ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

UDC 621.316.11

A. Bondarchuk, PhD, Assoc. Prof.,
E. Nechiporuk
Odessa National Polytechnic University, 1 Shevchenko Ave., Odessa, Ukraine, 65044; e-mail: asb@te.net.ua

ANALYSIS OF THE IMPACT OF GLOBAL CLIMATE WARMING ON ELECTRIC CONSUMPTION OF MULTIFLAT HOUSES IN THE ODESSA CITY

А.С. Бондарчук, Є.П. Нечипорук. **Аналіз впливу глобального потепління клімату на електроспоживання багатоповерхових будинків міста Одеса.** Наведено результати аналізу динаміки глобального потепління клімату на Землі та у межах м. Одесі за попереднє століття й останні роки. Дослідження виконано шляхом моделювання інформації Гідрометцентру за вказані періоди. За кореляційним аналізом первинної інформації встановлено, які з чинників, таких як температура приземних шарів повітря, тривалість денної частини доби, атмосферний тиск, вологість та швидкість повітря, хмарність небосхилу більше всього впливають на динаміку електроспоживання об'єктів міста. Виявлено глибину впливу температурної динаміки довкілля, яка за коефіцієнтом кореляції Пірсона показала найбільш сильний від'ємний зв'язок із електроспоживанням 216-квартирного будинку. Установлено значне, порівняно з попередніми роками, зростання літнього електроспоживання, що пояснюється інтенсивною роботою, як правило, побутових кондиціонерів, холодильних, вентиляторних установок мешканців багатоквартирного будинку через аномальну температуру зовнішнього повітря. Екстраполяцією значень температурної динаміки довкілля прогнозовано ймовірну величину підвищення регіональної температури на кінець 2025 року. Це дозволило визначити очікувану величину збільшення електроспоживання багатоквартирного будинку через встановлену залежність його від зростання регіональної температури повітря за вказаний період. Обчислення виконано за прикладною програмою в середовищі MathCad на основі використання параметрів макромоделі річного електроспоживання багатоповерхового житлового будинку. Отримана інформація може використовуватися енергогенерувальними та електропостачальними компаніями для планування своєї нормальної діяльності, яка сприятиме комфортному і безпечному життю для населення міста, уникнення кризових ситуацій, що впливають на надійність електропостачання, усунення наслідків кліматичних аномалій.

Ключові слова: глобальне потепління клімату, електроспоживання, багатоквартирний будинок, прогнозування

A. Bondarchuk, E. Nechiporuk. **Analysis of the impact of global climate warming on electric consumption of multiflat houses in the Odessa city.** The results of the analysis of the dynamics of global climate warming on the Earth and within the city of Odessa in the previous century and in recent years are presented. The study was performed by modeling the Hydrometercenter information for the indicated periods. The correlation analysis of the primary information revealed which factors, such as the temperature of the ground layers of air, the duration of the daytime, atmospheric pressure, humidity and air velocity, the cloudiness of the sky, most influence the dynamics of power consumption of city objects. The depth of influence of the temperature dynamics of the environment is revealed, which by Pearson's correlation coefficient showed the strongest negative connection with the power consumption of the 216-apartment house. Significant, as compared to previous years, growth of summer electricity consumption has been established, which is explained by intensive work, as a rule, of household air conditioners, refrigeration and ventilation units of residents of an apartment building due to the abnormal ambient air temperature. Extrapolation of the values of the temperature dynamics of the environment predicts the probable magnitude of the regional temperature increase at the end of 2025. This made it possible to determine the expected magnitude of an increase in electricity consumption of an apartment building due to its dependence on the increase in regional air temperature over the specified period. The calculation is based on an application program in the MathCad environment based on the use of macromodel parameters of annual electricity consumption of a multiflat residential building.The information received can be used by energy and electricity companies to plan their normal activities, which will contribute to a comfortable and safe life for the city's population, avoid crises that affect the reliability of electricity supply, eliminate the effects of climate anomalies.

