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USING THE ENERGY EFFICIENCY HUB IN THE UNIVERSITY ENERGY MANAGEMENT SYSTEM IN THE CONTEXT OF PREVENTING A NEW OUTBREAK OF THE COVID-19 PANDEMIC

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BACKGROUND AND OBJECTIVES. The problem addressed by the project is the need to develop a new approach to energy saving and energy efficiency management in higher education institutions (HEI), whose main components are energy management, energy audit, energy certification, monitoring based on the reasonable use of international standards ISO 50001: 2011, which allows reducing or completely eliminating the barriers to energy efficiency measures related to lack of awareness of energy saving potential.

METHODS. The international protocol of efficiency measurement and verification is proposed to be used as a basis for methodological support of energy efficiency analysis and control in the automated information system of energy efficiency analysis. The method of rationing of heat energy consumption, which takes into account the required level of statistical significance of energy resources saving when carrying out energy saving measures, was used to control the energy efficiency of HUB use of knowledge on energy efficiency. The methodological support of the subsystem of analysis of energy efficiency of heat energy resources consumption is considered.

FINDINGS. A three-part system for improving the energy efficiency of a university based on the HUB of energy efficiency knowledge is proposed: an automated dispatch management system; an automated information system for energy efficiency analysis and a corporate management system for the heat and power complex.

CONCLUSION. Compliance with the consumption rate calculated using the proposed method during the whole study period (second half of 2019 – beginning of 2021) allows to obtain a statistically significant value of thermal energy savings, which will significantly reduce the energy costs of the university in the COVID-19 pandemic crisis. An example of the use of the proposed energy efficiency knowledge HUB for building 4 of the Kyiv National University of Technologies and Design is presented.

KEYWORDS: Energy Efficiency Knowledge HUB; COVID-19; University.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
16	2	0

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ВИКОРИСТАННЯ ХАБУ ЗНАНЬ З ЕНЕРГОЕФЕКТИВНОСТІ В СИСТЕМІ ЕНЕРГОМЕНЕДЖМЕНТУ УНІВЕРСИТЕТУ В УМОВАХ ЗАПОБІГАННЯ НОВОГО СПАЛАХУ ПАНДЕМІЇ COVID-19

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ПОСТАНОВКА ПРОБЛЕМИ ТА ЗАВДАННЯ. Проблема, на вирішення якої спрямовано проект, полягає в необхідності розробки інтегративного підходу щодо управління енергозбереженням та енергоефективністю закладів вищої освіти (ЗВО), основними складовими якого є енергоменеджмент, енергоаудит, енергосертифікація, моніторинг на основі обґрунтованого використання міжнародних стандартів ISO 50001:2011, що дозволяє знизити або повністю ліквідувати стримуючі бар'єри впровадження енергоефективних заходів, які відносяться до недостатньої поінформованості про потенціал економії; недостатньої або фрагментарної інформації про енергоефективність, енергоефективної грамотності серед студентів і науково-педагогічного персоналу, відсутності інтерактивної системи показників енергоефективності; недостатньої уваги до питань енергоефективності існуючих в ЗВО систем та процесів.

МЕТОДИ. В якості основи методичного забезпечення аналізу і контролю енергоефективності в автоматизованій інформаційній системі аналізу енергоефективності пропонується використовувати міжнародний протокол вимірювання та верифікації ефективності. Для контролю енергоефективності використання ХАБ знань з енергоефективності використаний метод нормування споживання теплової енергії, що враховує необхідний рівень статистичної значущості економії енергоресурсів при проведенні енергозберігаючих заходів. Розроблено методичне забезпечення підсистеми аналізу енергоефективності споживання теплоенергетичних ресурсів.

РЕЗУЛЬТАТИ. Запропоновано систему підвищення енерегоеффективності університету на базі ХАБ знань з енергоефективності з трьох частин: автоматизована система диспетчерського управління; автоматизована інформаційна система аналізу енергоефективності та корпоративна система управління теплоенергетичним комплексом.

