenance [9].

The university has embraced these developments by installing demonstration units of renewable energy sources on campus. These installations serve multiple purposes: they contribute to the university's energy needs, provide hands-on learning opportunities for students, and act as tangible examples of sustainable practices for the community. By integrating renewable energy technologies into its infrastructure, the university reduces its carbon footprint and positions itself as a leader in promoting renewable energy adoption.

Solar PV systems for self-consumption are designed to meet the energy needs of a business or institution during the day. The difference is automatically taken from the centralized electrical grid if not enough solar energy is generated. The main economic benefit of such systems is the savings on electricity costs that the energy supplier would otherwise incur. In this case, the business or institution's operation cycle is essential. The ideal scenario is when peak energy demand coincides with the daily activity of the sun. In this case, such systems can be installed in offices, factories, warehouses, supermarkets, car washes, schools, government agencies, and other facilities where stable consumption occurs during the day. In **Fig. 5.3**, the blue line represents the generation of the solar PV system, and the orange line represents the enterprise's energy consumption. As can be seen, the solar PV system can meet the enterprise's energy needs during the day, with only a tiny amount of energy being drawn from the grid.

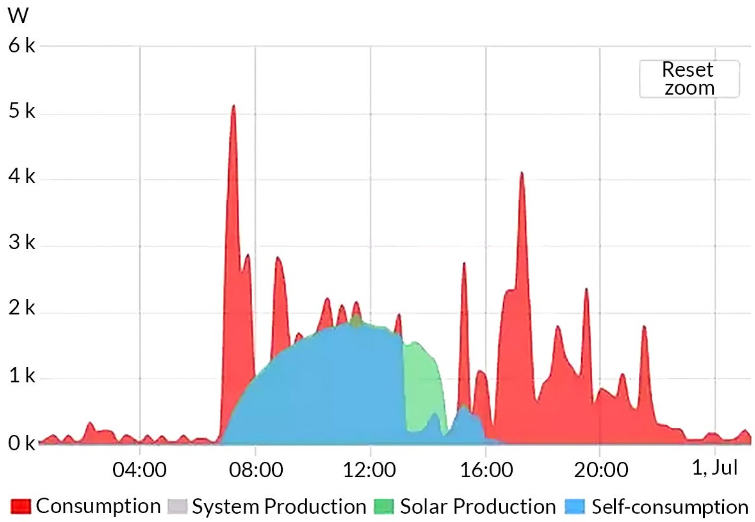

Fig. 5.3 Solar PV system coverage of daily energy consumption at an enterprise
Source: [10]

It should be noted that decentralization of electricity supply is a strategically important direction, as reducing electricity consumption from traditional energy sources by switching to alternative energy sources installed near the consumer can potentially lead to the unloading of electrical networks of distribution system operators, reducing losses in them.

A demonstration solar power plant was installed and commissioned to demonstrate the operation of a solar power plant (SPP) designed to compensate for its own electricity consumption and demonstrate the capabilities of renewable (solar) energy equipment for energy saving.

The assembled SPP is in a publicly accessible place – the laboratory of the physical foundations of renewable energy sources of the Department of Energy Management and Technical Diagnostics of IFNTUOG. Structurally, the SPP is built according to the grid scheme and consists of a solar panel array, a grid inverter, and a smart meter through which it is connected to the electrical network. For the implementation of the SPP according to the structural diagram shown in **Fig. 5.4**, a grid inverter and a smart meter from the Fronius company were selected [11].

As noted above, the demonstration solar power plant (SPP) equipment is located in the laboratory of the physical foundations of renewable energy sources of the Department of Energy Management and Technical Diagnostics (EMandTD) of IFNTUOG. This includes a grid inverter (with a capacity of 3 kW), a DC switchgear with protection and switching devices, and an AC switchgear to connect to the electrical network and the corresponding energy consumption accounting (**Fig. 5.4**).

The array of photovoltaic panels with a total capacity of 3420 W (the capacity of the array is chosen higher than the capacity of the grid inverter to compensate for the decrease in the efficiency of photovoltaic panels during heating), which consists of 12 photovoltaic panels, is located on the roof of an adjacent single-story building, accessible for inspection. The DC voltage from the array of photovoltaic batteries is supplied to the grid inverter via an overhead line (**Fig. 5.5**).

The display and demonstration of the operation of the demonstration SPP are carried out both on the screen of the grid inverter and using the Fronius Solar web application (**Fig. 5.6**).

