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NATIONAL UNIVERSITY OF OIL AND GAS «GUBKIN UNIVERSITY»

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This Symposium is dedicated to cutting-edge research in the field of ecology, regional sustainability and carbon neutrality of industries with the opportunity to discuss.

Objective: Develop a scientific agenda and topics for joint work of Chinese and Russian scientists to achieve carbon neutrality of industries, as well as promote the development of scientific and educational cooperation in the field of ecology, environmental protection and carbon neutrality.

This collection of works is based on the materials of the Sino-Russian symposium on reducing emissions and improving the environmental component of the energy industry held in a remote format on the basis of Gubkin University and China University of Petroleum (East China) on January 22-23, 2024.

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ISSUES OF IMPORT SUBSTITUTION OF NON-AQUEOUS DRILLING FLUIDS AND THE DEVELOPMENT OF ECOTOXICOLOGICAL REQUIREMENTS FOR THEM FOR OFFSHORE DRILLING

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Keywords: *non-aqueous drilling fluids, import substitution, offshore drilling, ecotoxicity, biotesting*

Research Relevance

Under the conditions of sanctions restrictions, an important aspect of industrial development is the creation of domestic developments, which for Russia are especially associated with import substitution in the oil and gas industry. Prospects for the further development of oil and gas production in Russia are associated with the development of the country's offshore oil and gas resources: projects in the Arctic, the Far East, the Caspian, Black, Azov and Baltic seas. Marine ecosystems are vulnerable to conditions of high anthropogenic pressure due to natural and climatic conditions. The volumes of oilfield chemicals used in the fields are large, and therefore there is a high risk of environmental pollution from chemicals and hydrocarbons generated, including during well drilling. Drilling is typical for both prospecting and exploration work and industrial development of the field. At the same time, even when implementing high-tech processes using environmentally acceptable chemical products, drilling waste is generated: drilling cuttings, spent drilling fluids and drilling wastewater, which are significant sources of environmental impact. In this regard, it is necessary to solve the problem of ensuring comprehensive environmental safety during drilling operations and reducing the volume of generated waste.

The environmental hazard of drilling waste lies in three aspects. Firstly, suspended fine substances affect the mechanical filtering apparatus of aquatic organisms, causing their death and breaking the trophic chains of the aquatic

ecosystem. Secondly, suspended fine substances have a high adsorption capacity and concentrate toxicants on their surface, increasing their toxicity. Thirdly, fine particles are carried by bottom currents over long distances, thereby creating voluminous plumes of increased turbidity.

International and national experience in environmental regulation of the offshore oil and gas complex (MARPOL, OSPAR, HELCOM, Convention for the Protection of the Black Sea against Pollution, Framework Convention for the Protection of the Marine Environment of the Caspian Sea, Arctic Monitoring and Assessment Program AMAP) prohibits the discharge of drill cuttings into the sea and regulates their export and subsequent disposal on land [1]. When using drilling fluids on a non-aqueous basis, only BS are formed; the formation of other types of drilling waste is eliminated through purification up to 90-95%, regeneration and reuse of the drilling fluid.

One of the priority areas of environmental protection in the field of oil and gas production should be ecotoxicological regulation of used drilling fluids and generated drilling waste. At the moment, to assess the environmental hazard of drilling mud, maximum permissible concentrations of drilling mud are established for water bodies used for fishing purposes [2,3]. However, the development and approval of environmental and fishery standards for them is ineffective, since drilling fluid and drill cuttings do not have a constant composition. To obtain a comprehensive environmental assessment, it seems appropriate to use a combination of environmental modeling and biological testing.

Purpose of Research

The purpose of the work is to analyze the prospects for import substitution of non-aqueous drilling fluids, develop samples, and also develop ecotoxicological requirements for non-aqueous drilling fluids for offshore drilling.

Research Methods

In this research work, the following research methods were used: environmental modeling by calculating the hazard class of drilling fluids and generated waste, as well as an experimental method - biotesting.

