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HEAT AND MASS EXCHANGE PROCESSES DURING DRYING OF COMPOSITE MIXTURE FROM PEAT WASTE AND CORN STALK

Abstract: *This paper presents a study of the heat and mass exchange processes of drying composite raw materials based on the solid residue after the extraction of humic substances from peat and nutritious corn stalk. A study of the drying kinetics of the composite mixture was conducted and energy-efficient modes were determined. The kinetics of heat-moisture exchange during drying of the composite mixture was calculated, and the kinetic regularities of drying were determined and summarized.*

Keywords: *peat, corn stalk, drying*

Introduction

One of the main problems of the modern world is the search for and supply of renewable energy resources that could compete with oil and natural gas.

Biofuel is an alternative type of fuel obtained as a result of the processing of animal or vegetable raw materials, as well as organic industrial waste and household products. Alternative energy considers biofuel as an option to replace traditional – coal, oil, natural gas, etc.

Among the non-traditional types of solid fuels known in Ukraine, it is worth paying attention to peat – an organic rock formed as a result of incomplete biochemical decomposition of dead marsh plants in conditions of excess moisture with a lack of oxygen, which contains up to 50% of mineral components on a dry matter basis.

Peat contains a large number of humic substances. Because of this, peat has significant energy and agrochemical potential and is used as a local fuel, as well as raw material for the production of greenhouse and consumer soils and organic fertilizers. Peat fuel is the cheapest and most efficient when transported over short distances. The cost of a unit of energy obtained from peat is 3 times cheaper than the cost of the same energy obtained from natural gas [1].

If humic substances are removed from it, and the rest is burned, then this unique natural resource can be used more rationally. The main method of obtaining humic substances is an alkaline reaction with ammonia solutions or potassium or sodium hydroxides. Such processing turns them into water-soluble salts – potassium or sodium humates with high biological activity. The composition of functional groups and the structure of molecular fragments of humic acids depends on the method of their production.

In the production of humic liquid or solid fertilizers, the humic component is extracted from peat [2]. After extraction, a solid residue remains, which can be used more rationally in the future. The creation of new compositions based on peat or its residues after extraction give a positive result when it is burned.

Materials and methods

Suitable materials, such as milled peat and nutritious corn stalk, were used for research. Milled peat has an initial moisture content of 13.18% and an ash content of 27.23%. Corn stalk have a moisture content of 8.45% and an ash content of 9.8%.

The resulting mixture of peat residues after extracting fertilizers and nutritious corn stalk was dried on an experimental stand with an automatic system for collecting experimental data and processing it. The automated data acquisition system reads data at a rate of 7 values per minute. During the drying process, data on the time of the experiment, the temperature in the middle of the drying chamber and the mixture, and the change in the mass of the material were read [3].

Results

Figure 1 shows the change in the moisture content and drying temperature of the mixture based on the solid residue of peat after the extraction of the humic component with crushed nutritious corn stalk at temperatures of 70°C and 100°C. As can be seen from Figure 1 increase in the temperature of the coolant from 70°C to 100°C intensifies the drying process by 1.8 times.

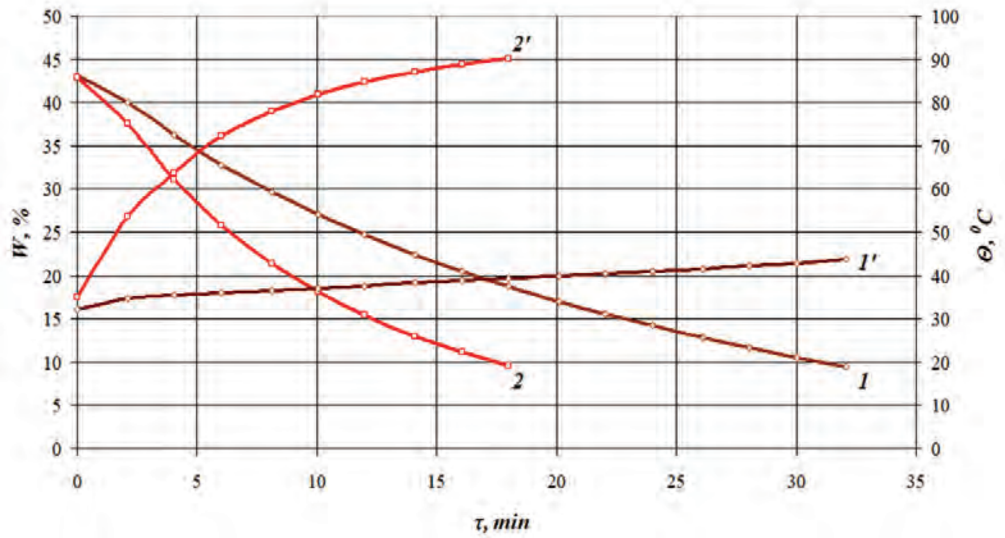

FIGURE 1. *Change in moisture content (1, 2) and temperature in the middle of the layer (1′, 2′) of the mixture based on the solid residue of peat after extraction and crushed corn stalk ratio 1:1 over time, V = 3 m/s, h = 10 mm, particle size ≥0.5 mm: 1, 1′ – 70°C; 2, 2′ – 100°C*

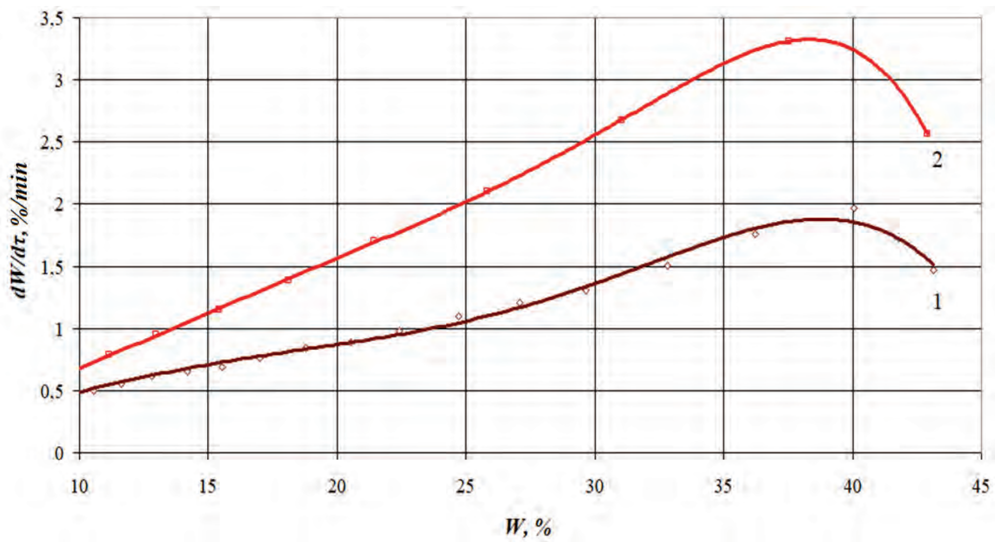

FIGURE 2. *Change in the speed of the mixture based on the solid residue of peat after extraction and crushed corn stalk ratio 1:1, V = 3 m/s, h = 10 mm, particle size ≥0.5 mm: 1 – 70°C; 2 – 100°C*

Figure 2 shows the change in the presented change in the drying speed of the mixture based on the solid residue of peat after the extraction of the humic component with crushed nutritious corn stalk at temperatures of 70°C and 100°C. As can be seen from Figure 2 drying speed at a temperature of 70°C – 1.9%/min., and at a temperature of 100°C – 3.4%/min.

The nature of the drying process, which is depicted on the curves of drying kinetics, drying speed and temperature curves, is determined by the physic-chemical and structural-mechanical properties of the material, which affect the form of moisture connection with it, the diffusion nature of the phenomenon, as well as the method of heat introduction, otherwise regularity of interaction of the body with the environment. A variety of factors and their interrelation makes it difficult to obtain analytical dependences of material drying kinetics. Therefore, when describing the drying process, empirical dependences are used. The most similar method of calculating the kinetics of drying is a method based on the study of the general regularities of the process, which brings the theory and practice of drying closer together [4].

According to the appropriate methods, the kinetics of heat-moisture exchange during drying of the composite mixture was calculated [4, 5].

To study the kinetics of drying, composite mixtures were taken based on the solid residue after the extraction of humic substances from peat and nutritious residues of corn in a ratio of 1:1. After calculation according to the given method, generalized drying kinetic curves and drying speed curves were obtained.

Analysing the generalized drying curves, we can say that all drying modes fit on one curve with an error of no more than 10% (Fig. 3).