Keywords: global warming climate, power consumption, multiflat houses, forecasting

Introduction. Dynamics of power consumption of multi flat residential houses is a non-stationary time series, due to the influence of such factors as the daily occupancy of the residents of the houses, temperature and air velocity, cloudiness, duration of the light part of the day, etc. A special place among the listed factors of influence is the temperature of the air, which is directly dependent on the intensity of the energy of solar radiation, which through the atmospheric layers reaches the Earth's surface [1]. In recent years, there has been a global warming of the climate through processes occurring in the atmosphere, oceans and the effects of human activities, and so on. This is accompanied by an increase in heavy storms, floods or prolonged droughts, which significantly affect the energy con-

DOI: 10.15276/opu.3.59.2019.05

sumption of cities and towns, with energy and energy companies being prepared to overcome them. An analysis of recent research and publications indicates that the impact of global warming on human health, urban economics, including the dynamics of energy consumption of industrial, utility and utility facilities, is increasing.

A comprehensive assessment of climate change vulnerability in Ukraine highlights the humanitarian, environmental impacts and measures taken to adapt the city to climate change provided in [2]. The vulnerability of the city's energy systems is described, which may be manifested in the growth of non-electricity demand, the decrease in the reliability of electricity supply due to increased wind and ice formation on the wires and their damage, the substation flooding due to floods, etc. However, there is no analysis of regional temperature dynamics in recent years and calculations regarding its impact on residential electricity consumption. The monograph [3] presents the results of the study of the problem of global planetary climate change and its possible negative effects in the natural environment and economy of Ukraine and the world. The main of these manifestations in particular sectors of the economy are examined, strategies, guidelines and mitigation measures are identified, taking into account two possible alternative trends in climate change – further warming and the alternative cooling cycle.

Meanwhile, the results of the impact of climate change on electricity consumption of housing and communal services in recent years, when the highest environmental temperature in Ukraine has been observed, are not reflected in the work. Environmental threats in European cities and major climate change measures are outlined in [4]. However, the analysis of the peculiarities of the present and the forecast of these challenges in Ukraine, which is important for the sustainable development of the economy in the country, is not presented. There are no such materials in [5]. The work [6] shows the application of anomaly-based analysis to describe extreme summer heat waves in Eastern China during 1981 – 2013 using two reanalysis products. However, these events are determined over an area of more than 300×500 km^2, which does not reflect their impact on the supply of specific objects. In [7], a retrospective analysis of the frequency of heat wave episodes and analysis of their spatial and temporal distribution, duration and intensity without the effects on the power consumption of city objects were carried out. The effect of air temperature on the electricity consumption of objects in some regions of the country is shown; the climatic, astronomical, and social conditions of China are different from the domestic ones [8]. In [9], the demand for electricity in California under low and high global warming scenarios is predicted, and critical values for electricity consumption by consumers are determined depending on these options.

The purpose of the study is to evaluate the dynamics of regional climate warming over the previous century and recent years and the impact of these changes on the consumption of multi flat residential houses and the extra load on it to the city's electrical grids.

Main part. Solar energy, which is converted into a warm atmosphere in the earth's atmosphere, is a major component affecting the processes of global warming. The NASA's long-term space analysis shows that the sun becomes brighter and radiates more energy to the earth, which contributes to rapid planetary warming through the greenhouse effect (Fig. 1) [1].

According to the data of the Odessa Hydrometeorological Center, the average annual regional dynamics of air temperature at the height of 2 m over the previous century and the trend line of the process, shown in Fig. 2.

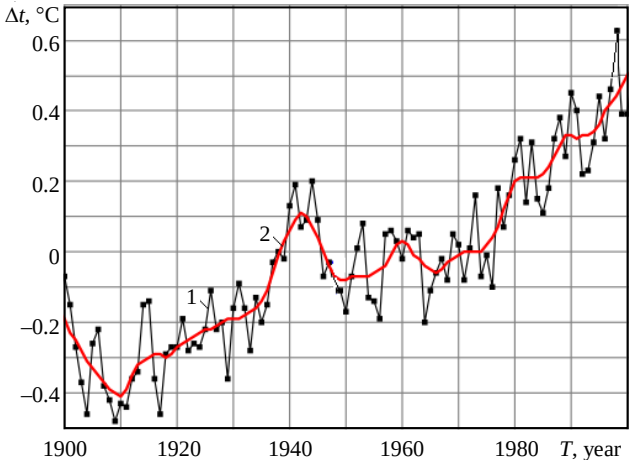

Fig. 1. The annual average (1) and the moving average (2) of the dynamics of planetary temperature, relative to the average temperature for 1951 – 1980

ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

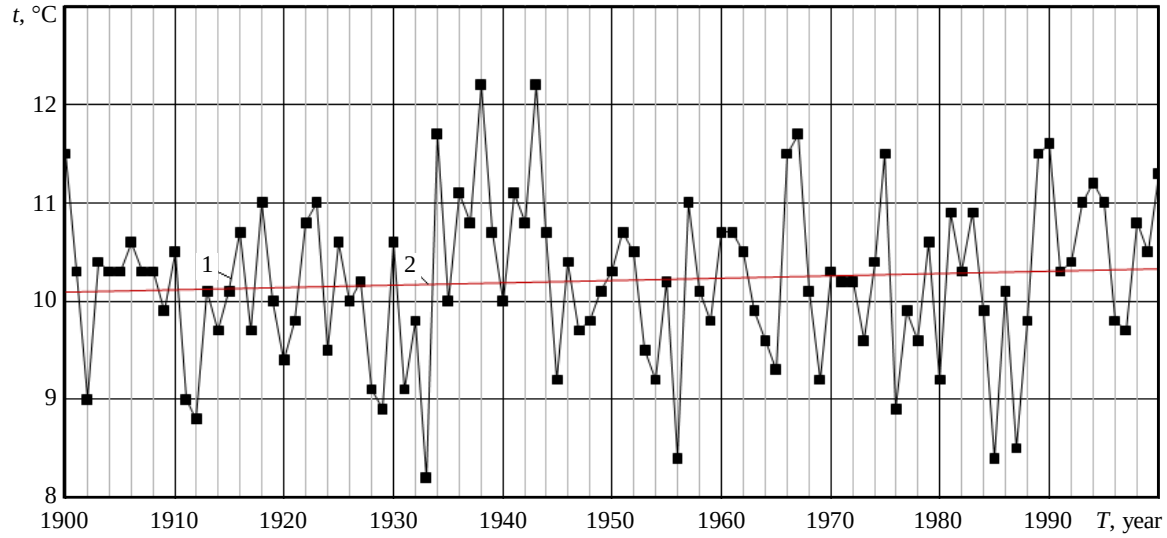

Fig. 2. Average annual (1) and trend line (2) of regional temperature dynamics in the city

The lines of the process trend equation have the following form:

$$y = 0.0024x + 10.089. \quad (1)$$

Comparing the results of the previous century, we observe an increase in the average annual planetary temperature of 0.7 °C, and of the regional one 0.24 °C, which indicates the influence of the proximity of the sea on the inhibition of the process.

For the last 15 years, there has been a further warming of the environment of the city, the average annual temperature dynamics of which, according to the Odessa Hydrometeorological Center, is shown in Fig. 3.