ВИСНОВКИ. Дотримання норми споживання, розрахованої з використанням запропонованого методу, протягом усього досліджуваного періоду (друга половина 2019 – початок 2021) дозволяє отримати статистично значущу величину економії теплової енергії, що істотно знизить витрати на енергію університету в умовах кризи пандемії COVID-19. Представлений приклад використання запропонованого ХАБ знань з енергоефективності для будівлі 4 корпусу Київського національного університету технологій та дизайну.

КЛЮЧОВІ СЛОВА: ХАБ знань з енергоефективності; COVID-19; університет.

INTRODUCTION.

Energy saving is a pressing issue for the development of the Ukrainian economy. The problem of efficient use of energy resources is particularly acute in higher education. First of all, it is connected with moral and technological obsolescence of fixed assets of higher education, which are currently worn out by 60–70%. At the same time, a large share of depreciation of fixed assets is represented by buildings and structures, drainage, water and heat supply systems.

In the context of the COVID-19 pandemic, some universities are now introducing energy generation systems operating in certain buildings (miniboilers, cogeneration units) (García *et al.*, 2020), and the installation of individual heating substations is a requirement for new buildings and modernisation of already constructed ones (Nayak *et al.*, 2021). The use of local control systems for energy generation and consumption together with automated monitoring and control systems increases the flexibility of energy supply management and not only saves energy, but also improves the quality of energy supply (Nicola *et al.*, 2020).

University building heating systems are an example of this approach in the COVID-19 pandemic (Werth *et al.*, 2021). As most domestic and foreign universities in the COVID-19 pandemic are focusing on energy conservation, various advanced energy conservation technologies are being introduced and tested as part of their research activities (Di Stefano *et al.*, 2000). Therefore, university building heating systems can use several different types of energy generation and consumption units, operating in different modes and providing electricity and heat to buildings of different purposes (Xing *et al.*, 2019).

However, in a COVID-19 pandemic, the presence of a large number of different types of heat sources and consumers in heating systems significantly complicates the analysis of the efficiency of both the heating system as a whole and its individual elements (Abu-Rayash *et al.*, 2020; Wang *et al.*, 2021). At the same time, under the conditions of the COVID-19 pandemic, the application of automated control and management systems allows processing a large amount of statistical information, which makes it especially relevant to develop the application of modelling, forecasting and rationing methods in the tasks of energy efficiency analysis of complex heterogeneous heat supply systems within the framework of university energy management (Liu *et al.*, 2019; Zhong *et al.*, 2020).

The aim of the study is to propose a mechanism for using Hub knowledge on energy efficiency in a university's energy management system in the context of preventing a new outbreak of the COVID-19 pandemic. The study was conducted in 2020 based on data from the Kyiv National University of Technologies and Design (KNUTD).

MATHERIALS AND METHODS.

Energy saving technologies are being introduced in various energy efficiency programmes. An international efficiency measurement and verification protocol has been developed to evaluate the savings from energy saving measures. According to this protocol, the energy savings E_s after energy saving measures are calculated as the difference between the consumption E_{bp} in the base period, calculated under comparable reporting period conditions, and the actual consumption in the reporting period E_{rp} (equation 1):

$$E_s = E_{bp} - E_{rp}. \quad (1)$$

In doing so, a baseline period energy consumption model must be used to calculate energy consumption under comparable conditions, depending on the factors affecting the energy consumption of the system. In particular, to calculate savings in heating systems, the protocol gives an example in which a linear regression on the outdoor temperature is used to construct a base period consumption model. According to the acceptable uncertainty principle of this protocol (Zhong *et al.*, 2020): savings are considered statistically significant if they are larger than the statistical variation of the base period model. Since the standard error of the protocol is used as a measure of variation, savings are assumed to be twice the standard error of the base period model.

In this case, if the calculated consumption of E_{bp} from the base period model is the sum of several independently determined consumption values E_{bp_i}, then the total standard deviation of estimated consumption E_{bp} is the geometric sum of the standard deviations of several independently determined values E_{bp_i} (eq. 2):

$$RMSE_{bp} = \sqrt{\sum_{i=1}^{N} RMSE_{bp_i}}, \quad (2)$$

where N is the number of independently determined consumption values.