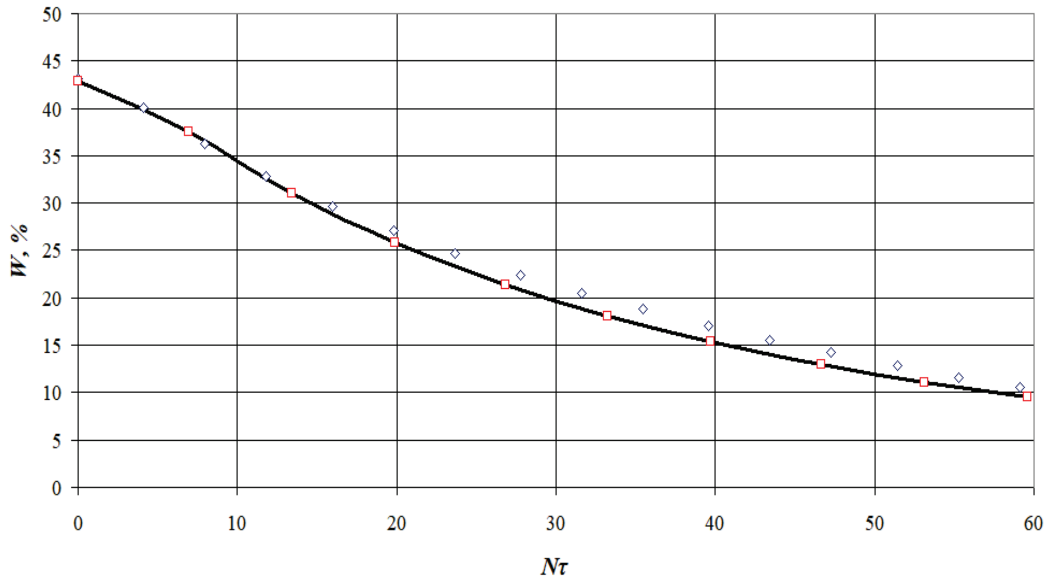

Figure 3. *Generalized drying curves of the mixture based on the solid residue of peat after extraction and crushed corn stalk in the coordinate system W – N τ*

Carrying out graphical differentiation of the generalized curve of drying kinetics, presented in Figure 3, obtained the generalized curve of the drying speed of the composite mixture, which is presented in Figure 4.

The total duration of the process in the absence of the first drying period:

$$\tau_T = \frac{1}{N}\left(\frac{1}{\chi_1}\lg\frac{Wk_1}{Wk_2} + \frac{1}{\chi_2}\lg\frac{Wk_2}{W_k}\right) = \frac{1}{N}\left(\frac{1}{0.011}\lg\frac{40}{11.6} + \frac{1}{0.010}\lg\frac{11.6}{9.5}\right) =$$

$$= \frac{1}{N}(48.89 + 8.2) = \frac{57.09}{N}$$

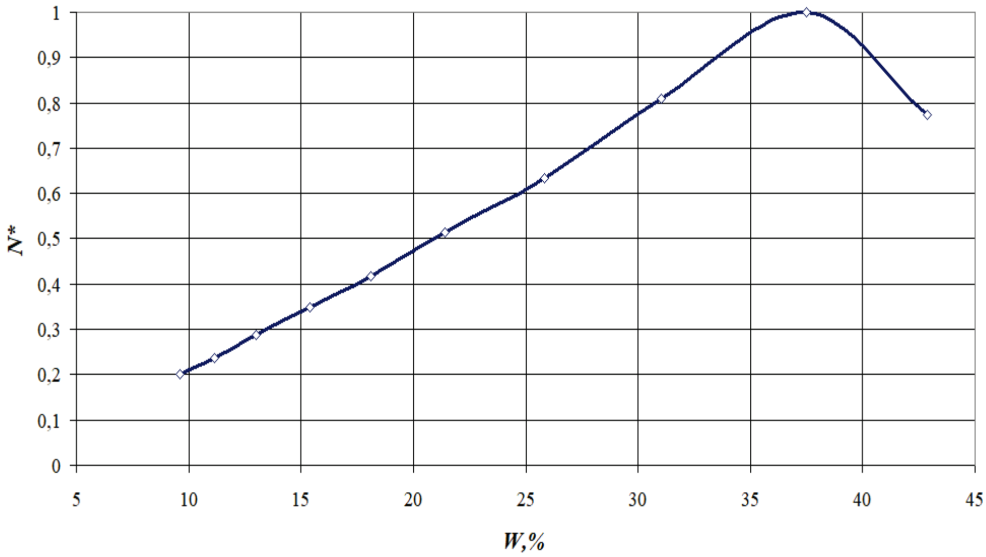

***FIGURE 4.** Generalized curves of the drying speed of the composite mixture based on the solid residue of peat after extraction and crushed corn stalk*

Conclusions

The drying kinetics of the composite mixture based on the solid residue of peat after extraction and crushed corn stalk were investigated, and effective drying modes were determined. The kinetic regularities of convective drying of the composite mixture based on the solid residue of peat after extraction and crushed corn remains were determined and summarized.

References

[1] Sniezhkin Yu.F., Petrova Zh.O., Korinchuk D.M., 2019, *Effective thermal technology of processing peat into fuel and fertilizer*. Renewable energy and energy efficiency in the XXI century: materials of the XX international scientific and practical conference, May 15-16, 2019, Kyiv: Interservice, 616 [in Ukrainian].

[2] Sniezhkin Yu.F., Petrova Zh.O., Korinchuk D.M., 2018, *Method of obtaining organo-mineral fertilizers based on humic substances*. Patent of Ukraine No. 117651 from 27.08.2018 [in Ukrainian].

[3] Sniezhkin Yu., Petrova Zh., Novikova Yu., Petrov A., 2020, *Technology of complex processing of peat*. Energy and automation, No. 5, 32-41. http://dx.doi.org/10.31548/energiya2020.05.032.

[4] Sniezhkin Yu.F., Paziuk V.M., Petrova Zh.O., Chalaiev D.M., 2012, *Heat pump grain dryer for seed grain*. Kyiv: Polygraph Service LLC [in Ukrainian].

[5] Snezhkin Yu.F. Petrova Zh.O., 2018, *Energy-efficient thermal technologies of functional raw materials processing*: monograph. Kyiv: Naukova dumka [in Ukrainian].

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FORMATION OF RISK PROFILE FOR THE INTEGRATION OF RENEWABLE ENERGY SOURCES INTO THE ELECTRICITY SUPPLY SYSTEM

Abstract: *Maintaining the reliability, stability and efficiency of the electricity system is becoming a challenge due to the uncontrolled increase in the number of renewable energy sources. Therefore, there are issues of finding the optimal location of RES capacities with the required technical characteristics. The solution of such a task can be realized by using a risk management system.*

The work is devoted to the development of a methodology that allows, based on the risk profile, to make a generalized decision on the connection of RES to the power supply system. The article defines the concept of "risk profile of RES integration into the power supply system", proposes an algorithm for making a generalized decision on the connection of distributed generation to the power supply system. The basic principles of profile formation are also proposed in order to further consolidate the risk profile of RES integration into the power supply system at the regulatory level.

Keywords: *renewable energy sources, power supply system, risk profile, risk indicator, risk profile passport, fuzzy logic method*

Introduction

According to the Energy Strategy of Ukraine until 2035, the development of energy based on renewable energy sources (RES) is an important area that increases the level of energy security and reduces anthropogenic impact on the environment. It is envisaged to increase the share of RES in the total balance of installed capacities to 25% by 2035, which is about 24 million tons of oil equivalent under the baseline scenario [1].

In turn, the results of quarterly monitoring conducted by the State Agency on Energy Efficiency and Energy Saving of Ukraine show that at the end of 2021, there were about 45 000 households in Ukraine that installed solar power plants (SPPs) with a total capacity of 1.2 GW [2]. The capacity of such SPPs is chosen by the owner, and is usually equal to the maximum capacity defined by the Law of Ukraine "On Alternative Energy Sources" [3]. And for the construction of RES often choose land plots in rural areas with a weak distribution network.

At the same time, there are a number of risks related to the impact of RES sources on the planning, organization of operation and management of power grids. That is, the development of "green" energy takes place without considering the real needs of the energy system of Ukraine in additional generating capacities. This leads to problems such as the need to increase maneuvering capacity, deterioration of the quality of electricity, the need to modernize lines, the growth of debt under the "green" tariff, the emergence of higher harmonics and reactive power flow, as well as the introduction of non-market methods for using the constraint management system [4].