The toxicity of dispersion media of drilling fluids was assessed by biotesting using luminous bacteria, ciliates, daphnia and artemia as test objects with a preliminary calculation of the hazard class.

Research Results

According to the results obtained, all tested samples have hazard class 4 and are low-hazard. Biotesting confirmed the calculation results. However, it was found that the most optimal way to assess the toxicity of non-aqueous drilling fluids is biotesting due to the rapidity and integrity of the assessment. It is recommended to conduct biotesting using regional indigenous organisms as test objects to obtain more complete and reliable results. It is also necessary to adapt known methods in relation to the specifics of non-aqueous drilling fluids and their waste, to take into account a number of other factors based on environmental research methods, in particular the effect of biological accumulation of pollutants in trophic chains, their chemical accumulation in adjacent environments, the possibility of transforming migrating substances into more toxic ones forms, etc.

Under the conditions of sanctions restrictions, it is recommended to import substitution of foreign drilling fluids with domestic analogues, which, in turn, are not inferior to foreign models in environmental safety.

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2. *The procedure for organizing the development and approval of maximum permissible concentrations of pollutants in the water of fishery water bodies.*

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GEOECOLOGICAL RISKS OF CLIMATE CHANGE: A VIEW FROM SPACE

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Keywords: *geoecological risks, geoinformation environment, space monitoring, hazardous natural and technologic processes, greenhouse gases*

The long period of implementation of oil and gas complex projects is accompanied by changes in the initial design conditions, which causes the emergence of uncertain situations and risks their management. A special place here is occupied by dangerous processes associated with climate change on the planet, leading to disruption of the natural and technological conditions for the implementation of projects. This situation causes to the activation of natural and techogenic sources of emergencies. In many cases, the level of their impact on objects of the geosphere (to the atmosphere, hydrosphere, lithosphere), technosphere (deposits, transport, storage facilities) and biosphere (vegetation, wildlife) is comparable with each other. This situation requires reliable differentiation of sources of occurrence and the development of a set of measures to minimize damage from their impact. This presupposes the need for information support for the implementa- tion of the project throughout its entire “life cycle”.

The need to solve this class of problems required a transition from the development of individual satellites to satellite constellations. They are used within the framework of the environ- mental research programs of the European Space Agency (ESA) Copernicus, the National Aero- nautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA) (USA), the Russian Space Agency «Roscosmos», of the China National Space Admin- istration (CNSA). This approach makes it possible to obtain more complete information about the dynamics of processes occurring in the atmosphere and to localize the sources of changes in its parameters.

An increase in the volume of transmitted and processed specialized information involves the use of automatic and automated modes for its interpretation and display. The presence of qual- itatively new information allows us to significantly expand the scope of its application. One of these areas is the use of space satellite constellations to localize the sources of natural and techogenic impacts of oil and gas complex facilities on the state of the atmospheric air during normal and emergency emissions of greenhouse gases.

To solve this class of problems, universal geoformation platforms implemented on the basis of geoportals have become widespread. This approach is used when studying the state of territorial objects based on geoportals of search engines Google Earth, Google Maps, Bing Map, Digital Globe, Kosmosnimki, Yandex. Maps, Yahoo! Maps, Virtual Earth, Gurtam Maps.

Along with universal search engines, thematic geoportals are beginning to become more widely used. They provide monitoring of the position of dynamic systems; of hazardous natural and techogenic processes, including: earthquakes and volcanic eruptions, forest fires. A special place here is occupied by geoportals that provide display of information received from new remote sensing satellites. Modern capabilities for observing objects of the earth's surface through satellite constellations create conditions for their integration into systems for monitoring and managing the safety of territories where there are sources of dangerous natural and techogenic processes, in par- ticular, oil and gas complex facilities. An example of this approach is systems that use a symbiosis of geoinformation platforms and aerospace remote sensing systems when analyzing large amounts of data based on artificial intelligence systems. It is used in the following tasks: of the assessing the level of greenhouse gas emissions, the activity of geodynamic processes and oil and gas shows at the objects under study.

