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Overview of the instrumentation base for monitoring greenhouse gases

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ABSTRACT. Introduction. The article describes the results of a comparative analysis of three large companies presenting on the market close control equipment for the control of climatically important parameters: LI-COR, Picarro and Gasera, and using nanotechnologies; the urgency of the ecological problem of finding a technical solution for the control of climatically active gases, including CO_2 in the atmospheric air, was studied. The aim of the work is to analyze the world leaders in the production of precision equipment for monitoring greenhouse gases in the manufacture of nanomaterials and in scientific centers for the study of climate change. **Methods and materials.** The study is based on the information from open information sources, materials and reviews of various fields of knowledge made by scientific researchers, who describe the features of the activities of these companies or are directly involved in product development, and then compile a report on their work. The article contains information from true sources, namely from the official websites of companies, which describes their history of creation and development process. Research methods are benchmarking and SWOT analysis. **Results and discussion.** The study carried out a comparative analysis of companies in terms of the duration of work in world markets and its impact on the quality and technical features of products. The article provides information about companies that have achieved very good results from the beginning of their foundation to the present. The species diversity of old and new generation quality control devices sold in markets around the world by the companies in question is the same, which leads to very high competition. A description of the companies' operations, their location, coverage of consumers is given, as well as the annual income from the sale of products, the amount of work that they do in the course of their activities. **Conclusion.** It was revealed that the companies LI-COR, Picarro, Gasera carry out the production of quality control devices that reproduce the required measurement parameters. Gas-analyzers of the companies are in demand in the market of precision control devices used to capture greenhouse gases in order to develop building nanomaterials, scientific research on the climate problems of modern society.

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KEY WORDS: climate, greenhouse gas, control devices, benchmarking, nanomaterial.

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INTRODUCTION

The climate agenda is one of the global tasks of leading environmental organizations. The climate pact was signed in 1995 in Kyoto, where a decision was made on the need to reduce emissions of greenhouse gases, including CO_2, from industrial sources, and a standard was set for their emissions [1].

One of the following climate agreements within the framework of the UN activities is an act signed in 2015 in Paris. According to this document, the countries that signed it commit themselves to taking measures to reduce the concentration of CO_2 in the atmospheric air of the region. Also, within the framework of the Paris Agreement, the goal of the participating countries was set to develop measures on a regional scale to prevent the global air temperature from exceeding 1.5°C by 2100 [2].

The Glasgow climate pact 2021 set a goal for conference attendees to reduce carbon emissions to the lowest possible level. The participants of the conference committed themselves to abandon the use of coal, which cannot be used in carbon dioxide capture technology, in all in-