Purpose of the research

The purpose of the article is the formation of a risk profile of RES integration into the power supply system. This will allow making a generalized management decision on the connection of distributed generation sources.

Material and research results

Today, the main directions of modern energy policy in the world are harmonized with strategic environmental security in the context of sustainable economic development. Currently, more and more countries are aiming at the transition to 50 percent or more of renewable energy sources in the energy sector. According to Bloomberg [5], by 2050, wind and solar together will account for more than 50% of global electricity production, and together with energy storage systems – 80%. Oil use will peak in 2035 and then fall by 0.7% p.a. to return to 2018 levels in 2050. The peak of coal-fired electricity is forecast in China in 2027 and in India in 2030, but then the share of its use will fall and reach 18% by 2050 (in 2020 – 26%). Each country is developing its own way to achieve the goal, which differs from others in terms of implementation time, scope, target areas. This is due to the need to improve energy security and the task of preventing global climate change by reducing carbon emissions into the atmosphere.

In the research [4], it was found that further development towards increasing the share of SPPs in the generation of the power system poses a significant challenge to the effective management of the distribution network and creates problems for its normal functioning. Accordingly, there is a need to put forward requirements for the main equipment or to install additional equipment for flexible and dynamic regulation of RES operation. Therefore, decision-making on the integration of RES into the power supply system should be based on the analysis of the modes and processes that arise under different options of RES connection. Consequently, there is a new scientific and technical problem of ensuring the effective integration of RES into the power supply system. Solving this problem requires a systematic approach to avoid inefficient and irrational use of RES opportunities.

In order to assess and compare possible problems at the level of transmission and distribution system operators caused by the connection of RES, it is advisable to introduce the concept of "risk". The international document that interprets the meaning of terms in the field of risk management is ISO Guide 73:2009 [6]. In addition, they are the basis of a unified methodological approach to the perception of other international documents in this area. The risk of RES integration means an event, condition or state that may or may not occur in the future and negatively affect the efficiency of RES. The efficiency of RES is described by a set of desired results achieved with the successful implementation of RES in the electricity supply system. The emergence of possible risks is due to the presence of causes (processes or phenomena) that contribute to their occurrence and explain why the risk is inevitable. Such phenomena are called risk factors. In turn, the risk profile is considered as a description of a set of risk indicators (criteria with predefined parameters), which is the result of collecting, analyzing and systematizing information. This profile may include risks related to the entire system as a whole or some of its local parts.

When the object of study is the electric power system and its subjects, the following risks are proposed as a general classification [7]:

- risks associated with danger to human life, natural, environmental;
- production and technological (reflect the probability of failure of technical systems and their individual elements);
- financial and economic (lack of data on the real cost and technical condition of electrical equipment, the problem of obtaining objective technical and economic information on the consequences of various accidents, damages, failures, shortages of electricity);
- legal (inconsistency of the current legislation with the current problems of the electric power system);

- informational;
- socio-political;
- commercial.

To date, there is no effective, comprehensive system for assessing and managing the risks of integrating RES into the electricity supply system. Practical aspects of risk management in this segment are not sufficiently researched and covered, considering the experience of the leading countries of the world. Therefore, there is an urgent need to create a comprehensive risk management system for the integration of RES, which will be adapted to the current realities of the energy system of Ukraine. Given the described problem, we propose an algorithm for making a generalized decision when connecting RES to the power supply system (Fig. 1).

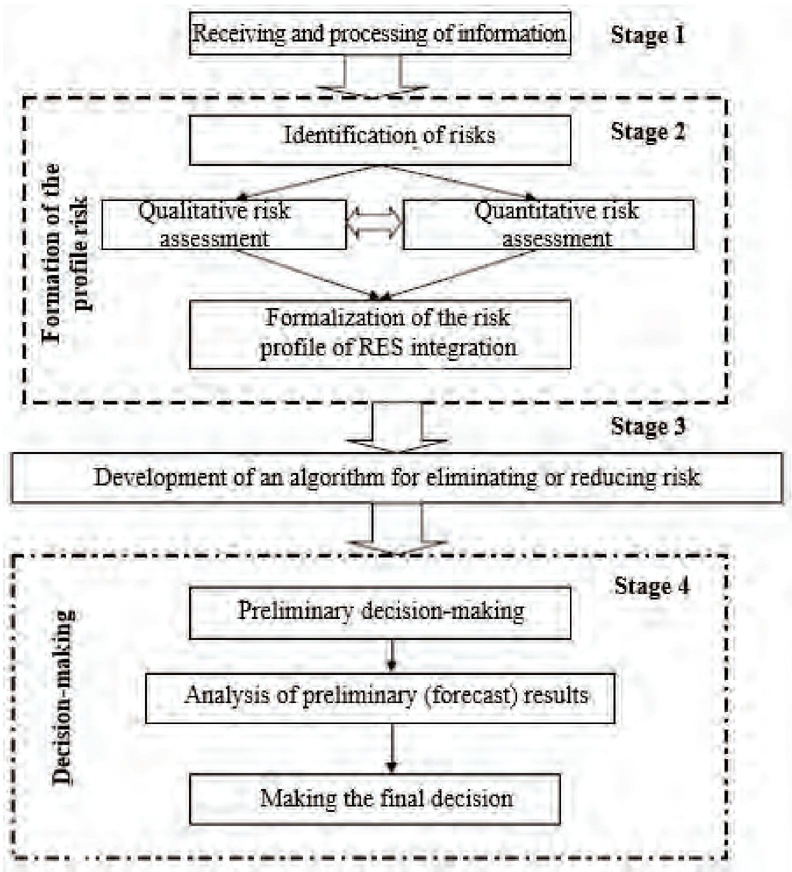


***FIGURE 1.** Risk assessment and management system*

Risk management of RES integration should be based on the results of risk assessment, technical, technological and economic analysis of the potential of the electricity supply system. It should also forecast the impact of these sources on the electricity system and its entities. In addition, risk management should include a methodology for making a generalized decision on the integration of RES.

According to the proposed algorithm, the first stage is the analysis of existing system parameters. The next stage is based on the analysis, identification and assessment of risks, and includes: 1) identification of conditions and factors influencing the occurrence of risks; 2) identification of risk areas; 3) identification of risk indicators; 4) qualitative and/or quantitative assessment of the probability of risks and possible damage in case of their occurrence.

In Ukraine, the relationship between electricity producers/suppliers and consumers in the retail electricity market is regulated by the Rules of the Retail Electricity Market [8]. It is necessary to pay attention to this when determining the priority risk indicators. According to paragraph 5.1.2 of these Rules, the distribution system operator is obliged to comply with the quality indicators of electricity supply. The indicators show the level of reliability (continuity) of electricity supply, commercial quality of electricity distribution services and quality of electricity. The level of power supply reliability is associated with such a risk as imbalance of active energy. It is caused by an increase in load variability of balancing power plants. Already now, there is a lack of balancing measures, which forces the transmission system operator to apply the RES Limit Management System. In order to ensure the flexibility, safety and reliability of the energy system, it is necessary to develop highly maneuverable capacities and increase the volume of the energy storage system. However, the use of these systems is a rather extensive issue, the solution of which is beyond the scope of this article.

One of the main risks of RES integration is the mismatch of the physical parameters of the supplied electricity. In Ukraine, the parameters of electricity quality at the boundary between the transmission system operator and the consumer must comply with the parameters defined in DSTU EN 50160:2014 [9]. The main parameters for low voltage (LV) $Un \leq 1$ kV and their normalized values are given in Table 1. It is important to note that temporarily in Ukraine the standard nominal voltage between the phase and neutral conductor is 220 V. However, the state has committed to switch to $Un = 230$ V in the future to comply with European power quality standards. Therefore, this voltage value is considered further in the article.

Therefore, the following parameters can be used as primary risk indicators: indicators of the quality of electricity at the boundary of the balance between the distribution system operator and the consumer; characteristics of the supply voltage and their normalized values; indicators of the reliability of electricity supply.