The goal of the work is the development and practical testing of geoinformation strategies for managing geoecological risks of climate change through space-based systems for monitoring the level of greenhouse gas emissions at oil and gas complex facilities.

To achieve this goal, the work considers [1-5]: natural and tecnogenic sources of greenhouse gas emissions into the atmosphere; capabilities of existing and perspective remote sensing systems in solving environmental problems; features of technologies for interpreting images of greenhouse gas emission sources in geographic information systems; examples of experimental testing of technologies for controlling the emission of emergency greenhouse gas emissions at oil and gas complex facilities.

The results of the analysis showed the limitations of the technologies used in solving in- dustrial safety problems in cases of accidents, which is due to the lack: of the integrated network for monitoring the condition of oil and gas complex facilities based on space, air (unmanned) and ground observation systems; of methods for verifying the level of greenhouse gas emissions obtained by various sensors under normal and emergency observation modes; of techniques for interfacing data obtained by various remote sensing systems within a single geographic information environment of the territory.

Elimination of the noted limitations will make it possible to increase the efficiency of using environmental satellite constellations for monitoring greenhouse gas emissions in the areas where oil and gas complex facilities are located in order to ensure their industrial and environmental safety.

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NUCLEAR ENERGY IN THE LIGHT OF SUSTAINABLE DEVELOPMENT OF THE RUSSIAN FEDERATION: PROSPECTS AND INNOVATIONS

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Keywords: *energy, nuclear, ecology, innovation, prospects*

The global energy crisis coupled with the course on the climate agenda has acutely raised the question before the world community of the need for accelerated development of a compromise source of energy - affordable and reliable, but at the same time universal and environmentally friendly. Nuclear power fully meets these criteria. Over the last year, this type of energy has not only confidently regained key positions in the global energy arena, but is also rapidly expanding its prospects in the future world fuel and energy balance. Russia is the leader of the world nuclear industry, possessing enormous technological and scientific potential. The purpose of this paper is to assess the risks and opportunities for the development of the Russian nuclear complex in a turbulent external environment. The methods of statistical and system analysis were used for the study.

Today, the share of nuclear generation in Russia is about 20%, and in its European part it reaches 40% - it is the most significant source of "clean" energy. The main drivers of development of the Russian nuclear industry are innovative developments. Thus, by 2030, it is expected that Russia's share in the market of small capacity nuclear power plants (SCNPPs) will cross the 20% threshold. ASMM is one of the main areas of the modern Russian nuclear industry, in which the Russian Federation is ahead of many countries in terms of technology by almost ten years. To date, about 80 ASMM projects are being developed in 20 countries, but only Russia and China have already put these projects into practice. An example is the floating station in Chukotka, launched in 2019. If we talk about the near future, an ASMM will be built in Yakutia on the basis of the "icebreaker" reactor unit RITM-

200. This plant will provide energy to the Kyuchus gold deposit. This will solve the problems of power supply to certain hard-to-reach regions.

Through the development of ASMM and other innovations, Russia plans to increase the share of nuclear energy in the country's total energy balance to 25% by 2040.

Russian companies are the leaders in new nuclear projects, with a total of more than 25 nuclear reactors with a capacity of 22885 MW being built worldwide. Chinese companies are in second place, building 19 reactors with a capacity of 18264 MW in the PRC.

Rosatom State Corporation in Russia builds and operates conventional NPPs, ASMMs, and research reactors. For example, construction of two units with VVER-TOI reactors continues at the second stage of Kursk NPP. The reactor vessel was installed at power unit No. 1, and construction of the evaporative cooling tower, the highest in Russia, was completed in the fall. Preparatory work has begun at the sites of Leningrad and Smolensk NPPs, where two new units will be built each. Innovative technologies are being actively introduced into production. For example, we can single out the innovative fast reactor with lead coolant and stationary fuel cycle BREST-OD-300 (the so-called innovative reactor of natural safety). In terms of safety, BREST-OD-300 will have a number of significant advantages over any reactor in operation today - it will shut down on its own in case of any parameter deviation (see figure 1). Innovations also concern the issues of spent fuel and waste utilization, for example, the Kurchatov Institute has developed a new method of cheap storage of spent nuclear fuel.