Given that each value calculated from a linear regression model is an independent value, then if the regression was constructed, for example, to determine daily consumption in the reference period, the total standard deviation of the definition of total consumption under comparable conditions for N days in the reference period will also be calculated according to equation (3):

$$RMSE_{bp} = RMSE_{bp_{lr}} \sqrt{N}, \quad (3)$$

where $RMSE_{bp_{lr}}$ is the standard deviation of the determination of daily energy consumption obtained according to the linear regression model built.

In accordance with the principle of acceptable uncertainty, the total savings E_s obtained for N days of the reporting period will be considered statistically reliable if the following condition (eq. 4) is fulfilled

$$\sum_{i=1}^{N} E_{s_i} > 2RMSE_{bp_{lr}}\sqrt{N}, \quad (4)$$

where E_{s_i} is the energy savings on the i-th day of the reporting period.

The above inequality (4) implies a new formulation of the rationing problem, related to ensuring the implementation of the principle of acceptable uncertainty at the end of the reporting period. For the problem of operational daily rationing, we reformulate the principle of acceptable uncertainty as follows: the savings will be considered statistically reliable at the end of the reporting period of N days if the savings on each day of the reporting period E_{s_i} is twice the root mean square error $RMSE_{bp_{lr}}$ of the daily energy consumption, divided by the square root of N (eq. 5):

$$E_{s_i} > 2RMSE_{bp_{lr}} \div \sqrt{N}. \quad (5)$$

Thus, compliance with expression (5) for each day of the accounting period is a sufficient condition for the resulting savings to be statistically significant at the end of the accounting period.

RESULTS AND DISCUSSION.

The general scheme of automated energy management of university energy complexes based on the Energy Efficiency Knowledge Hub (the result of the calculations of Equations 1 to 5) is presented in Figure 1.

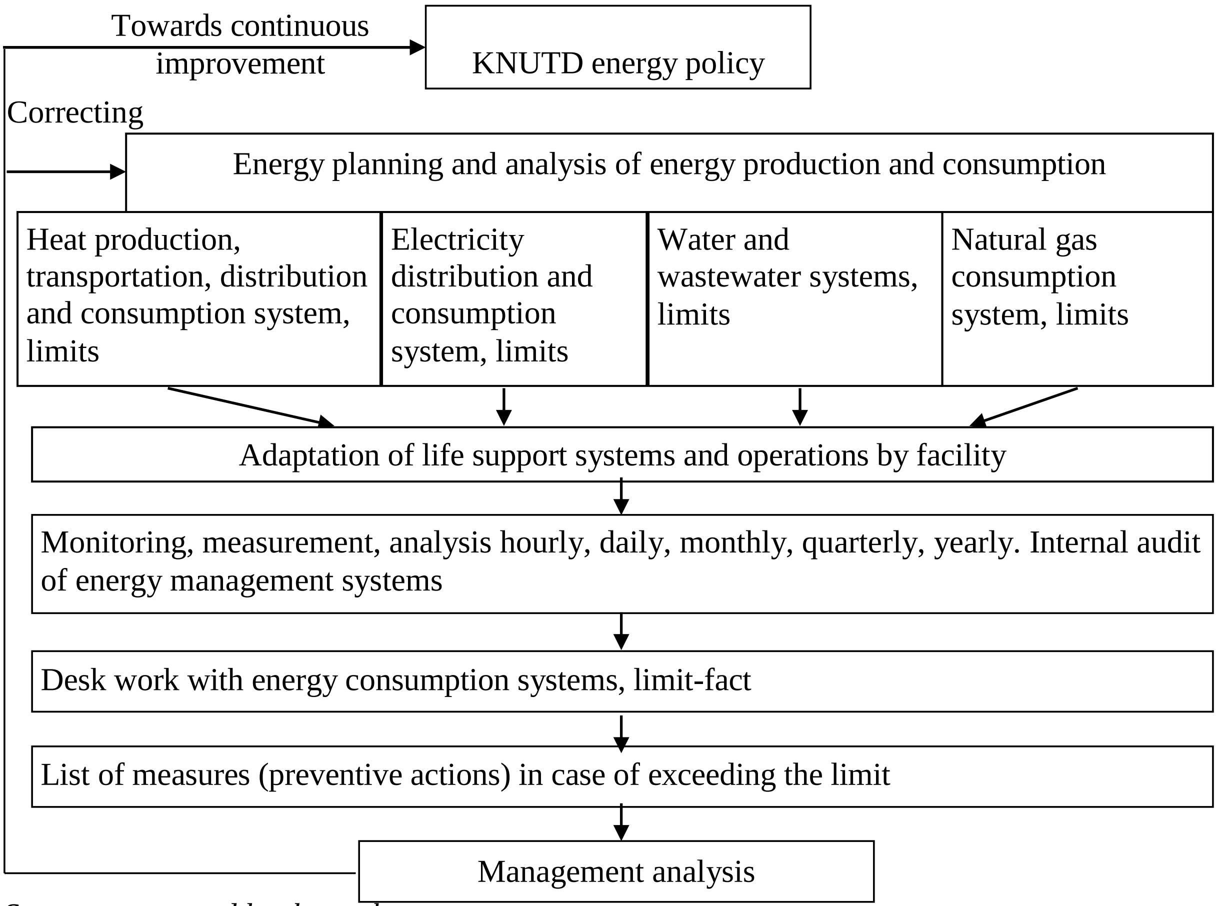
The basis for the proposed automated energy management system is the ISO 50001 Energy Management Systems standard (Vieira *et al.*, 2020; Shaposhnikova *et al.*, 2016).