TABLE 1. *Normalized values of power quality indicators of LV*

Name of the indicator	Allowable value of the indicator
Frequency	50 Hz ±1% (49.5...50.5 Hz) for 99.5% of the time per year
	50 Hz +4%/-6% (47...52 Hz) for 100% of the time per year
Voltage	230 V ±10% (207…253 V)
Long term severity	≤ 1 for 95% of the observation time
The total harmonic distortion	≤ 8%

The main objective and final result of the "Risk Profile Formation" stage is the formalization of the risk profile of RES integration. The issue of risk profile formation is related to the creation of its logical and effective structure. This is aimed at the possibility of further application of the methodology for making a generalized decision on the connection of RES to the power supply system. These conditions are provided by filling in risk profiles. Profiles can be presented in the form of a risk profile passport, as well as a risk profile program code. In the field of customs control, which operates in Ukraine, risk management measures are fixed by regulatory documents [10] and are implemented in practice. Therefore, the basic principles of profile formation can be used in our study, in particular in the form of a risk profile passport. The risk passport (Fig. 2) is designed to reflect the key characteristics of the risk of RES integration. It is used to form a risk profile and ensure the elimination of the risk or reduction of its negative impact.

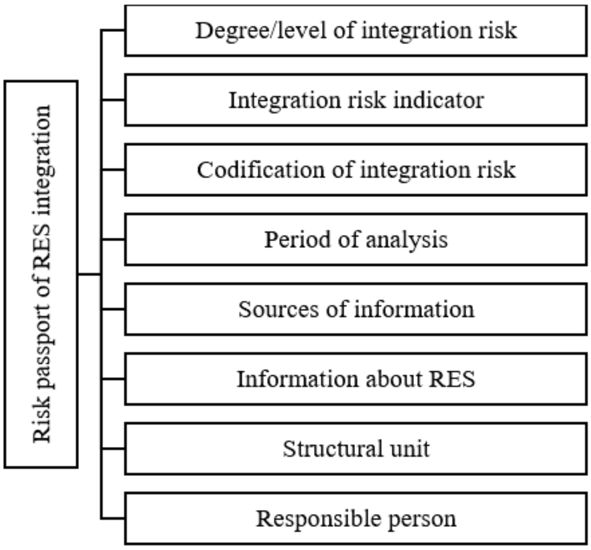


***FIGURE 2.** Risk passport of RES integration into the electricity supply system*

To ensure the fulfillment of the tasks, the RES integration risk passport should contain the following indicative list of information fields [11]:

- Degree/level of integration risk. It reflects the level of risk of RES integration, which was assessed according to the established criteria (indicators). The same risk may have different degrees depending on the values of the indicators. This is the main component for risk management.
- Integration risk indicator. It reflects the criteria (indicators) for which there is a high level of risk and which have been selected for further risk assessment and management.
- Codification of integration risk. It displays a code with encoded information about the risk. This is used to effectively use the passport in terms of recognizing and identifying similar situations in other local networks. The risk code is formed by placing *n* indices of classification categories in a certain order.
- Period of analysis. This indicates the period of time for which the data was processed to determine the integration risk.
- Sources of information. This section specifies the information and analytical support used to identify the integration risk. Determining the risk of RES integration should be based on the processing of information and analytical data of structural units, dispatchers, etc.
- Information about RES. It indicates the available information about the facility (capacity, installation location, parameters of the main RES equipment). It is also proposed to appoint a risk owner. He will be responsible for minimizing the risk of RES integration into the electricity supply system.
- Structural unit. The unit that carries out analytical work on risk identification is indicated here.
- Responsible person. This indicates the official responsible for maintaining the risk profile of RES integration into the electricity supply system.

When forming a risk profile for the integration of RES into the electricity supply system, there are situations when decisions need to be made with significant incomplete information, lack of statistical estimates, incomplete description of the system at the point of connection. The nature of the risk factors may be unclear, with varying degrees of confidence in these factors. Thus, the risk assessment procedure is often implemented in conditions that are poorly formalized, as well as in conditions of unclear and incomplete representation of the factors affecting the risks.

Fuzzy logic algorithms are one of the most acceptable for solving the problems of modeling risk avoidance in the integration of RES. Here are the main advantages of using the fuzzy logic model [12]:

- fuzzy logic methods make it possible to qualitatively, verbally describe risk factors by introducing the concepts of linguistic variables. The content of these variables is clear to the expert, as they are defined not by numbers, but by fuzzy concepts;
- the use of fuzzy sets allows formalizing more flexible relationships between the factors of each of the studied risks. This is more consistent with the nature of the studied real interactions in the power industry, in particular in the power supply system;
- fuzzy methods make it possible to make decisions in conditions of incomplete information by synthesizing and analyzing qualitative values. This is important for making a generalized decision on the connection of RES.

Practical application

We considered the process of modeling the fuzzy logic method using the Matlab package. Fuzzy modeling in the Matlab environment is carried out using the Fuzzy Logic Toolbox extension. It implements dozens of functions of fuzzy logic and fuzzy inference. This package is one of the most common tools for risk profile formation. To describe the set of risk indicators, we used a number of factors that directly reflect the problem of effective RES integration. This category includes the following factors: higher harmonics (Ku), voltage deviation from Un (ΔU) and reactive power flow ($\cos\varphi$). According to the algorithm, the selected factors were analyzed, and a scale for evaluating linguistic variables was formed. For each output indicator we proposed to use three term sets of linguistic variables: "low", "medium" and "high" (see Table 2).

TABLE 2. *Scale for assessing linguistic variables*

Factors			Range	Scale for evaluation of indicators		
				low (L)	medium (M)	high (H)
Higher harmonics	Ku	%	0…10	0.9…0.94	0.92…0.98	0.96…1.0
		Rel. unit	0.9…1.0			
Voltage deviation from Un	ΔU	%	±15 (196…264 V)	0.85…0.91	0.88…0.97	0.94…1.0
		Rel. unit	0.85…1.0			
Reactive power flow	$\cos\varphi$		0.75…1.0	0.75…0.85	0.8…0.95	0.9…1.0

At the next stage, a number of rules were formed by using expert data obtained in the previous study [4]. It allowed forming a risk profile of RES integration into the electricity supply system based on the selected indicators. Figure 3 shows the roadmap of the whole fuzzy inference process. The last graph in the fourth column represents the total weighted solution for a given system, which depends on the input values of the selected factors. It is important to note that this view of the rules allows the interpretation of the entire fuzzy inference process at the same time. It also shows how the shape of certain membership functions affects the overall result.

The "result" for our case can be considered the degree of integration of RES into the power supply system. It can be viewed at different values of physical parameters of the network in the case of RES connection. For example, at relative values of Ku = 0.95, ΔU = 0.96, $\cos\varphi$ = 0.92, the integration rate is 0.786, and at Ku = 0.92, ΔU = 0.9, $\cos\varphi$ = 0.85 – it decreases to 0.5. That is, there is a mechanism for making a generalized decision when integrating RES by using the described method of fuzzy logic. We also obtained the output surface of our system by using the functionality of the selected software (Fig. 4). It shows the entire possible range of the integration index based on the range of the input set of risk factors.

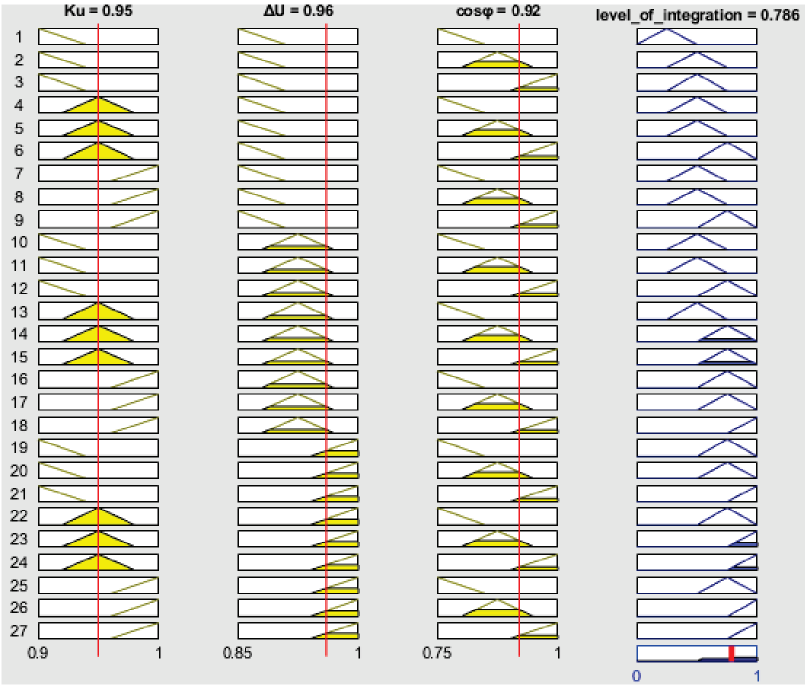
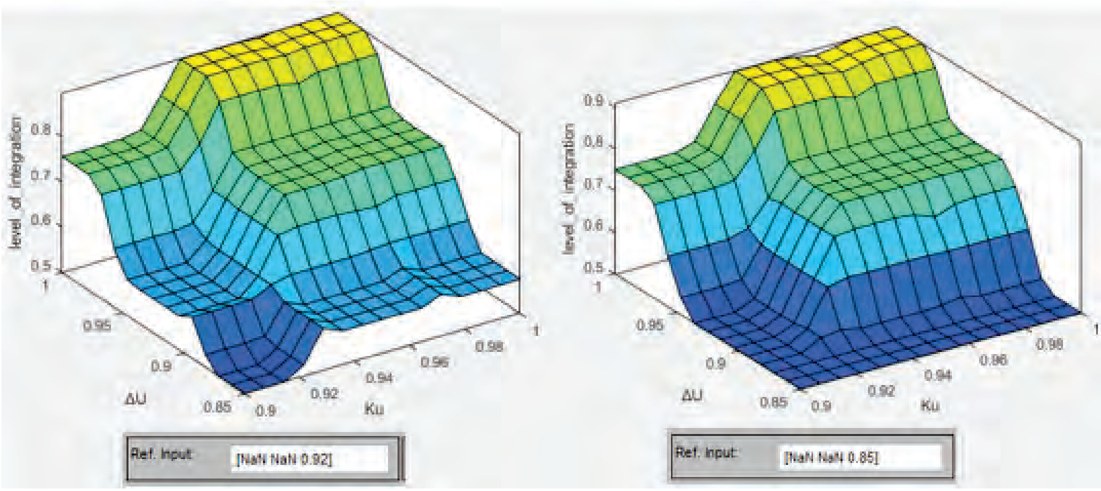