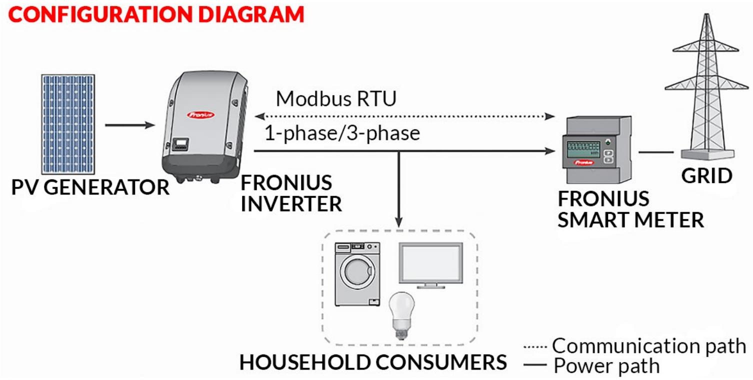

Fig. 5.4 Structural diagram of a solar power plant
Source: [11]

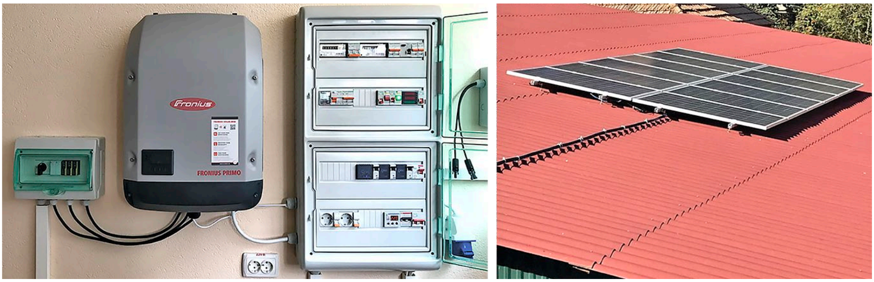

Fig. 5.5 Grid inverter, DC and AC switchgear, and solar panel array installed at the demonstration grid-connected solar power plant

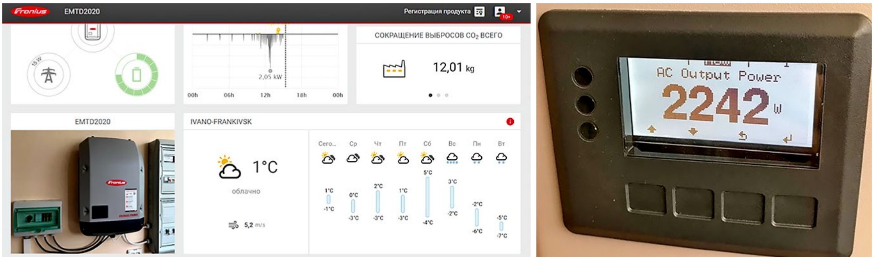

Fig. 5.6 View of demonstration photovoltaic station in application of Fronius Solar web

In addition to the Fronius smart meter, located in the AC switchgear, energy monitors are used to monitor electricity consumption and the operation of the SPP in compensation mode. For direct measurement of total consumption, the D103 smart-MAIC energy monitor with current shunt transformers is used to measure generation from the SPP. To determine the consumption of electrical energy from the primary consumers after the switchgear, which is the electric boiler and the lighting system of the common areas of the department, universal D105 smart-MAIC energy monitors are used that are connected to the telemetry pulse outputs of electromechanical electric meters located in the switchgear. A page was created in the web application of the energy monitoring system for the university building to display the operation of the demonstration SPP (**Fig. 5.7**).

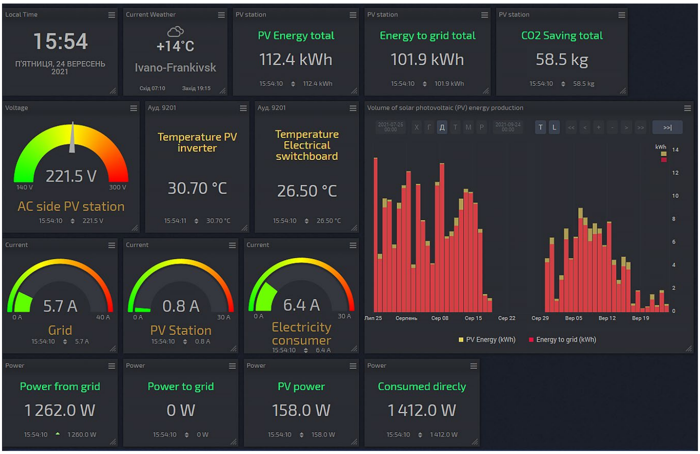

Fig. 5.7 Dashboard of the demonstration photovoltaic station for energy monitoring at the university building at the application

5.2.3 Energy consumption monitoring system

Continuous monitoring of heat, electricity, and water consumption in public buildings is fundamental to effective energy management and conservation efforts. By obtaining hourly data on energy usage for individual consumers and specific areas within buildings, organizations can gain a precise understanding of actual energy needs. This granular insight enables energy-supplying organizations to plan and distribute energy more efficiently, aligning supply with demand and reducing wastage.