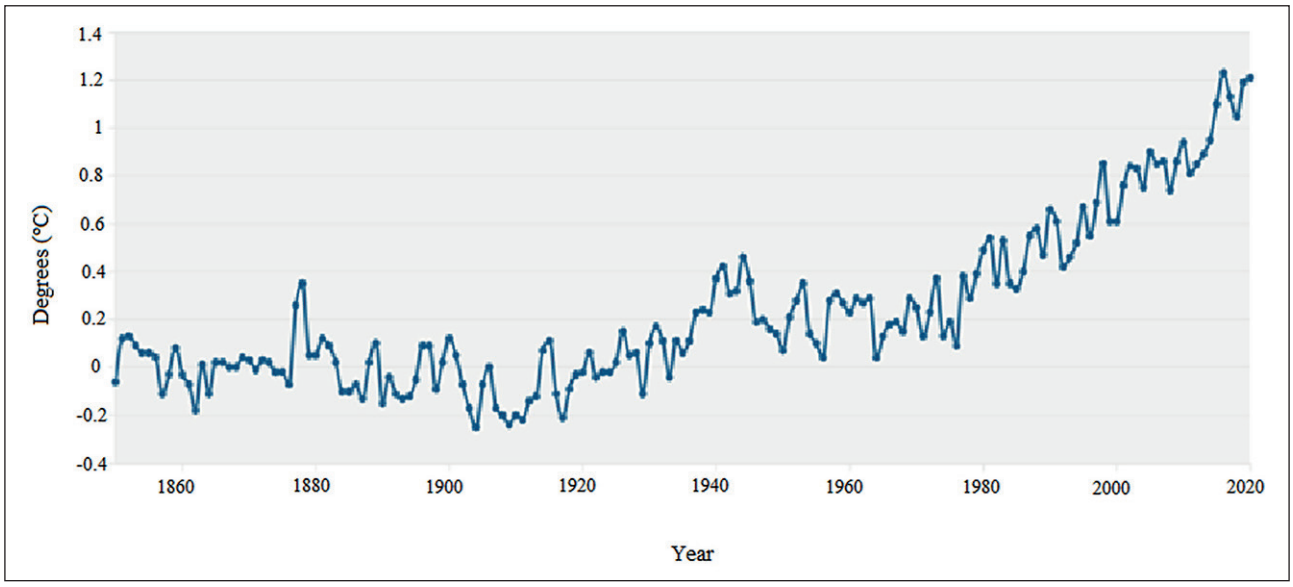

Fig. 1. **Temperature difference from 1850 to 2020, according to the World Meteorological Organization**

dustries. In addition, a number of countries, including the USA, have signed an agreement to reduce CH_4 emissions by 30% by the end of 2100. According to the UN climate report, for 2021 the air temperature has increased by 1.1°C compared to the beginning of the century (Figure 1) [3].

Thus, the global climate agenda is designed to solve the problem of global warming by 1.5°C by 2100. Efficiency in taking measures to reduce the concentration of greenhouse gases that trap solar radiation in the atmosphere is scientifically substantiated.First, the measures taken by world organizations to annually reduce the level of emissions of climate-active gases have led to a decrease in the growth of their concentration. This is due to the remote influence of emissions from the early industrial period.Secondly, an increase in the temperature of the earth's surface leads to tremendous changes in ecosystems. Thus, according to the Intergovernmental Panel on Climate Change (IPCC), by 2100 the level of the world ocean will rise by 0.2 m. Due to the increase in air temperature, processes continue to reduce the amount of ice in the oceans. Every year, the likelihood of extreme weather events increases. For example, in 2021, Hurricane Ida was the most powerful hurricane, which was assigned a fourth category of danger. Since 1980, 13 hurricanes of the fifth hazard category have occurred in the Atlantic Ocean (average wind speed is 270 km/h) [2].

According to UN conventions, the most common and longest lived greenhouse gas is carbon dioxide (CO_2). Its concentration in the atmospheric air is the highest among other greenhouse gases. According to the World Meteorological Organization, in 2019 its concentration reached 410 ppm and amounted to 148% of the pre-industrial period (1850–1900). In addition, over the past 25 years, the concentration of CO_2 has increased by 20%.

The next most common greenhouse gas in the atmosphere is methane. The lifetime of the gas in air is less than 10 years. As of 2019, its concentration in the air was 1877 ppb. According to the World Meteorological Organization, the concentration of methane has increased by 260% compared to the pre-industrial period (1850–1900). Over the past 25 years, the background concentration of methane in the atmospheric air has increased by 16% [3].

World climate organizations note the smallest increase in nitrous oxide (N_2O) in the atmospheric air. So, over the past 25 years, its content has grown by 9%. As of 2019, the concentration of gas in the air was 332 ppb, which is 123% higher compared to 1850–1900. Despite the low concentration in the atmosphere compared to carbon dioxide, nitrous oxide has a greater impact on the formation of the greenhouse effect. In addition, the lifetime of a gas molecule in air is about 150 years [3].