FIGURE 3. *Results of fuzzy logic for given parameters of the power supply system*



(a) (b)

FIGURE 4. *The surface of the fuzzy conclusion at the input parameters ΔU, Ku at cos φ = 0.92 (a) and cos φ = 0.85 (b)*

The resulting model makes it possible to visually assess the probabilities of the situation that may result from the connection of the RES installation. It is necessary to adhere to the parameters of the yellow and green zones of the profile to obtain the highest efficiency of RES. The blue zone, on the contrary, is characterized by the greatest risks for the normal functioning of the system. It shows a categorically unacceptable integration under the given parameters of the system and RES. Getting into the blue zone is also not recommended, as there is low efficiency from RES and a higher probability of risk consequences.

Thus, we have developed a fuzzy inference of risk in the integration of RES into the grid by such factors as higher harmonics, voltage deviation from *Un* and reactive power flow. The resulting model makes it possible to visually assess the probabilities of the situation that may result from the connection of a RES installation to the grid. In this method, the quality of decision-making is determined by the base of fuzzy rules. Supplementing the model with other factors, overcoming possible contradictions of the rules and increasing the intellectual level of the fuzzy logic system will allow making a generalized decision on the integration of RES into the power supply system. The obtained results will be used to develop a methodology for controlled and efficient development of renewable energy. This methodology will be carrying out a feasibility study of the choice of location and technical scheme for connecting RES to the power supply system. It will also allow determining the relevant requirements for the parameters of the electrical installation at the stage of issuing technical specifications to the customer.

Conclusions

Further increase in the share of RES in the total generation of the power system poses a significant challenge for the effective management of the distribution network and creates problems for its normal functioning. Therefore, decision-making on the integration of RES into the power supply system should be based on the analysis of the modes and processes that arise under different options for connecting RES. There is a need to put forward requirements for the main equipment or to install additional equipment for flexible and dynamic regulation of RES operation at the stage of forming technical specifications.

In the process of the research, the concept of "risk profile of RES integration into the power supply system" was defined. An algorithm for making a generalized decision on the connection of distributed generation to the power supply system was proposed. The basic principles of profile formation were also proposed for further consolidation of the RES integration risk profile at the regulatory level. However, the absence of a complete description of the system at the point of connection, the lack of accurate statistical estimates of risk factors and the presence of factors in qualitative or interval form objectively require the use of the mathematical apparatus of fuzzy logic theory.

The Mamdani algorithm is used to assess the risks of integrating RES into the power supply system. The fuzzy system rule base is formed and the membership functions of input parameters for the algorithm implementation are determined. The application of the Mamdani method allows to qualitatively describe the possible causes of the connection problem. It also provides a mechanism for assessing risk avoidance and planning possible solutions for RES integration.

The work will continue on further development of the methodology for making a generalized decision on the connection of RES. Because a properly proposed methodology to reduce risks will greatly facilitate the rapid integration of these sources into the energy system of Ukraine. Controlling the development of renewable energy at the stage of issuing technical conditions will ensure the combination of electricity production from renewable sources with other energy facilities of the Ukrainian system.

References

[1] Energy strategy of Ukraine for the period up to 2035. Ministry of Energy and Coal Industry of Ukraine. http://mpe.kmu.gov.ua/minugol/control/uk/publish/article?art_id=245239564&cat_id=245239555 (accessed 25 March 2022).

[2] Monitoring results for 2021. State Agency on Energy Efficiency and Energy Saving of Ukraine. https://saee.gov.ua/uk/news/4085 (accessed 21 May 2022).

[3] On Alternative Energy Sources: Law of Ukraine of 20.02.2003 No. 555-IV: as of 19 August 2022. https://zakon.rada.gov.ua/laws/show/555-15#Text (accessed 22 May 2022).

[4] Stepanenko V., Zamulko A., Veremiichuk Y., Nakhodov V., 2022, *Assessment of risk for the integration of renewable energy sources into the electricity supply system*. "POWER ENGINEERING: economics, technique, ecology". No. 2, pp. 64-74. ISSN 1813-5420. https://doi.org/10.20535/1813-5420.2.2022.261372.

[5] New Energy Outlook 2020. Bloomberg Executive Summary. https://assets.bbhub.io/professional/sites/24/928908_NEO2020-Executive-Summary.pdf (accessed 1 May 2022).

[6] ISO Guide 73, Risk Management – Vocabulary. Geneva: International Standards Organisation, 2009.

[7] Kozhevnikov A., 2015, *Risks of subjects of the electric energy market in the conditions of reforming the energy system of Ukraine*. Electronic scientific journal "Derzhavne upravlinnya: udoskonalennya ta rozvytok". No. 3. http://nbuv.gov.ua/UJRN/Duur_2015_3_12 (accessed 25 September 2022).

[8] On Approval of the Rules for the Retail Electricity Market: Resolution of National Energy and Utilities Regulatory Commission of 14.03.2018 no. 312: as of 21 May 2022. https://zakon.rada.gov.ua/laws/show/v0312874-18#Text (accessed 25 September 2022).

[9] DSTU EN 50160: 2014 Characteristics of power supply voltage in general purpose electrical networks (EN 50160: 2010, IDT).

[10] The Procedure for risk analysis and assessment, development and implementation of risk management measures to determine the forms and scope of customs control. Ministry of Finance of Ukraine, 2015. Ofitsiinyi visnyk Ukrainy, 70, 2323.

[11] Sushkova E., Shkurenko N., 2019, *Formation of the tax risk profile for organization the risk enterprises documentary review*. Pryazovskyi Economic Herald. No. 4(15). https://doi.org/10.32840/2522-4263/2019-4-44 (accessed 27 September 2022).

[12] Zamulko A., Veremiichuk Y., *Evaluation of efficient usage of methods of the electric power consumption control under the conditions of uncertainty*. Visnyk of Vinnytsia Polytechnical Institute" No. 2, pp. 16-21. https://visnyk.vntu.edu.ua/index.php/visnyk/article/view/1097 (accessed 27 September 2022).

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VALIDATION OF THE FANGER MODEL AND ASSESSMENT OF SBS SYMPTOMS IN THE LECTURE ROOM

Abstract: *Currently, the conditions of the internal environment should be close to comfortable, so that every person who stays in the room does not feel heat discomfort or other ailments resulting from it. Taking this into account, this study focused on the symptoms of SBS (dizziness, nausea, eye pain and runny nose) experienced by 69 people in a modern lecture hall of the Kielce University of Technology. It turned out that the analysed ailments were felt by the study group (which in turn could have caused a decrease in concentration during classes). In addition, the article compares the actual thermal sensations of people to the values obtained from the Fanger model.*

Keywords: *SBS, fanger model, lecture room*

Introduction

Thermal comfort is a very important aspect of well-being in closed interiors. It is important to create such parameters of the microclimate that you do not feel any ailments. However, any change in air temperature, humidity or carbon dioxide can make a person start to feel pain in the eyes, dizziness or a runny nose.