Implementing advanced metering systems and energy management software allows for real-time tracking and analysis of consumption patterns. This information can highlight areas of excessive use, identify inefficiencies in building systems, and uncover opportunities for energy-saving measures. For instance, if certain zones within a building consistently show higher energy consumption, targeted interventions such as upgrading insulation, optimizing HVAC systems, or promoting energy-conscious behaviors among occupants can be employed.

Moreover, continuous monitoring supports predictive maintenance by signaling when equipment is operating sub-optimally or nearing failure, thereby preventing energy losses and reducing downtime. It also facilitates compliance with energy regulations and certifications by providing documented evidence of consumption and efficiency measures.

In essence, the availability of detailed consumption data empowers both energy providers and building managers to make informed decisions that enhance energy efficiency, reduce operational costs, and contribute to environmental sustainability. By focusing on areas with high energy usage, organizations can implement strategic improvements that yield significant long-term benefits.

Advancing energy efficiency within public buildings requires innovative solutions that address the unique challenges these structures present. Recognizing this, the university has embarked on developing a specialized information and measurement system (IMS) for monitoring energy resource consumption. The primary aim is to implement a pilot version of this IMS in a university building, laying the groundwork for broader application across the campus and potentially serving as a model for other public institutions.

Globally, numerous solutions exist for energy monitoring in buildings [12]. However, public buildings like universities often encompass large areas with a multitude of rooms and facilities, resulting in a significant number of measurement points for various energy parameters and microclimate conditions. This complexity necessitates an IMS that is not only effective but also simple to implement and cost-efficient.

Key considerations include:

– integration with existing systems: the IMS must seamlessly integrate with current metering devices to avoid redundant infrastructure costs;

– user-friendly interface: visualization and data storage should be accessible and easily configurable without requiring specialized technical skills, enabling facility managers and other stakeholders to interact with the system effectively;

– flexibility and scalability: the system should be adaptable to accommodate future expansions or technological advancements, ensuring long-term viability.

In Ukraine, existing approaches to energy monitoring in public buildings are often limited. They primarily involve the implementation of energy management systems that rely heavily on manual data collection [13]. Such methods lack the capability to provide detailed hourly or daily consumption data, restricting the ability to perform real-time analysis or respond promptly to inefficiencies. This manual approach also increases the likelihood of errors and data gaps, hindering accurate monitoring and decision-making.

Continuous monitoring of heat, electricity, and water consumption is fundamental to effective energy management. Having access to hourly energy consumption data for individual consumers and specific points within buildings enables a granular understanding of actual energy needs. This detailed information is crucial for:

– optimizing energy distribution: collaborating with energy-supplying organizations to plan appropriate energy distribution based on real consumption patterns;

– identifying inefficiencies: detecting areas with unusually high energy consumption to target interventions and improve overall energy efficiency;

– enhancing decision-making: providing data-driven insights that support operational decisions, such as adjusting heating schedules or implementing energy-saving measures.

Given these needs, developing an automated IMS for monitoring and managing energy supply has become an urgent task. The proposed system aims to:

– provide real-time data: offer continuous, automated monitoring of energy consumption and microclimate parameters, facilitating timely responses to any anomalies or inefficiencies;

– support operational management: enable the management of energy supply systems based on operational decisions derived from real-time data analysis;

– improve energy efficiency: contribute to reducing energy consumption and operational costs by identifying and addressing inefficiencies promptly.

The development process involves selecting appropriate hardware and software components that meet the university's requirements. This includes:

– sensors and meters: deploying devices that accurately measure various energy parameters and environmental conditions;

– data acquisition systems: implementing robust systems to collect and transmit data reliably from multiple points across the building;

– communication networks: establishing secure and efficient communication protocols to ensure seamless data flow between devices and central systems;

– data management platforms: utilizing platforms that allow for easy visualization, analysis, and storage of collected data.

Implementing such an IMS enhances operational efficiency and aligns with the university's commitment to sustainability and environmental stewardship. It provides several additional benefits:

– educational opportunities. Serves as a practical tool for students and researchers to engage with real-world energy management technologies, fostering innovation and expertise in the field;

– community leadership. Positions the university as a leader in sustainable practices, setting an example for other institutions and contributing to broader societal shifts toward energy efficiency;

– compliance with regulations. Helps meet legal and policy requirements related to energy use, potentially qualifying the university for grants, incentives, or recognition programs.

Moreover, the IMS can facilitate advanced functionalities such as predictive maintenance and energy forecasting. The system can predict potential equipment failures or maintenance needs by analyzing historical data and consumption patterns, preventing downtime and additional costs. Energy forecasting allows the university to anticipate future energy demands, enabling better budgeting and resource allocation.

Based on the requirements in [14], an Information and Measurement System (IMS) for monitoring energy consumption was built. Authors within the framework of the EU-funded project NET4SENERGY conducted a thorough study to find the most optimal solution for creating an IMS for energy monitoring of a university building that meets the abovementioned requirements [15]. Smart devices of the Ukrainian company smart-MAIC were chosen to build the monitoring system [16].