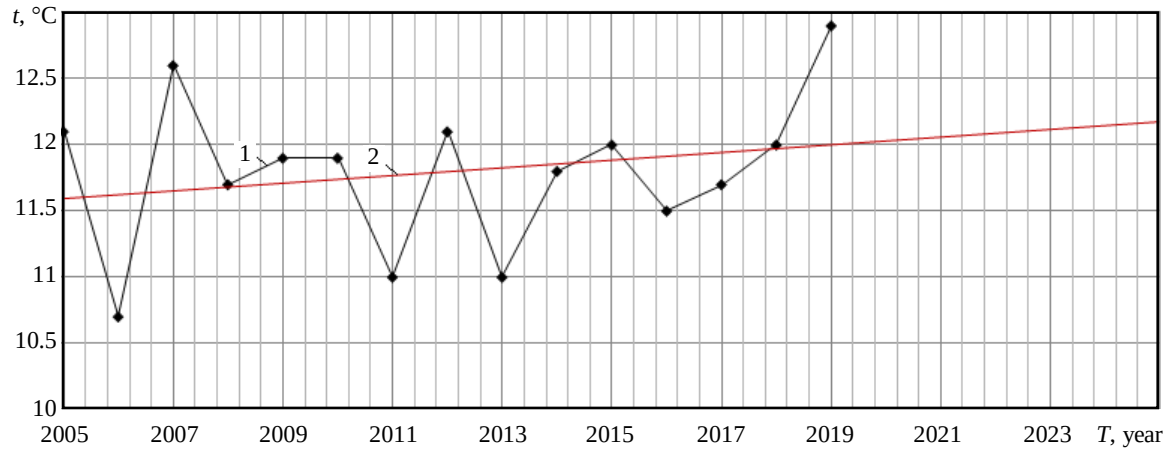

Fig. 3. Average (1) and trend line (2) of regional temperature speakers in the city

The lines of process trend equation have the following form:

$$y = 0.0293x - 47.13089.$$

Extrapolation of temperature dynamics to 2025 determined that for the period since 2005 the average annual temperature would increase by 0.4 °C, which indicates that the regional temperature increase will accelerate compared to the previous century by 0.7 °C.

Using the MS Excel data analysis package, a correlation analysis of the effects of climatic and astronomical indicators on power consumption was performed, which by Pearson's correlation coefficient showed a strong negative relationship in air temperature (Table 1).

Table 1

Correlation analysis of the influence of climatic and astronomical indicators for electricity consumption of the city objects

Sign	Electrical Consumption	Temperature air	Day length	Atmospheric pressure	Air humidity	Wind speed	Cloudiness
Electrical Consumption	1						
Temperature	–0.763	1					
Day length	–0.537	0.51	1				
Atmospheric pressure	–0.004	–0.156	–0.173	1			
Air humidity	–0.227	0.163	0.106	–0.0755	1		
Wind speed	–0.196	–0.068	–0.342	0.095	0.027	1	
Cloudiness	0.112	–0.117	–0.084	–0.264	0.391	0.368	1

Having received such data, we present the macro model of the annual electricity consumption of the 216-apartment building and determine by its parameters the relation with the dynamics of the average weekly regional air temperature (Fig. 4) [10 – 12].

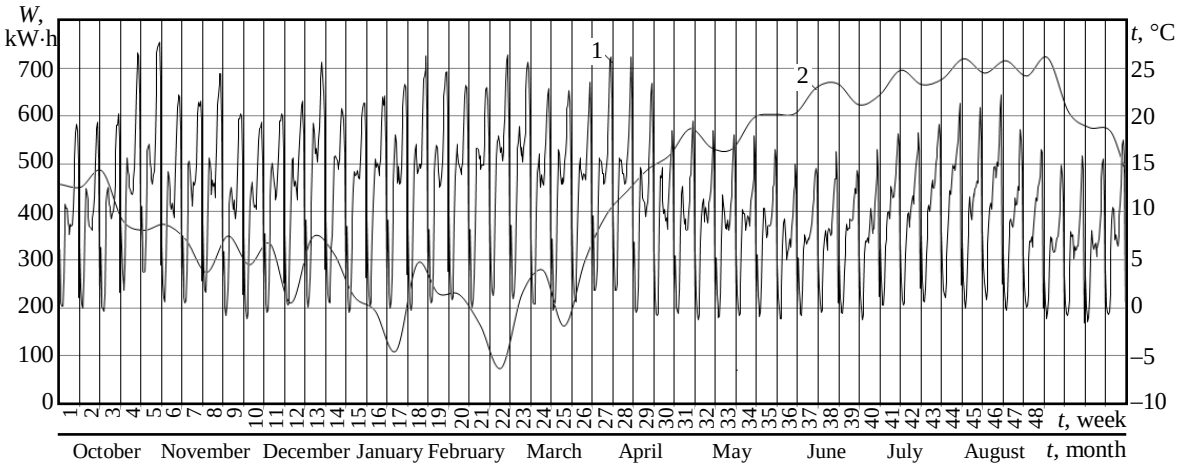

Fig. 4. Macro model of annual residential electricity consumption (1) and trend line (2) of regional air temperature dynamics in the city territory

Assessment of the effect of increasing the average daily air temperature at t °C > 22 °C on electricity consumption ΔW (t °C) of a multi-storey 216-apartment building by the difference ΔW between electricity consumption at t °C > 22 °C and t °C < 22 °C in the summer, is defined as:

$$\Delta W(t°\text{C}) = \frac{\Delta W}{\Delta t°\text{C}}, \quad kW \cdot h \text{ / degr.} \tag{3}$$