Many authors of studies try to discuss this topic – sick building syndrome like [1-3]. On the other hand, the authors of [4] showed in their studies that adequate ventilation will ensure good air exchange, reducing the appearance of infections. In addition, authors from China [5] examined 2370 buildings, confirming that it is the indoor environment that is the factor influencing the appearance of SBS. Another example of research related to SBS as well as productivity was Licina and Yildrim [6], who showed that SBS symptoms were below 20%.

The main purpose of the work is to find out whether the students of the Kielce University of Technology in one of the modern lecture halls may experience such syndromes as dizziness, runny nose, nausea and eye pain.

Methodology

The study was carried out in one of the modern lecture halls belonging to the Kielce University of Technology. In order to conduct the research, a meter called BABUC-A, an Italian manufacturer, was used, and a questionnaire was completed by a group of 69 (age 20-25) people regarding their well-being during the classes, i.e. symptoms related to the sick building syndromes.

Results

Using the BABUC-A meter, internal environmental parameters were obtained for air temperature of 26.2°C, carbon dioxide content of 1223 ppm, and relative humidity of 53.3%. In addition, for the Body Mass Index, the average was 17.71. First, the results regarding the feeling of dizziness were discussed. It turned out that women felt more dizzy than men. Secondly, eye pain was examined. This symptom was confirmed by "I definitely feel" only women (around 10%), while that for "I rather feel" by around 10% for males and females. The rest of the group declared that they "didn't feel anything" or "rather didn't feel anything". Moving on to the next ailment, i.e. the feeling of nausea, it was surprising that the men themselves declared feeling it. Women did not constitute any percentage share. One of the most frequently chosen ailments was a runny nose, as 19% of women and 9% of men indicated that they developed a runny nose after staying in this room. The prevailing conditions that prevailed during the study were definitely not conducive to well-being. Therefore, the answers related to the assessment of thermal sensations and dissatisfaction with the prevailing internal conditions were analysed. The results showed that the actual thermal sensations of people calculated on the basis of surveys (TSV – Thermal Sensation Vote) and the PMV (Predicted Mean Vote) index, calculated on the basis of the ISO 7730 [7] standard, are within the known range of thermal comfort from the ISO 7730 standard of cm from -0.5 to +0.5. However, it should be noted that people nevertheless rated the indoor environment as good (TSV) as it was -0.15, as opposed to the PMV which was +0.42. Moreover, the PPD (Predicted Percentage of Dissatisfied) indicator was analysed for student surveys and according to the ISO 7730 [7] standard. The feeling of discomfort by students was definitely lower than the data obtained from the ISO 7730 standard.

Conclusion

In the room examined for sick building syndromes, the values for the examined ailments were similarly high for eye pain, dizziness, and runny nose, with the exception of nausea. After analyzing the validation of the Fanger model, discrepancies between the model calculations and the experimental data were noticed. The conclusion that arises after the study is that the possibility of increasing the flow of fresh air could lead to a reduction in the feeling of SBS symptoms.

References

[1] Suzuki N., Nakayama Y., Nakaoka H., Takaguchi K., Tsumura K., Hanazato M., Hayashi T., Mori C., 2021, *Risk factors for the onset of sick building syndrome: A cross-sectional survey of housing and health in Japa*n, Building and Environment, 202. Doi: 10.1016/j.buildenv.2021.107976.

[2] Hu J., He Y., Hao X., Li N., Su Y., Qu H., 2022, *Optimal temperature ranges considering gender differences in thermal comfort, work performance, and sick building syndrome: A winter field study in university classrooms*, Energy and Buildings, 254. https://doi.org/10.1016/j.enbuild.2021.111554.

[3] Sun Y., Zhang Y., Bao L., Fan Z., Wang D., J. Sundell, 2013, *Effects of gender and dormitory environment on sick building syndrome symptoms among college students in Tianjin, China*. Building and Environment, 68, pp. 134-139. Doi: 10.1016/j.buildenv.2013.06.010.

[4] Aguilar A.J., de la Hoz-Torres M.L., Costa N., Arezes P., Martínez-Aires M.D., Ruiz D.P., 2022, *Assessment of ventilation rates inside educational buildings in Southwestern Europe: Analysis of implemented strategic measures*. Journal of Building Engineering, 51. https://doi.org/10.1016/j.jobe.2022.104204.

[5] Fan L., Ding Y., 2022, *Research on risk scorecard of sick building syndrome based on machine learning*. Building and Environment, 211. https://doi.org/10.1016/j.buildenv.2021.108710.

[6] Licina D., Yildirim S., 2021, *Occupant satisfaction with indoor environmental quality, sick building syndrome (SBS) symptoms and self-reported productivity before and after relocation into WELL-certified office buildings*. Building and Environment, 204. Doi: 10.1016/j.buildenv.2021.108183.

[7] ISO International Organisation for Standardization, Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria International Standard ISO 7730 2005

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PROSPECTS OF BIOMETHANE PRODUCTION IN UKRAINE

Abstract: *Prospects and potential for the development of biomethane production in Ukraine are presented. The biomethane potential due to anaerobic digestion from the most prospective feedstock types is estimated as 9.7 billion* m^3CH_4*/year in 2020.*
The total biomethane production in Ukraine could reach 1.0 billion m^3*/year in 2030 and 4.5 billion* m^3*/year in 2050.*

Keywords: *bioenergy, biomass, biogas, biomethane*

Introduction

Biomethane as a close analogue of natural gas can be used for the production of heat and electricity, as a fuel for transport as well as raw materials for the chemical industry. In addition, the production of biomethane is in line with the idea of circular economy as it converts agricultural by-products or household waste into energy ensuring the recycling of nutrients to agricultural land. The common opinion of experts in biogas sector is that "biomethane is the future of biogas".

Prerequisites and advantages of biomethane production in Ukraine

Ukraine has the largest area of agricultural land in Europe, and, accordingly, one of the world´s best potentials of agricultural raw materials for biomethane production. Highly developed existing natural gas supply network in Ukraine (both main pipelines (GTS) and distribution networks (GDS)) with all necessary infrastructure compatible for biomethane transmission as technically close analogue of natural gas. That includes storage facilities, pipelines, valves, regimes of operation, operator instructions, automatics, and personnel qualification. Connection of existing main gas pipelines of Ukraine to the European hubs creates possibility for biomethane export to the EU.

Biomethane is ready for injection into the gas network today unlike hydrogen. No investment is required in the modernization of gas networks (GTS and GDS) and gas equipment (gas burners, engines, turbines, valves etc.). Biomethane can help to load the Ukrainian GTS after the termination of the contracts with Russia.

Biomethane plants, in addition to biomethane, generate digestate, which can become the main organic fertilizer needed for the revival of Ukrainian soils.

Investments in biomethane plants are close to investments in biogas plants with electricity generation (approximately 2.5-3.0 thousand EUR/kW_{el}). The approximate calculations are as follows: a biomethane plant with a capacity of 10 million m^3/year of biomethane, is an analogue of a biogas plant with a capacity of 4 MW_{el}, and it will cost about 10 million Euros. Accordingly, to deliver one billion m^3

of biomethane into the natural gas network, Ukraine needs 100 plants of 10 million m^3/year. Accordingly they will cost one billion Euros in total.

The roadmap for the development of bioenergy in Ukraine until 2050 provides for the introduction and growth of biomethane production in Ukraine to 1.7 billion m^3/year in 2035 and up to 3 billion m^3/year in 2050 (Geletukha et al., 2021).

By author's estimates the total biogas production could reach 1.6 billion m^3/year CH_4 in 2030 (Geletukha et al., 2022). The significant part of that biogas could be upgraded to biomethane. Total biomethane production could be 1.0 billion m^3/year in 2030. It is expected that biomethane could partly (0.2 billion m^3/year) be exported to the EU. The rest could be utilized locally for combined heat and electricity generation in CHP units (0.5 billion m^3/year), heating and industry applications (0.23 billion m^3/year) and for transportation purpose (0.08 billion m^3/year). In such a way biogas sector could serve the growing demand in sustainable and clean energy from the transport and industry sectors.

Feedstock for biomethane production

A variety of organic materials can potentially be used for biogas production, including specially grown crops, by-products and wastes from plant and animal products, animal husbandry wastes, and other anthropogenic wastes. Due to the limited statistical data available to serve as input data for further estimation of waste volumes only main types of wastes and by-products are covered by this assessment including the following organic materials:

1. Animal husbandry wastes, including cattle manure, pig manure, poultry litter, sheep and goat manure formed during animal keeping at the enterprises.
2. Maize silage, specially grown.
3. Crop residues of major crops, including wheat, rye, barley, maize, sunflower, soybean, rapeseed and sugar beet.
4. Food & beverage industry by-products and wastes.
5. Sewage sludge from municipal treatment facilities.
6. Organic fraction of solid waste.