The climate problem poses scientific challenges for society related to the peculiarities of the behavior of climatically active gases, including CO_2, in the atmospheric air, as well as the study of possible ways to reduce the concentration of greenhouse gases.A tool for determining the concentration of substances and solving environmental problems are systems for automated control of the content of substances in the air. To this date, pollutant control devices are installed in industrially loaded cities [1–2]. However, stations for monitoring the chemical composition of urban air with gas analyzers for carbon dioxide, methane, and nitrous oxide are not widely used. Thus, the development of an automated control system for greenhouse gases is one of the main tasks of scientific research in the framework of decarbonization projects.

The solution of the scientific problem of studying and analyzing the behavior of climatically active gases in atmospheric air is based on the influence of various factors on their momentary content. The main factors affecting the change in the concentration of gases in the air are meteorological conditions, such as air temperature and humidity, wind direction and speed. In addition, due to the deposition of carbon dioxide by plants, including trees, the gas concentration depends on vertical air currents. Thus, the system for monitoring the content of greenhouse gases, implemented to solve scientific problems, is a set of instruments, including sensors of meteorological parameters, high-precision gas analyzers based on nanotechnologies, anemometers, and other related equipment. It should be noted that the range of changes in the concentration of climatically active gases is small and is calculated in ppm (parts per million). Thus, gas concentration monitoring devices must have high accuracy in the required measurement range.

Currently, a promising area of industry is the use of greenhouse gases, namely CO_2, as a raw material for the production of nanomaterials used in various sectors of the economy, including construction.

METHODS AND MATERIALS

As research methods in this work, the basics of building automated process control systems (APCS) are used. APCS is based on the connection and coordination of greenhouse gas control devices and control systems (storage, processing, operations).

The choice of monitoring instruments is based on benchmarking and SWOT analysis of global manufacturers of precision greenhouse gas measuring instruments. The SWOT analysis methodology is based on the study of the strengths, weaknesses of gas analyzers of climatically active gases; studying the opportunities and threats of manufacturing companies. Benchmarking technology allows you to evaluate the achievements of competing companies in order to implement successful practices in your own production.

The initial data were official sources and reporting of the activities of the companies LI-COR, Picarro, Gasera.

RESULTS AND DISCUSSION

A scheme of the organizational structure for solving a scientific problem has been developed (Fig. 2). The scheme clearly shows that the success of the work of the scientific team is laid at the initial stage of the development of the control system.

In the modern market, devices for monitoring climatically active gases are represented by three companies: LI-COR, Picarro and Gasera. All of them are world leaders in the production and sales of devices for controlling gases in atmospheric air based on nanotechnologies.

As a result, may be said that the accuracy of measurements of greenhouse gas concentrations around the world depends on the result of the work of the teams of the considered companies, since they produce products that make it possible to measure, calculate and prevent the threat associated with changes in global indicators of the current climate situation.

Touching upon the topic of nanotechnologies, today nanomaterials and nanotechnologies are used in almost all areas of the national economy and the environment as a whole. The use of nanopreparations as microfertilizers for the scientific tasks of crop production is due to an increase in the resistance of crops to unfavorable weather conditions and an increase in crop productivity (on average, by 1.5–2 times). Most food (potatoes, cereals, vegetables, fruits and berries) and industrial (cotton, flax) crops are used as objects of study.

The obtained results of the study are the basis for the creation of instruments for measuring the parameters of the soil cover and other environmental components [4]