Research results. An analysis of 216 apartment building behavior and ambient air temperature over the course of a year shows an “inertia” with a delay in electricity consumption relative to the temperature change that occurs over the next week (12 and 13, 37…40 and 41…49 weeks) or over a longer period of time. It depends on many factors, such as the rate of increase / decrease of temperature, the sensitivity of utilities to heat supply, the rate of change of the mixture of temperature in apartments, the presence of electric heating devices, the financial status of residents and others.

Such phenomena in Fig. 4 can be observed at the end of October, March and early November, April, when the heating season begins late or earlier. At this time, residents are using electrical appliances to complete the district heating system.

According to the calculations for applications in the MathCad environment, electricity consumption increases by 3.7 % of the average weekly temperature during the exceeding of the average daily

ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

temperature from 22 °C to 27 °C, which is observed in July and August. If the average daily outside air temperature drops below 14 °C, for every 1 % electricity consumption increases by 1.09 % of the total weekly. Household electricity consumption is estimated to increase by 10.9 % due to the warming of the regional climate by the end of 2025.

Discussion of research results. An important aspect of the proposed research methodology is the comparison of planetary with regional climate warming, since the proximity of the sea plays a significant smoothing effect on the region's heat and cooling waves. This is evidenced by the difference in temperature fluctuations in the environment over the previous century (0.7 °C planetary and 0.24 °C regional). These processes are probabilistic, depending on many circumstances, so the results are related to a specific object – a multi flat building with its own features of building insulation structures, the presence of automated thermal points, with the behavior of residents, aware of climate risks and more. The use of the macro model of the annual electricity consumption of the 216-apartment building gives an opportunity to observe critical situations and to evaluate them from the point of view of danger, to avoid their concerted actions between energy generating companies, energy supply companies and residents. Predicting the effects of global warming in the short and long term will contribute to the real planning and normal operation of companies and the comfortable life of the city's population.

Conclusions. Conducted scientific studies have yielded the following results and conclusions.

1. Retrospective information on global and regional climate warming was modeled at the basis of the Hydrometeorological Center data, which revealed the tendency of the processes development in the future. It is determined that in the period from 2005 to 2025, the average annual temperature will increase by 0.4 °C, which indicates an acceleration of the regional temperature increase, compared to the global warming in the previous century by 0.7 °C.

2. A macro model of the annual electricity consumption of the 216-apartment house was built based on the information of the automated system of commercial accounting of electricity, which clearly gives an opportunity to observe critical moments during the year. For example, in Fig. 4 it is possible to observe the “slowdown” of the process of growth of power consumption in July, August relative to the temperature dynamics, which is explained by the thermal inertness of building structures, which maintain for some time the temperature in the premises relative to the outside. According to the macro model parameters, it is possible to determine the rate of increase of power consumption depending on the temperature dynamics.

3. An analysis is made and an assessment of the impact of climate warming on the power consumption of a multi-storey building, the methodology and results of which can be used by energy companies to plan their normal activities.

Література

1. GISS Surface Temperature Analysis. 2019. URL: https://data.giss.nasa.gov/gistemp/.
2. Оцінка вразливості до зміни клімату: Україна / О.Г. Шевчук, О. Власюк, І. Ставчук та ін. Київ : Myflaer, 2014. 74 с.
3. Тенденції змін планетарного клімату та їх можливого впливу на основні сектори української економіки / за ред. Хвесика М.А. Київ : Логос, 2012. 268 с.
4. Urban adaptation to climate change in Europe. Luxembourg: Publications Office of the European Union. 2016. 135 p. URL: https://www.eea.europa.eu/publications/urban-adaptation-2016/download
5. Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA Report No 2/2012. URL: http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change.
6. Yun Chen, Qi Hu, Yinming Yang, Weihong Qian. Anomaly based analysis of extreme heat waves in Eastern China during 1981–2013. *RMetS*. 2016. P. 509–523. DOI: https://doi.org/10.1002/joc.4724.
7. Shevchenko O., Lee H., Snizhko S., Mayer H. Long term analysis of heatwaves in Ukraine. *International Journal of Climatology*. 2013. DOI: https://doi.org/10.1002/joc.3792.
8. Yating Lia , William A. Pizer, Libo Wu. Climate change and residential electricity consumption in the Yangtze River Delta, China**.** *PNAS*. 2018. P. 472–477. DOI: https://doi.org/10.1073/pnas.1804667115.