The development and pilot implementation of an advanced Information and Measurement System for energy monitoring are currently underway at the Department of Energy Management and Technical Diagnostics (EMandTD) of Ivano-Frankivsk National Technical University of Oil and Gas. The EMandTD department occupies approximately one-third of educational building No. 9, encompassing two floors and incorporating various autonomous electric heating systems. This complex energy infrastructure presents an ideal environment for modeling the IMS, facilitating its potential replication across other university buildings and public institutions.

The architecture of the pilot IMS is illustrated in **Fig. 5.8**. The system is designed to capture high-resolution data on electrical and thermal energy consumption and cold and hot water usage within the university building. Additionally, it continuously monitors key microclimate parameters in each classroom, including air temperature, relative humidity, and carbon dioxide (CO_2) concentration. An external meteorological module complements the system by recording outdoor environmental conditions such as ambient temperature, humidity, and atmospheric pressure trends.

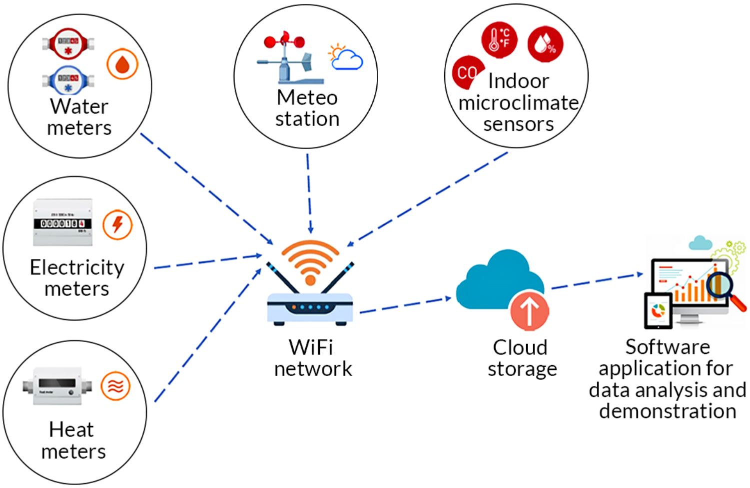

Fig. 5.8 Structure of the pilot information-measurement system for energy monitoring of the university building

The IMS employs a network of interconnected sensors and metering devices based on the smart-MAIC product line. These devices are engineered to monitor events, conditions, and processes, and include:

– electricity meters: both single-phase and three-phase electricity meters are equipped with ring or plug-in current transformers. These devices measure voltage and current parameters, facilitating the calculation of power consumption with high precision;

– pulse counters: devices with temperature sensors and analog inputs can record consumption data for utilities such as water and gas through pulse signals from standard utility meters;

– environmental sensors: devices measuring microclimate parameters contribute to indoor environmental quality assessments (IEQ).

All devices conform to the DIN-rail casing standard EN 60715:2017, allowing for seamless installation within existing electrical panels. This modularity ensures ease of integration and scalability, which is critical for expansive facilities like university buildings.

The IMS utilizes a combination of wired and wireless communication protocols for data acquisition and transmission. Measurement devices are connected via Modbus RTU over RS-485 communication lines, a robust industrial standard for serial communication in energy monitoring systems. Data collected from the devices are aggregated by a central data logger equipped with Internet connectivity, which transmits the data to a cloud-based server using secure MQTT (Message Queuing Telemetry Transport) protocols. This approach ensures reliable and efficient data transmission, even in environments with variable network connectivity.

In the classrooms, the IMS focuses on tracking microclimate parameters to optimize energy usage while maintaining occupant comfort. The universal smart-MAIC D105 data logger is the central hub for environmental sensors, connecting temperature-humidity and CO_2 sensors.

Temperature and humidity sensors. The AM2302 digital sensors (also known as DHT22) measure temperature and relative humidity. These sensors employ capacitive humidity sensing and thermistor temperature sensing technologies, providing temperature measurements in the range of –40 °C to +80 °C with an accuracy of ±0.5 °C, and relative humidity measurements from 0 % to 99.9 % with an accuracy of ±2 %. These sensors' high accuracy and reliability are critical for precise environmental monitoring.

Carbon dioxide sensors. The MH-Z41A infrared CO_2 sensor is used to measure indoor CO_2 concentrations, ranging from 0 to 5000 ppm with an accuracy of ±50 ppm. This non-dispersive infrared (NDIR) sensor operates based on the absorption of infrared light by CO_2 molecules, offering high accuracy and stability. Monitoring CO_2 levels is essential for assessing indoor air quality and ensuring adequate ventilation, which can impact both occupant health and cognitive performance.