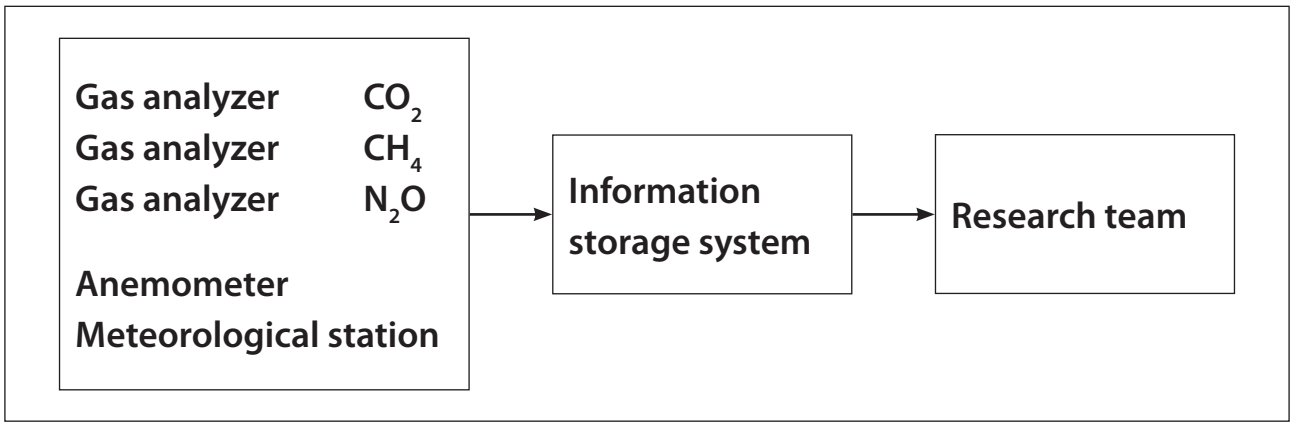

Fig. 2. **Scheme of the organizational structure for solving a scientific problem**

in the companies LI-COR, Gasera. Sensors allow you to measure the parameters of the environment to obtain data on its current state.

Technologies have been developed for the use of carbon dioxide as a raw material for the production of cement. In 2008, in the state of California (USA), Calera developed a technology for capturing and processing CO_2 into a target product. Namely, concrete, cement used in construction technologies were obtained. Similar developments were obtained at CarbonCure Technologies, America's Carbon Sciences.

Japanese scientists have developed a way to process CO_2 into nano-organic scaffolds used in various fields of the economy. The basis of the methodology is the capture of carbon dioxide from atmospheric air and concrete production waste. The basic component of the developed methodology for the production of nanomaterials for construction companies is the registration of CO_2 in the air. Thus, the choice of quality control instruments is an important step in the process of atmospheric gas processing.

LI-COR. LI-COR head office is situated in North Carolina, USA, with a very strong influence in the North American mainland. The type of company is private, because the founder of the company himself, using personal efforts and means, developed it into a world famous company. The company has been operating for 50 years, and during this period it has expanded its consumer zone to a large scale, so the company's annual income reaches up to €14 million.Products manufactured by a given company, are introduced by devices, measuring systems and software for use in biological research instruments. They are used in such areas as agronomy, ecology, plant physiology, the study of the carbon cycle of climate change. Score in the rating Expertology, the company received a rating of 9.2, which is one of the highest ratings in the rating of companies manufacturing products of this type.

The company produces portable process analysis systems such as: LI-6800, LI-600, LI-7000, LI-7200, LI-7500, LI-7550, LI-7700, LI-7810, LI-8100, Pearl thermal imager. They are compact, high-precision, high-performance analyzers that can be used in the most unfavorable weather conditions, including rain, snow and fog. These devices are characterized by low power consumption, due to which they can be used in the field without access to stationary AC power networks (power can be supplied from a solar battery).

LI-COR gas analyzers, similar to other companies' precision monitors, have high measurement accuracy and can be used under unfavorable weather conditions.

A distinctive feature of the LI-COR instruments is the use of infrared spectroscopy technology, which allows density measurements using infrared rays.

These devices are currently used in almost all countries of the Eurasian continent, as well as in North and South America, as well as in the research laboratories of JCS SERVICES, Ormic, PolutionS.r.l., Armgate SIA, Armgate UAB, The Dutch Scientist, ISOscience, Apel, MIT, KNJ, Amiston, Massanalys Spectrometry Nordic AB.

The strengths of this company are that it was founded long before Picarro and Gasera. LI-COR has established itself over the course of its existence as a company with reliable, high-quality measurement products, which gives it an edge over other, less well-known competitors that were founded a little later. Also, the company annually produces a large number of units of products, due to which, the company feels confident in the competition in the market, as they have a wide range of consumers.