According to the above scheme, the automated system of automated energy management of university energy complexes based on the Energy Efficiency Knowledge Hub should include 3 subsystems:

1. Automated system of dispatch control of fuel and energy complex. The main functions of the subsystem are operational control, analysis and management of generation and consumption of energy resources (Gryshchenko *et al.*, 2017).

2. Automated information system for energy efficiency analysis of the fuel and energy complex (AIS for energy efficiency analysis of the fuel and energy complex). The main functions of the subsystem are modelling, energy efficiency analysis, rationing and optimal management of energy generation and consumption. Modelling makes it possible to calculate different modes of fuel and energy complex operation as well as to optimise these modes according to

the criteria of minimum energy consumption. Based on the simulation results, calculation of corrective impacts for the operational management system is carried out. Using the results of simulation, as well as operational and design data to control the selected modes of operation, the daily heat consumption rates are calculated. Based on operational results, energy savings are calculated for the power complex as a whole and for consumers connected to it.



Source: suggested by the author.

Fig. 1. **Block diagram of the energy management system of KNUTD**

3. Corporate Information System for Fuel and Energy Complex (CISFEC). The main function of this subsystem is to support decision making of the manager or energy management group in energy planning, energy policy development and implementation. The CISFEC analyses the results of the university's energy management activities on the basis of internal energy audits, adjusts the university's energy policy and plans energy efficiency measures.

An automated system, the main objective of which is to improve energy efficiency, should use objective methods for evaluating and monitoring energy consumption. Therefore, it is proposed to use the International Performance Measurement and Verification Protocol (IPMVP) (Kaplun *et al*., 2016), which describes the methodology for assessing the effectiveness of energy saving measures, as a methodological and regulatory support for this automated system.

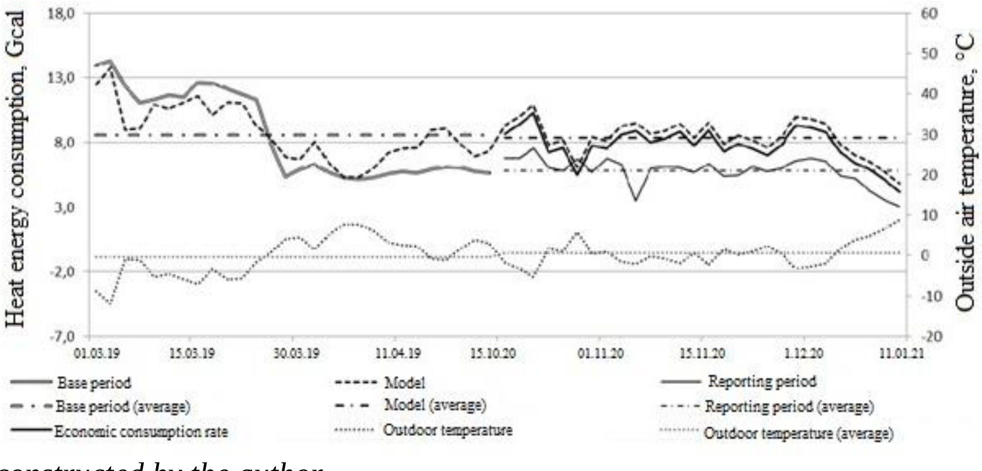
However, it is worth noting that the methodology described in the protocol can be used not only to assess the energy efficiency of energy complexes, but also to monitor energy efficiency during operation. At the same time, the purpose of such control should be the detection of inefficient modes of operation that prevent the achievement of the required level of energy savings.