To measure electricity consumption, particularly in classrooms equipped with electric heating, the smart-MAIC D103 energy monitor is deployed. This device connects to the three-phase power supply, measuring voltage and current through ring-type current transformers with a nominal rating of 100 A. The smart-MAIC D103 measures active and reactive power, power factor, and energy consumption with a relative error within 0 %, adhering to Class 1 accuracy standards as defined by IEC 62053-21. Accurate measurement of electrical parameters is crucial for identifying energy-saving opportunities and verifying the effectiveness of implemented energy efficiency measures.

Collected data are transmitted to a cloud-based data management system, where they are stored, processed, and made accessible for real-time analysis. The cloud infrastructure leverages scalable storage solutions and computational resources to handle the large volume of IMS-generated data.

The smart-MAIC Dashboard web application is the user interface for data visualization and analysis. This application aggregates data for specific classrooms or monitored areas, providing customizable dashboards where users can configure widgets, graphs, and tables to suit their analytical needs. Advanced data analytics features allow for trend analysis, anomaly detection, and performance benchmarking against predefined energy efficiency targets.

An example of the dashboard interface for a university classroom is depicted in **Fig. 5.9**. The dashboard displays real-time and historical data on energy consumption, environmental conditions, and utility usage, enabling facility managers to make informed decisions regarding energy management strategies.

The pilot implementation of the IMS at IFNTUOG provides a comprehensive platform for monitoring and analyzing energy consumption and environmental parameters at a granular level. By leveraging high-resolution data, the university can:

– identify energy inefficiencies. Detailed monitoring allows for detecting unusual energy consumption patterns, such as excessive heating or cooling, equipment malfunctions, or suboptimal operating schedules;

– optimize HVAC operations. Real-time microclimate data support the implementation of demand-controlled ventilation and temperature regulation, adjusting HVAC operations based on occupancy and indoor environmental quality requirements;

– enhance occupant comfort and health. Maintaining optimal indoor environmental conditions contributes to occupant comfort, well-being, and productivity. Monitoring CO_2 levels and other indoor air quality parameters enables timely interventions to improve ventilation when necessary;

– support predictive maintenance. Analysis of energy consumption trends and equipment performance can inform predictive maintenance programs, reducing downtime and extending the lifespan of assets;

– inform policy and investment decisions. Data-driven insights support strategic planning and investment in energy efficiency measures, renewable energy integration, and infrastructure upgrades.

The IMS is a valuable educational tool for students and faculty within the EMandTD department and beyond. It provides hands-on experience with state-of-the-art energy monitoring technologies, data analytics, and IoT systems, enriching the curriculum and fostering research in energy management, sustainability, and smart building technologies.

Students can engage in projects that involve:

– data analysis and modeling: applying statistical and machine learning techniques to analyze energy and environmental data, develop predictive models, and identify optimization opportunities;

– system integration and development: designing and implementing enhancements to the IMS, such as integrating additional sensors, developing control algorithms, or exploring new communication protocols;

– interdisciplinary research: collaborating across disciplines to study the interactions between building systems, occupant behavior, and energy consumption, contributing to the broader field of building science.

Fig. 5.9 An example of an information panel for a segment of the information and measurement system for energy monitoring in a university classroom

The modular design and standardized components of the IMS facilitate its scalability and replicability across other buildings within the university and in public buildings by analogy. By demonstrating the system's effectiveness in a pilot setting, IFNTUOG can develop guidelines and best practices for wider deployment, contributing to energy efficiency improvements at a larger scale.

This system is engineered to collect real-time data from a network of devices strategically installed throughout the building. These devices include sensors and meters that monitor various energy parameters such as electricity consumption, thermal energy usage, water consumption, and microclimate conditions like temperature and humidity.

Data acquired from these devices are transmitted to a cloud-based storage infrastructure, enabling instantaneous access for viewing and analysis. The utilization of cloud computing not only ensures scalability and flexibility but also facilitates remote monitoring capabilities. This approach allows for aggregating vast amounts of data without the constraints of on-premises storage limitations.

The cloud-hosted platform supports the smart-MAIC Dashboard web application, an interactive interface for data visualization and analysis. This application consolidates information for specific classrooms or other monitored spaces, providing comprehensive insights into energy consumption patterns. Advanced analytical tools within the dashboard enable further examination of the data, supporting the identification of inefficiencies and the development of targeted energy-saving strategies.

Users can customize their dashboards by configuring widgets, graphs, and tables according to their requirements. This personalization enhances the user experience and ensures that stakeholders can focus on the most pertinent data relevant to their roles. The intuitive dashboard design reduces the need for specialized technical skills, promoting broader engagement among facility managers, administrative staff, and researchers.

An information panel for a university classroom's energy monitoring system illustrates the real-time visualization of energy consumption metrics and environmental conditions within the space. By providing granular data at the room level, the system enables precise monitoring and management of energy use, contributing to energy efficiency and sustainability objectives.