The weak side of this company is that they have now stopped producing new generation products, which allows new young companies to gain a competitive advantage due to the presence of innovative products.

The company has the opportunity to improve skills and increase benefits for employees, thereby improving their performance and the desire to work at 100%. The company offers health and wellness benefits, including health insurance, dental insurance and vision insurance, to make life easier for employees and give them confidence in their future. This also applies to advanced training, positions, depending on the volume and quality of the employee's work, which does not depend on the time spent in the company.

Since the company occupies one of the first places in the ranking of companies for the production of these products, the threat is that a number of competitors have a desire to bypass it and get higher positions in the ranking.

Picarro. The company's head office is located in California, USA. The type of company is private, its founder is a scientific researcher.

The company produces gas analyzers of models such as: G2103, G2106, G2108, G2114, G2121, G2121-i for accurate real-time measurement of ethylene vapor, water and other substances with sensitivity to parts per billion with negligible drift for agricultural and soil science applications, which is distinguishing feature of Picarro control devices from sensors of other companies.

Picarro gas analyzers are currently used in such countries as: USA, England, France, Poland, Italy, in research laboratories Sumasi, ISOscience, Bizaio, AlphaChrom, HILGER, SISTEC.

Over the 23 years of its existence, the company has managed to cover the western and eastern hemispheres, and the geography of consumers covers the entire globe, while the company's income is €6.5 million, which is very worthy compared to other similar companies. This company produces gas concentration analyzers, with a volume of up to 35 million units per year, which are used in such areas as ecology, plant physiology, measurement of gas emissions in the air, leak detection for manufacturing

Table
Comparative analysis of the activities of companies producing greenhouse gas monitoring devices

Показатели	LICOR	Picarro	Gasera
1. Head office	Lincoln, North Carolina, USA	California, USA	Turku, Finland
2. Type of company	Private	Private	Limited Liability Company
3. Average income	€14 млн	€6,5 млн	€2,5 млн
4. Scope	Western and Eastern Hemisphere	Western and Eastern Hemisphere	Western and Eastern Hemisphere
5. Duration	50 years	23 years	17 years
6. Geography of consumers	The whole globe	The whole globe	Europe, West and East Asia, North America
7. Production	Instruments, measuring systems and software for biological research	Gas concentration analyzers	Portable measuring devices, gas analyzers
8. Quantity of work	Up to 80 million pieces of equipment per year	Up to 35 million pieces of equipment per year	Up to 10 million pieces of equipment per year
9. Application area	Agronomy, ecology, plant physiology, carbon cycle research and climate change	Ecology, plant physiology, measurement of air emissions, leak detection for commercial enterprises	Ecology, geology, photoacoustics, analysis of gases, liquids and solids, industrial research
10. Rating	9.2	8.5	8.1
11. Quality control test (QCT)	100%	100%	100%
12. Industry	Research, design, production	Research, industrial products	Manufacture of instruments and devices for measurement, testing and navigation
13. Influence	The whole globe	The whole globe	The whole globe
14. Peakdemand	From 2010 up to the present day	From 2015 up to the present day	From 2018 up to the present day
15. Year of foundation	1971	1997	2004

enterprises. The rating of this company is 8.5, this figure is very worthy and justified.

The strength of the company is that it is relatively young and well-established in a fairly short period of its existence. Picarro manufactures water and N_2O isotopic analyzers, 13C isotope composition systems, which is a feature among its other competitors in this field.

The weakness of the company is that it produces a rather small range of products, which significantly affects the sales market, when compared with companies that have a wider range of products.

The capabilities of this company lie in the fact that it is located directly in California, the USA state, not far from the center of all sales of other top-rated companies in demand. This gives it the opportunity to save time on the delivery of its products to consumers. Picarro also has the opportunity to improve the skills of employees for positions related to engineering. The development of new competencies by employees will increase the speed of intensive and financial development of the company. Also for their employees, they provide an opportunity for early retirement through the benefits of this company.