A system of energy management has been developed for each energy resource (heat, electricity, natural gas, wastewater and water consumption). For this purpose, four working groups should be established: production planning and analysis, development and adjustment, implementation and operation, monitoring and measurement – these systems should be fine-tuned and aimed at optimal use of the resources consumed.

The energy policy developed by the university should ensure the main activities of the university – academic, research and production, social, maintenance of the sanitary condition of the university territory, creation of comfortable conditions for the teaching staff and students.

In implementing it, we must first of all increase energy productivity – to increase energy efficiency through more efficient use of the energy consumed, to reduce energy consumption in general. In doing so, it is also necessary to reduce emissions and other environmental impacts (Kaplun *et al.*, 2016). In addition, with the energy resources saved, the university will put in place new energy-consuming facilities.

Once the system was commissioned, the energy efficiency of the university's thermal energy facilities was assessed and monitored (Shcherbak *et al.*, 2019). As an example of energy efficiency analysis and monitoring, consider monitoring the effectiveness of the implementation of an automated energy efficiency knowledge HAB at KNUTD (Kaplun *et al.*, 2016; Shcherbak *et al.*, 2021).



Source: constructed by the author.

Fig. 2. **Savings in thermal energy consumption of building 4 of KNUTD after implementation of the automated energy efficiency knowledge HUB**

Figure 2 shows a graph of heat consumption before and after energy saving measures based on the automated energy efficiency knowledge HUB. A statistical model (dashed line) of heat consumption as a function of outdoor temperature was built using the operational data of the base period (double solid line). After implementation of energy saving measures using the statistical model, consumption in the reporting period under comparable temperature conditions was calculated. The thick solid line indicates the effective heat consumption rate calculated according to the above method, exceeding which may lead to no savings or its low statistical significance in the reporting period. During system operation during the COVID-19 pandemic period (second half of 2019–2020), the inefficient consumption mode was promptly identified and its causes were eliminated. At the beginning of 2021, when comparing the norm of efficient heat consumption with the actual consumption (thin solid line), the minimum savings was 25%.

CONCLUSION.

The paper proposes the structure of an automated energy management system for a thermal power complex based on the KNUTD energy efficiency knowledge HUB. The described structure includes three interacting with each other subsystems. Each subsystem can be implemented separately at different management levels in the university. The automated system of dispatching management on the basis of HUB knowledge allows the service of operation to operatively manage the objects of the heat and power complex. The corporate information system of the fuel and energy complex, through which energy planning is carried out, is recommended to be implemented as part of the corporate management system of the organisation. At the same time, an automated information system for energy efficiency analysis of the university is proposed as a link between these subsystems, which allows controlling the efficiency of heat consumption in the heat and power complex. As a basis of methodological support for energy efficiency analysis and control in the automated information system of energy efficiency analysis it is proposed to use the international protocol of efficiency measurement and verification. A method of rationing heat energy consumption, taking into account the required level of statistical significance of energy resources saving when carrying out energy saving measures, is proposed to control the energy efficiency of the heat and power complex. Application of this method in the automated information system of university energy efficiency analysis is expedient, which was confirmed in the process of operation of the implemented automated system of energy management of thermal energy complex on the basis of HUB of knowledge on energy efficiency in Kyiv National University of Technologies and Design.