Results and discussion

The estimated biomethane potential from the most prospective feedstock types described above amounts to 9.73 billion m^3 CH_4 a year, as on 2020 (Fig. 1).

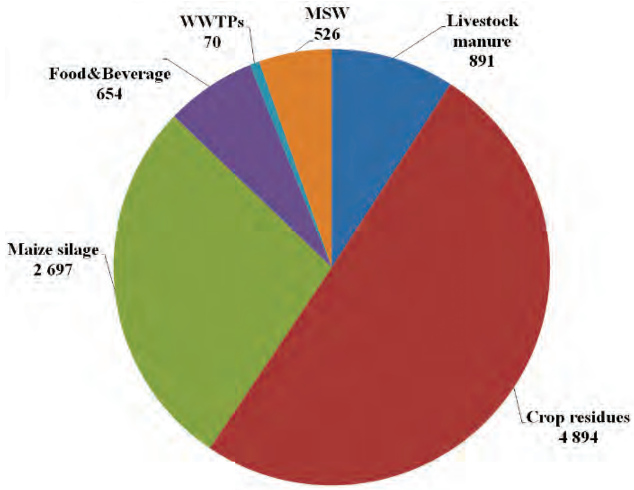

FIGURE 1. *Biomethane potential in Ukraine by feedstock type as on 2020, mln m^3 CH_4 a year (2020)*

Half of this potential is related to crop residues and one third to maize silage production. Animal husbandry wastes can contribute by 9.2%. Food & beverage industry can contribute by 6.7%. Organic fraction of MSW and wastewater sludge could contribute together by additional 6.1%. The potential of biogas production from municipal sewage sludge amounts to only 69.6 mln m^3CH_4 per year. The overall potential related to temporarily occupied territories of Ukraine amounts to 467 mln m^3CH_4 per year or 4.8%.

The most valuable potential among food&beverage by-products belongs to sunflower oil industry and sugar production. The overall potential that oil by-products could contribute amounts to 0.32 billion m^3CH_4 a year, whereas oil press cake only can give 203 mln m^3CH_4 a year. Sugar beet press can contribute 205 mln m^3CH_4 a year. The rest accounted types of by-products amounts to the little shares, however in total can contribute up to 35% to food & beverage biomethane potential. Estimated biomethane potential from food&beverage by-products related to TOT contribute only 0.4%.

In 2050, the total production potential of biogas/biomethane may increase to 17 billion m^3/year. A significant increase in capacity is projected due to the growth of industrial production, expansion of the raw material base for biogas/biomethane production, consolidation of livestock enterprises and the transition from solid waste disposal to the use of mechanical and biological treatment technology.

Regional level

At the level of regions of Ukraine, almost a half of the potential for biomethane production is concentrated in 6 regions of Ukraine (Vinnytsia, Kyiv, Cherkasy, Poltava, Dnipropetrovsk and Donetsk) (Figs. 2 and 3). The highest potential estimated in Vinnytsya region, while the lowest in Zakarpattya region. Biomethane potential by regions ranges from 38 to 846 mln m^3CH_4/year, averaged at 385 mln m^3CH_4/year by region.