The information panel (**Fig. 5.9**) shows the current values of temperature, humidity, and carbon dioxide concentration in the room and voltage, current, and consumed power for each phase of the power line. It is essential to analyze energy consumption, the thermal inertia of the building, and the efficiency of the heating, air conditioning, and ventilation system to track changes in the controlled parameters over time. The smart-MAIC Dashboard web application can build various graphical dependencies with different time granularity (minute, hour, day, week, month, year) and varying types of graphical trend display (line, area, bar chart). Additionally, the user can configure the required data output in a table, particularly for detailing consumption and costs, by setting the price for the energy carrier or hot/cold water, which the monitoring system tracks. For further analysis, for example, in the Excel environment (as a standard software tool for energy management tasks), the data aggregated in the table are exported in CSV format.

To assess the electrical energy consumption by the entire building or its part, the smart-MAIC D103 energy monitor is also used with the appropriate current transformers. The smart-MAIC device line uses current transformers from 100 A to 2000 A, which allows to control the load in a building up to 1.5 MW.

5.2.4 Sustainable energy and climate action planning at the university level

To establish a robust foundation for advancing the green transition within the university setting and to align with local municipal policies, the development and adoption of Sustainable Energy and Climate Action Plans (SECAPs) have been implemented. The SECAP serves as a comprehensive roadmap for the university, aiming to achieve its institutional commitments on climate change mitigation. It considers the sustainable development policies of Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG), European initiatives to reduce greenhouse gas emissions, and the university's goals to improve energy efficiency. These commitments include a targeted reduction of greenhouse gas emissions by at least 40 % by 2030 and the development of strategies for climate change mitigation and adaptation, as endorsed by the Covenant of Mayors.

The SECAP for the university encompasses several critical components designed to systematically address energy consumption and emissions. It begins with a declaration of milestones for reducing energy consumption and CO_2 emissions and increasing the share of renewable energy sources in the university's energy mix. This sets clear, measurable goals aligning with national and international climate objectives, providing a strategic direction for the university's sustainability efforts.

An outline of the campus facilities is provided, offering detailed descriptions of building envelopes, infrastructure condition, heating areas, and other relevant aspects. This comprehensive overview identifies key areas where energy efficiency improvements can be made. By understanding the current state of facilities, the university can prioritize actions that will significantly reduce energy consumption and emissions.

An in-depth analysis of heating losses is conducted based on the energy audit results, offering enhancements recommendations. Energy auditing is crucial in identifying inefficiencies in heating systems, insulation quality, and overall thermal performance of campus buildings. Implementing the recommendations from these audits can lead to substantial reductions in energy waste and operational costs, contributing to the university's sustainability goals.

Calculations estimating greenhouse gas emissions are derived from meticulous energy balance spreadsheets, enabling accurate emissions and energy use tracking. This data-driven approach facilitates benchmarking progress over time, allowing the university to assess the effectiveness of implemented measures and adjust strategies as necessary. It also ensures transparency and accountability in reporting emissions reductions to stakeholders and regulatory bodies.

The operational strategy outlined in the SECAP focuses on implementing energy efficiency measures, establishing robust energy monitoring systems, and increasing the use of renewable energy sources such as solar, wind, or biomass. The university enhances its energy administration practices and improves environmental reporting to maintain transparency and encourage continuous improvement. By adopting advanced monitoring technologies and management practices, the university can optimize energy use, detect anomalies, and engage in proactive maintenance, further driving efficiency gains.

A detailed description of planned measures to be implemented is provided, accompanied by estimates of the return on investments (ROI) for each proposed initiative. This economic analysis ensures that the planned actions are both environmentally beneficial and financially viable, promoting sustainable development in a holistic sense. By demonstrating favorable ROI, the university can justify investments in energy projects to stakeholders and secure funding or financing as needed.

An implementation plan with specific details outlines the steps necessary to achieve these goals, including timelines, responsible parties, and resource allocations. This plan is a practical guide for university administration, faculty, and staff, ensuring coordinated efforts across all departments. It emphasizes the importance of stakeholder engagement, recognizing that the participation of the entire university community is essential for the successful execution of the SECAP.

The development of the SECAP at IFNTUOG exemplifies how universities can effectively align their sustainability efforts with both local and European climate objectives. By integrating comprehensive planning, energy auditing, and strategic investments, the university positions itself as a leader in reducing greenhouse gas emissions and advancing the energy transition at the institutional level. This approach contributes to global climate goals and enhances the university's operational efficiency, reduces energy costs, and fosters a culture of sustainability among students, faculty, and the broader community.

An example of the developed SECAP for Ivano-Frankivsk National Technical University of Oil and Gas can be found [18]. This document is a model for other educational institutions seeking to implement similar strategies. By sharing best practices and lessons learned, IFNTUOG contributes to disseminating effective energy management and climate action planning methods in the higher education sector.