The threat is that the company produces a small range of products. This affects the sales market due to a small selection of measuring instruments. Thus, at the moment it is impossible to compete with higher and more developed companies of this type of production.

Gasera. The head office of the company is located in Turku, Finland. The type of company is a limited liability company, which distinguishes it from other similar companies, because. its founder is a group of people.

The company produces gas analyzers of the following models: Gasera ONE HF, Gasera ONE GHG, Gasera ONE PULSE, Gasera ONE SHED, Gasera ONE FORMALDEHYDE, Gasera OEM MODULE, Multipoint Sampler, Gasera ONE. They are photoacoustic gas analyzers that provide ppb sensitivity for reliable measurement of background levels of greenhouse gases, monitoring of hydrogen fluoride concentrations, and measurement of background levels of formaldehyde in various environmental components.

The difference between Gasera control devices and other companies is that their principle of operation is based on photoacoustic technology using tunable laser radiation.

Basically, these devices are used in the countries of Northern Europe, such as Iceland, Denmark, Sweden, Norway, Finland, Latvia, Lithuania, in the countries of Western and Eastern Asia, in the following research laboratories: Nofima, Bruker, Woods Hole Oceanographic, Fraunhofer, Leeden NOX.

Gasera is the youngest company compared to the other two described above. In this regard, the consumers of its products are mainly companies from Europe, Western and Eastern Asia and North America. But at the same time, over the 17 years of its existence, the company has raised its income to €2.5 million, which is quite a significant amount for a young company. Products supplied by Gasera are portable measuring devices and gas analyzers. The volume of sales of measuring instruments is 10 million units per year.

The scope of the company's products has been noted in such types of research as ecology, geology, photoacoustics, in the analysis of gases, liquids and solid materials, as well as in industrial research. The company's rating is 8.1, which is a decent rating for the short period of the company's existence, against the background of older companies.

The strength of the company is that it is a new generation company that was founded several years ago and at the same time has a good reputation in the market, as the quality of its products is on par with other higher-rated companies.

The weak side of the company is that it was founded 17 years ago and the peak of demand for the company began only in 2018. Gasera is little known on the market due to the small volume of products produced. Thus, the company's coverage of world markets, in comparison with other companies producing products of this type, is still insignificant. However, despite the limited number of consumers, the company's devices have positive reviews and recommendations.

Due to the fact that the company is located in the eastern hemisphere of the globe, it has the ability, compared to others, to create a large consumer reach for itself in this region. The company is geographically located in a very favorable country for living conditions, which gives them the opportunity to hire highly qualified specialists for themselves.

Due to the fact that Gasera is little known in the world market, strong companies that were founded decades ago and have proven themselves have the opportunity to crowd out and influence its sales volume. This is the main threat for this company.

Benchmarking of the world's best practices for the presentation of gas analyzers on the markets was carried out. The results of the analysis are presented in table.

CONCLUSION

LI-COR, Picarro, Gasera are world leaders in the production and sale of precision measuring instruments. However, LI-COR and Picarro, companies that were founded earlier than Gasera, have been able to establish themselves as reliable manufacturers throughout their life on the world market. They are the most successful and in demand. If the scientific potential of each of the companies under consideration is not updated on the basis of innovative developments in the near future, then potential consumers will switch to companies that produce products that meet the tasks set by society.

A comparative analysis of large companies producing high-precision control devices showed that despite the differences in the range, principle of operation of the equipment produced, geographical coverage, age, all of them are manufacturers in demand on the market. Thus, the products manufactured by LI-COR, Picarro, Gasera reproduce the measurement parameters required for solving scientific problems of developing nanomaterials based on the capture of atmospheric carbon dioxide, the development of the instrumental base of new generation carbon polygons.

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Kulakova E.S. – the author's personal contribution consists in suggesting an idea, collecting and processing material, and developing research results.

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