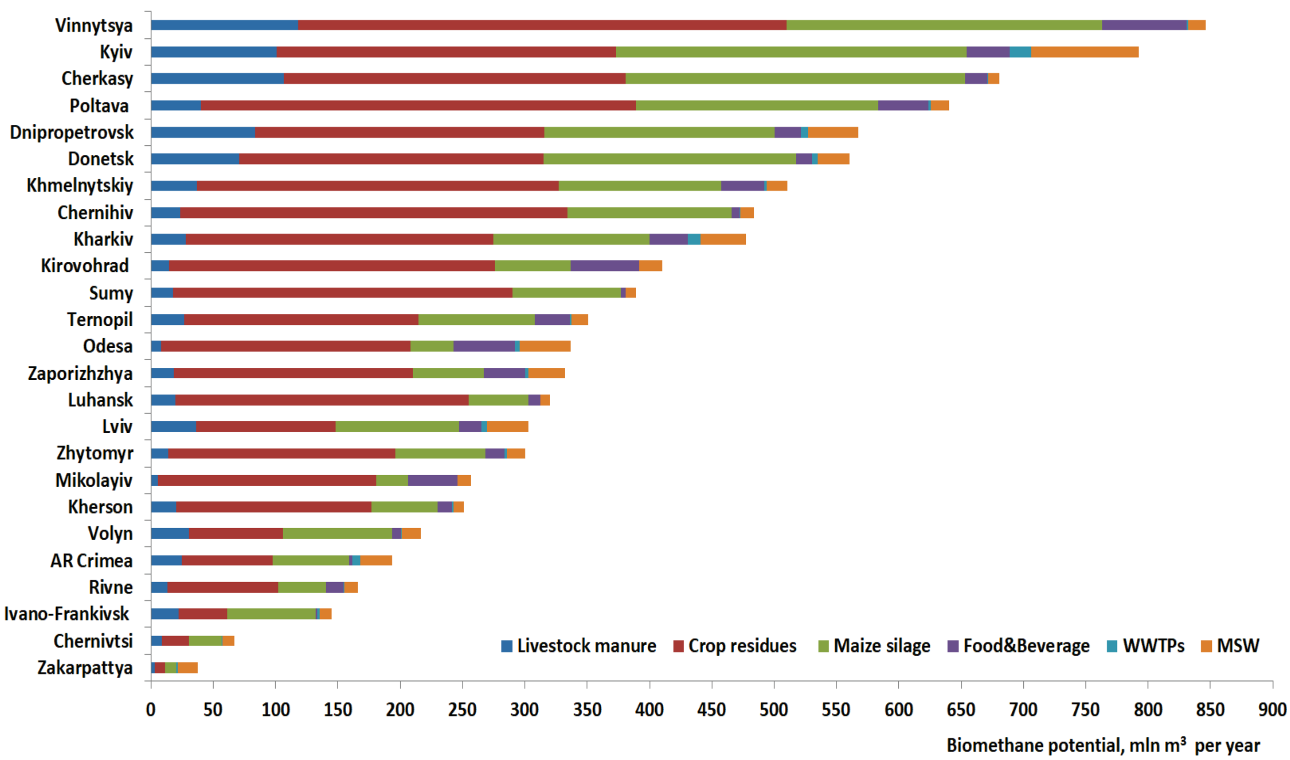

FIGURE 2. *Biomethane potential by regions and by feedstock type (2020)*

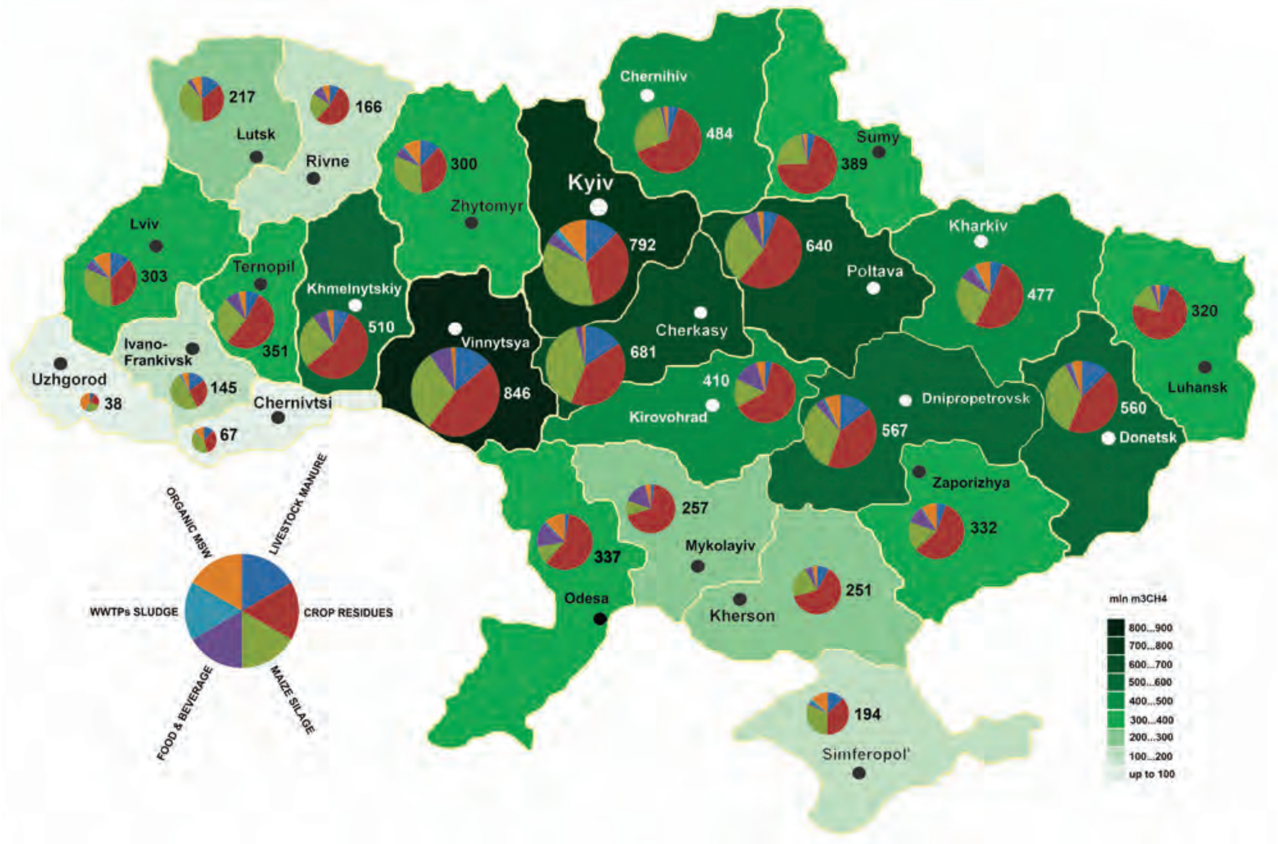

FIGURE 3. *Mapping biomethane potential by regions and by feedstock type, mln m$^3CH_4$ a year (2020)*

Conclusions

Current Ukraine's Energy Strategy sets an ambitious goal of achieving 11 Mtoe of biomass, biofuels and waste in the total supply of primary energy in 2035. It corresponds to 11.5% of the total primary energy supply. Biogas and especially biomethane will play important role in this development.

Production of biomethane with biogas upgrading to the quality of natural gas can significantly increase the energy efficiency of biogas utilisation. The main advantage of biomethane compared to green hydrogen is the possibility of its transportation using the existing gas infrastructure without modernisation.

We believe that in the coming years after the adoption of legislation to support the development of biomethane production, the most of biomethane produced will be exported to EU countries, which have created more favorable conditions for its consumption. As Ukraine's economy grows, more and more of the biomethane produced will remain for domestic consumption.

References

[1] Geletukha G., Zheliezna T., 2021, *Prospects for Bioenergy Development in Ukraine: Roadmap until 2050*. Ecological Engineering & Environmental Technology. 22(5), pp. 73-81. http://www.ecoeet.com/Prospects-for-Bioenergy-Development-in-Ukraine-Roadmap-until-2050,139346,0,2.html.

[2] Geletukha G., Kucheruk P., Matveev Y., 2022, *Prospects and potential for biomethane production in Ukraine*. Ecological Engineering & Environmental Technology. ISSN 2719-7050. Vol. 23, Issue 4, pp. 67-80. http://www.ecoeet.com/Prospects-and-Potential-for-Biomethane-Production-in-Ukraine,149995,0,2.html.

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THERMAL COMFORT ANALYSIS IN THE SMART SUSTAINABLE BUILDING

Abstract: *Modern times are a challenge for many building designers. Creating the internal environment, in particular in sustainable construction, puts the feeling of thermal comfort in the most important place. Therefore, 3 lecture halls in a smart building called Energis belonging to the Kielce University of Technology were examined. In addition to research related to thermal sensations and preferences, PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indices were also calculated on a group of students aged 21 to 25.*

Keywords*: Thermal Comfort, Smart Sustainable building*

Introduction

The society spends most of its life in a closed space, this applies to employees' offices, shops and houses. This is also significantly influenced by the trend of sustainable construction, equipped with a BMS system, various types of technological solutions using renewable energy sources.

Many authors are working on research related to thermal comfort. One such example is Becker and Paciuk [1], who examined 205 apartments in the summer and 189 in the winter, turning out that there is a difference between the PMV and the respondents' answers. Another example [2] focuses on 25 buildings with air conditioning. Again, as in research [1], PMV also did not coincide with people's assessment of their real heat sensations. Similarly to the works [3-5].

The aim of this study is to compare the results of the surveys with the actual results for an intelligent building.

Methodology

The building that was tested is called Energis and belongs to Kielce University of Technology, Poland. Three rooms were tested for temperatures from 22.9-24.6°C, air humidity from 33.01 to 49.4 and for the content of carbon dioxide ranging from 678-2607 ppm. Two methods were used for this purpose. The first one consisted of thermal impressions and humidity surveys, which were supplemented by students and the Testo 400 meter, which collected microclimate data through probes. A total of 37 people were examined, 13 women and 24 men.

Results

Thermal impressions, according to the respondents' assessment, for all tested rooms showed that about 85% of people described their feelings as "pleasantly cool", "comfortable" and "pleasantly warm". On the other hand, about 15% rated their feelings at the moment as "too warm" and "too hot".

Another value that appeared in the survey concerned the acceptability of temperature. About 59% of people found it acceptable, and about 38% found it comfortable. Only about 3% of the respondents declared that the temperature during the examination was no longer acceptable. Turning to room temperature preferences, about 62% would not decide to change it at all, as opposed to about 30% who would like it to be cooler or about 5% much cooler. Only about 3% would like the room to be warmer. The answers of the respondents have their overlap with the answers they marked. Because when assessing thermal sensations, the respondents mainly marked "pleasantly cool/warm" and "comfortable", but also values for "too warm/hot", which proves when asked about preferences that this environment could be cooler. The Thermal Sensation Vote (TSV) was compared to the PMV (Predicted Mean Vote) based on the ISO 7730 [6] standard, as was the PPD (Predicted Percentage of Dissatisfied). The TSV indicators for three rooms showed that in one of them people felt comfortable, in another the comfort range included in the ISO 7730 [6] standard of 0d -0.5 to +0.5 was slightly exceeded, and in the last tested room the TSV definitely exceeded the comfort range with a value above +0.75. More interestingly, the values for PMV were low in the room where the TSV was high. In a room where TSV was low, PMV was high. This proves that there is a significant difference between the real feelings of people and the norm, which assumes that where the environment is good according to the respondents, the PMV according to them is always much higher.

Conclusion

Summing up, according to the respondents, the examined classrooms met their thermal expectations. On the other hand, the Fanger model, which is the basis of the ISO 7730 standard, and the real thermal sensations of people at the moment have no overlap. So the conclusion is that it would be necessary to modify Fanger's model in such a way as to bring it as close as possible to the actual feelings of people.

References

[1] Becker R., Paciuk M., 2009, *Thermal comfort in residential buildings – Failure to predict by Standard model*. Building and Environment 44, pp. 948-960, http://dx.doi.org/10.1016/j.buildenv.2008.06.011.

[2] Broday E.E., Moret J.A., de Paula Xavier A.A., de Oliveira R., 2019, *The approximation between thermal sensation votes (TSV) and predicted mean vote (PMV): A comparative analysis*. International Journal of Industrial Ergonomics 69, pp. 1-8, https://doi.org/10.1016/j.ergon.2018.09.007.

[3] Mors S.T., Hensen J.L.M., Loomans M.G.L.C., Boerstra A.C., 2011, *Adaptive thermal comfort in primary school classrooms: Creating and validating PMV-based comfort charts*. Building and Environment 46, pp. 2454-2461, https://doi.org/10.1016/j.buildenv.2011.05.025.

[4] Manu S., Shukla Y., Rawal R., Thomas L.E., de Dear R., 2016, *Field studies of thermal comfort across multiple climate zones for the subcontinent: India Model for Adaptive Comfort (IMAC)*. Building and Environment 98, pp. 55-70, https://doi.org/10.1016/j.buildenv.2015.12.019.

[5] Vilcekova S., Meciarova L., Burdova E.K., Katunska J., Kosicanova D., Doroudiani S., 2017, *Indoor environmental quality of classrooms and occupants' comfort in a special education school in Slovak Republic*, Building and Environment 120, pp. 29-40, http://dx.doi.org/10.1016/j.buildenv.2017.05.001.

[6] ISO International Organisation for Standardization, Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria International Standard ISO 7730 2005.