Moreover, the SECAP initiative at the university level demonstrates the critical role that educational institutions play in combating climate change. Universities are not only centers of learning and research but also significant consumers of energy and resources. By adopting comprehensive action plans like the SECAP, universities can significantly reduce their environmental footprint, inspire students and staff to engage in sustainable practices and contribute to developing innovative solutions to global energy challenges. This proactive approach underscores the importance of integrating sustainability into all aspects of university operations, from infrastructure and resource management to education and community engagement.

The commitment to reducing greenhouse gas emissions by at least 40% by 2030 is a significant undertaking that requires concerted effort across multiple domains. It involves upgrading infrastructure to more energy-efficient systems, increasing the use of renewable energy, and promoting behavioral changes among the university community to support energy conservation. The SECAP provides a structured framework for these efforts, ensuring that they are strategic, coordinated, and effective.

The Sustainable Energy and Climate Action Plan (SECAP) is a roadmap for the university aimed at achieving its institutional commitments on climate change mitigation, taking into account the sustainable development policy of IFNTUOG, the European initiatives to reduce greenhouse gas emissions, as well as the university's goals to improve energy efficiency. These commitments include reducing greenhouse gas emissions by at least 40 % by 2030 and developing an approach to climate change mitigation and adaptation (the Covenant of Mayors).

SECAP for the university shall, in general, contain the following:

1. Declaration on milestones for energy consumption and CO_2 emission reduction, share of renewables.

2. Outline of campus with a description of facilities, a brief description of building envelope condition, heating area, etc.

3. Analysis of heating losses based on results of energy auditing with recommendations (optional).

4. Calculations of estimates of greenhouse gas emissions based on energy balance spreadsheets.

5. Operational strategy focused on energy efficiency measures, energy monitoring, use of renewable energy sources, energy administration, and environmental reporting.

6. Description of planned measures to be implemented with estimates on returns of investments for those proposed.

7. Implementation plan with a specific detailing.

An example of the developed SECAP of Ivano-Frankivsk National Technical University of Oil and Gas may be found [17].

5.3 Conclusions

This paper has outlined a comprehensive approach demonstrating the pivotal role universities can play as regional leaders in implementing sustainable energy and climate policies harmonized with European Union standards. Through a tri-directional strategy piloted at Ivano-Frankivsk National Technical University of Oil and Gas, the study showcases the integration of a demonstration solar power station, the development of an Information and Measurement System for energy consumption and indoor climate monitoring, and the institutional efforts embodied in the university's Sustainable Energy and Climate Action Plan.

The demonstration solar power plant at IFNTUOG represents a significant advancement in the university's energy infrastructure. By generating electricity from renewable sources, the plant reduces the university's reliance on traditional fossil fuels and contributes to lowering its carbon footprint. This initiative serves the university's energy needs and acts as a tangible example of renewable energy implementation, inspiring students, staff, and the broader community to embrace sustainable practices.

The pilot information and measurement system for energy monitoring is another critical component of the university's strategy. By collecting high-resolution data on energy consumption and indoor environmental conditions across university buildings, the IMS enables the identification of areas where energy efficiency improvements are most needed. This data-driven approach facilitates informed decision-making, allowing for targeted interventions that optimize energy use, reduce operational costs, and enhance occupant comfort. The IMS also provides an educational platform for students and researchers to engage with cutting-edge energy management technologies.

The development of a Sustainable Energy and Climate Action Plan marks the university's institutional commitment to contributing toward the green transition at the municipal level. The SECAP outlines clear objectives, strategies, and implementation plans to reduce greenhouse gas emissions, improve energy efficiency, and integrate renewable energy sources. By aligning with local policies and European initiatives such as the Covenant of Mayors and the EU Green Deal, IFNTUOG positions itself as a leader in sustainability efforts within the higher education sector.

Moreover, these initiatives exemplify how universities can catalyze regional adoption of EU-harmonized sustainable energy and climate policies. IFNTUOG's efforts advance its sustainability goals and contribute to Ukraine's alignment with EU environmental and energy standards. Ukraine's commitment to harmonizing its sustainable energy policies with the EU is crucial to its broader European integration strategy. This alignment is driven by the need to comply with EU regulations, access funding opportunities, and participate actively in the EU's ambitious climate and energy frameworks, such as the European Green Deal and the Fit for 55 packages. By adopting practices and standards consistent with these EU directives – such as implementing the ISO 50001 Energy Management System and developing the SECAP in line with the Covenant of Mayors – IFNTUOG not only advances its own sustainability goals but also supports Ukraine's broader ambitions to integrate with the European community. This harmonization facilitates collaboration and access to funding opportunities and supports Ukraine's efforts to enhance its energy security and environmental sustainability in line with European standards.