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ABBREVIATIONS:

%	Percentage
CISFEC	Corporate Information System for Fuel and Energy Complex
COVID-19	Corona Virus Disease 2019, corona virus infection 2019-nCoV
Eq.	Formula of calculation
Fig.	Figures
HEI	Higher education institution
HUB	Common connection point
IPMVP	International Performance Measurement and Verification Protocol
KNUTD	Kyiv National University of Technologies and Design

REFERENCES:

Abu-Rayash, A.; Dincer, I. (2020). Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. Energy Res. Soc. Sci., 68: 101682.

Di Stefano, J. (2000). Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia. *Energy,* 25(9): 823–839.

García, S.; Parejo, A.; Personal, E.; Ignacio Guerrero, J.; Biscarri, F.; León, C. (2021). A retrospective analysis of the impact of the COVID-19 restrictions on energy consumption at a disaggregated level. *Appl. Energy,* 287: 116547.

Gryshchenko, I.; Shcherbak, V.; Shevchenko, O. (2017). A procedure for optimization of energy saving at higher educational institutions. *East.-Eur. J. Enterp. Technol.,* 6(3/90): 65–75.

Kaplun, V.; Shcherbak, V. (2016). Multifactor analysis of university buildings' energy efficiency. *Actual Probl. Econ.,* 12(186): 349–359.

Liu, J.; Yao, Q.; Hu,Y. (2019). Model predictive control for load frequency of hybrid power system with wind power and thermal power. *Energy,* 172: 555-565.

Nayak, J.; Mishra, M.; Naik, B.; Swapnarekha, H.; Cengiz, K.; Shanmuganathan, V. (2021). An impact study of COVID-19 on six different industries: Automobile, energy and power, agriculture, education, travel and tourism and consumer electronics. *Expert Syst.,* 10.1111/exsy.12677: 1–32.

Nicola, M.; Alsafi, Z.; Sohrabi, C.; Kerwan, A.; Al-Jabir, A.; Iosifidis, C.; Agha, M.; Agha, R. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *Int. J. Surg.,* 78: 185–193.

Shaposhnikova, K.; Shimov, V. (2016). ISO 50001-Energy management system. The concept implementation of energy management systems. Sci. Soc., 3-2: 63–68.

Shcherbak, V., Ganushchak-Yefimenko, L., Nifatova, O., Dudko, P., Savchuk, N., Solonenchuk, I. (2019). Application of international energy efficiency standards for energy auditing in a University buildings. *Global Journal of Environmental Science and Management*, 5(4), 501-514. doi: 10.22034/GJESM.2019.04.09.

Shcherbak, V., Gryshchenko, I., Ganushchak-Yefimenko, L., Nifatova, O., Tkachuk, V., Kostiuk, T., Hotra, V. (2021). Using a sharing-platform to prevent a new outbreak of COVID-19 pandemic in rural areas. *Global Journal of Environmental Science and Management*, 7(2), 155–170. doi: 10.22034/gjesm.2021.02.01.

Vieira, E.; dos Santos, B.; Zampieri, N.; da Costa, S.; de Lima, E. (2020). Application of the Proknow-C methodology in the search for literature about energy management audit based on international standards. In: Thomé, A.; Barbastefano, R.; Scavarda, L.; dos Reis, J.; Amorim, M. (eds) Industrial engineering and operations management. IJCIEOM 2020. *Springer Proc. Math. Stat.*, 337: 463–475.

Wang, Q.; Zhang, F. (2021). What does the China's economic recovery after COVID-19 pandemic mean for the economic growth and energy consumption of other countries? J. Cleaner Prod., 295: 126265.

Werth, A.; Gravino, P.; Prevedello, G. (2021). Impact analysis of COVID-19 responses on energy grid dynamics in Europe. Appl. Energy, 281(116045): 1–24.

Xing, X.; Yan, Y.; Zhang, H.; Long, Y.; Wang, Y.; Liang, Y. (2019). Optimal design of distributed energy systems for industrial parks under gas shortage based on augmented ε-constraint method. *J. Cleaner Prod.*, 218: 782–795.

Zhong, H.; Tan, Z.; He, Y.; Xie, L.; Kang, C. (2020). Implications of COVID-19 for the electricity industry: A comprehensive review. *CSEE J. Power Energy Syst.*, 6(3): 489–495.

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