9. Maximilian Auffhammer. Simulating the impacts of climate change, prices and population on California's residential electricity consumption. 2012. 30 p. URL: https://are.berkeleyedu/~auffhammer/ papers/AA_2012_rev.pdf.
10. Lezhniuk P.D. Bondarchuk A.S., Hoholiuk O.P. Application of macromodeling method as bases for forecasting electrical consumption of multiflat houses. *Tekhnichna Elektrodynamika.* 2019. No 6. P. 74–80.
11. Bondarchuk A.S. Development of the graphoanalytic method for calculating electric load at civilian objects. *Eastern-European Journal of Enterprise Technologies.* 2017. № 4/8 (88). P. 4–9.
12. Bondarchuk A. S., Lezhniuk P. D. A graphic method for the research into electrical load dynamics in residential apartments. *Computational Problems of Electrical Engineering*. 2017. Vol. 7, № 2. P. 73−77.

References

1. GISS Surface Temperature Analysis. (2019). Retrieved from: https://data.giss.nasa.gov/gistemp/.
2. Shevchuk, O.H., Vlasyuk, O., & Stavchuk, I. et al. (2014). *Climate Change Vulnerability Assessment: Ukraine.* Kyev: Myflaer.
3. Khvesyka, M.A. (Ed.) (2012). *Trends in planetary climate change and their possible impact on major sectors of the Ukrainian economy*. Kyev: Lohos.
4. Urban adaptation to climate change in Europe. (2016). *Luxembourg: Publications Office of the European Union.* Retrieved from: https://www.eea.europa.eu/publications/urban-adaptation-2016/download.
5. Urban adaptation to climate change in Europe. (2012). *Challenges and opportunities for cities together with supportive national and European policies.* EEA Report No 2/2012. Retrieved from: http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change.
6. Yun Chen, Qi Hu, Yinming Yang, & Weihong Qian. (2016*). Anomaly based analysis of extreme heat waves in Eastern China during 1981–2013,* 509–523. DOI: https://doi.org/10.1002/joc.4724.
7. Shevchenko, O., Lee, H., Snizhko, S., & Mayer, H. (2013). Long term analysis of heatwaves in Ukraine. *International Journal of Climatology*. DOI: https://doi.org/10.1002/joc.3792.
8. Yating Lia , William, A. Pizer, & Libo Wu. (2018). Climate change and residential electricity consumption in the Yangtze River Delta, China**.** *PNAS*, 472–477. DOI: https://doi.org/10.1073/pnas. 1804667115.
9. Maximilian Auffhammer. (2012). *Simulating the impacts of climate change, prices and population on California's residential electricity consumption*. Retrieved from: https://are.berkeleyedu/~auffhammer/ papers/AA_2012_rev.pdf.
10. Lezhniuk, P.D. Bondarchuk, A.S., & Hoholiuk, O.P. (2019). Application of macromodeling method as bases for forecasting electrical consumption of multiflat houses. *Tekhnichna Elektrodynamika, 6*, 74–80.
11. Bondarchuk, A.S. (2017). Development of the graphoanalytic method for calculating electric load at civilian objects. *Eastern-European Journal of Enterprise Technologies, 4/8 (88)*, 4–9.
12. Bondarchuk, A.S., & Lezhniuk, P.D. (2017). A graphic method for the research into electrical load dynamics in residential apartments. *Computational Problems of Electrical Engineering, 7, 2,* 73−77.

Бондарчук Анатолій Сергійович; Bondarchuk Anatolii, ORCID: https://orcid.org/0000-0003-1232-5403
Нечипорук Євгенія Павлівна; Nechiporuk Evgeniy, ORCID : https://orcid.org/0000-0002-8443-2446

Received November 03, 2019
Accepted November 26, 2019