The successful implementation of these projects demonstrates IFNTUOG's dedication to energy efficiency and environmental stewardship. As a leader in the field of energy efficiency in Ukraine, the university's initiatives serve as a testament to its commitment to reducing environmental impact and fostering a culture of sustainability. These efforts benefit the university and contribute to broader societal goals of combating climate change and promoting sustainable development and climate EU-harmonized policies.

The tripartite approach detailed in this paper-combining renewable energy deployment, advanced energy monitoring systems, and comprehensive strategic planning-provides a replicable model for other public buildings and educational institutions in Ukraine and beyond. The integration of these elements showcases how universities can effectively lead by example, driving the adoption of sustainable practices at the municipal and national levels. In light of the EU Green Deal and global climate objectives, other European higher education institutions may adopt similar strategies to advance the energy transition.

In conclusion, universities are uniquely positioned to lead regional efforts in the energy transition by integrating EU-harmonized sustainable energy and climate policies into their operations and communities. Being a valuable part of their local community, they act as a demonstrator and working examples for the promotion of sustainable energy and climate actions in line with respective municipal policies. By leveraging their resources, expertise, and influence, they can implement practical solutions that reduce emissions, enhance energy efficiency, and educate future generations. The initiatives undertaken by IFNTUOG highlight the profound impact that higher education institutions can have in shaping a sustainable future, reinforcing the imperative for continued efforts and collaboration in this critical endeavor. The successful implementation of the proposed triplicate approach shall lead to adopting similar projects at other public buildings in Ukraine. Other European higher education institutions may consider it given the EU Green Deal.

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References

1. A Green Deal roadmap for universities (2023). Report. Available at: https://eua.eu/resources/publications/1078:a-green-deal-roadmap-for-universities.html
2. Climate change (2021). Report summary. European Union. Available at: https://climate.ec.europa.eu/system/files/2021-07/report_summary_2021_en.pdf
3. Win the Energy Challenge with ISO 50001 (2011). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat.
4. The ISO Survey-2012 (2013). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat. Available at: http://www.iso.org/iso/home/standards/certification/iso-survey.htm
5. ISO 50001 Energy Management Systems – Requirements with Guidance for Use (2011). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat.
6. Dobes, V. (2013). New tool for promotion of energy management and cleaner production on no cure, no pay basis. Journal of Cleaner Production, 39, 255–264. https://doi.org/10.1016/j.jclepro.2012.08.007
7. Renewables 2020 Analysis and forecast to 2025 (Solar PV) (2020). International Energy Agency. Available at: https://www.iea.org/reports/renewables-2020#overview

8. Pershyi spilnyi z IFC vebinar na temu "Soniachni elektrostantsii dlia vlasnoho spozhyvannia dlia ukrainskykh pidpryiemstv" (2021). UKRGASBANK. Available at: https://www.ukrgasbank.com/eco/webinar_ifc
9. Chomu vse bilshe ukrainskykh kompanii investuiut u soniachni elektrostantsii dlia vlasnoho spozhyvannia (2021). Informatsiyne ahentstvo "Interfaks-Ukrayina". Available at: https://ua.interfax.com.ua/news/blog/740411.html
10. Rogers, S. (2016). Solar Immersion – Maximise your solar power self consumption. Gold Coast Solar Power Solutions. Available at: https://gold-coast-solar-power-solutions.com.au/posts/solar-immersion/ Last accessed: 18.10.2024
11. Export limitation? No problem. Choose the Fronius solution for Limited or zero feed-in situations. Fronius International. Available at: https://www.fronius.com/~/downloads/Solar%20Energy/Flyer/SE_FLY_Export_Limitation_Solution_EN_UK.pdf
12. Mataloto, B., Calé, D., Carimo, K., Ferreira, J. C., Resende, R. (2021). 3D IoT System for Environmental and Energy Consumption Monitoring System. Sustainability, 13 (3), 1495. https://doi.org/10.3390/su13031495
13. Nguyen, V. K., Zhang, W. E., Mahmood, A. (2021). Semi-supervised Intrusive Appliance Load Monitoring in Smart Energy Monitoring System. ACM Transactions on Sensor Networks, 17 (3), 1–20. https://doi.org/10.1145/3448415
14. Guide on monitoring of building energy efficiency (2015). USAID. Municipal energy reform in Ukraine. Kyiv. Available at: https://pdf.usaid.gov/pdf_docs/PA00MD8N.pdf
15. Rybitskyi, I., Karpash, M., Yavorskyi, A., Tsykh, V. (2021). Indoor climate and energy monitoring system at educational institutions. Building Smart Communities for the Future: SMART solutions for energy. Technical University of Košice, 69–76.
16. Smart-MAIC. Smart meters for any consumption. Available at: https://smart-maic.com/en/
17. Sustainable energy and climate action plan for 2021–2030 (2021). IFNTUOG. Available at: https://nung.edu.ua/sites/default/files/2021-12/SECAP-eng.pdf