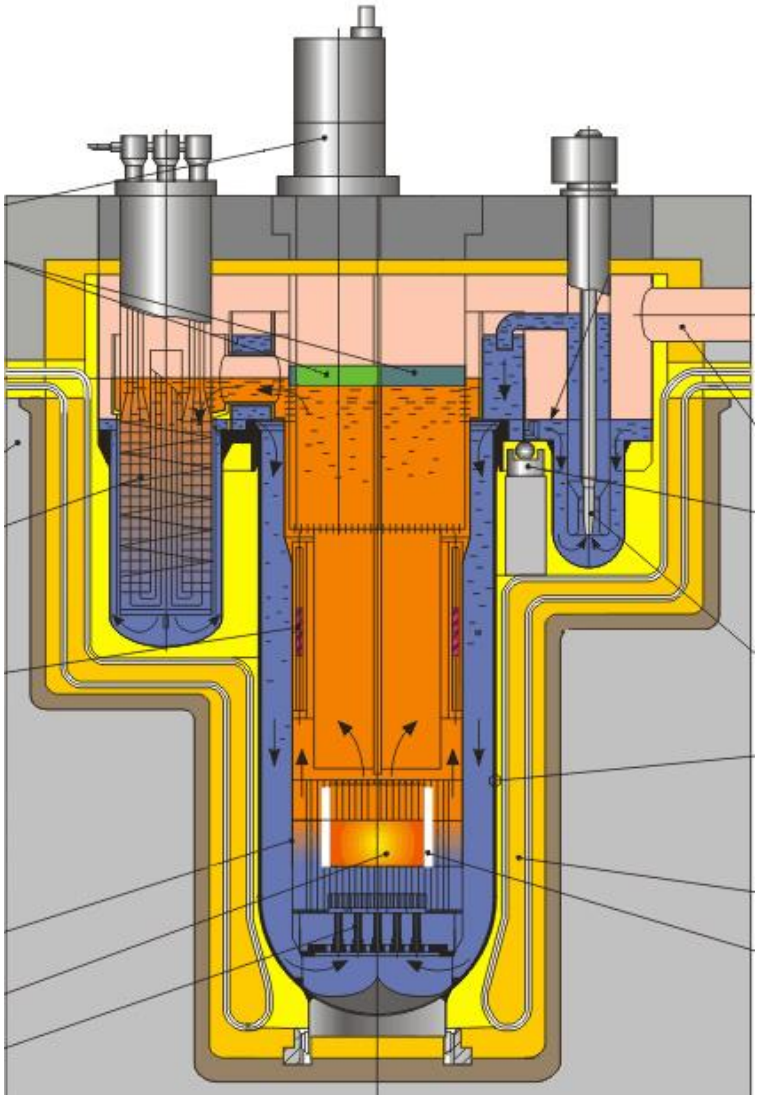

Figure 1 - Schematic diagram of the implemented reactor BREST-OD-300

Special attention is paid to the issues of industrial and environmental safety at all nuclear facilities. In particular, the concentration of radioactive substances in the air, cooling water bodies, soil and vegetation, etc. is monitored in the monitoring zone (the monitoring zone, for example, at Kalinin NPP is 11 km around the plant) for several dozens of indicators; the results of control and monitoring are published in public reports.

Nuclear power has significant potential to ensure energy and environmental security of countries, regions and the planet as a whole, provided that the risks associated with the presence of sources of increased danger, human factor, the need

to comply with special requirements for the storage and disposal of spent nuclear fuel and radioactive waste are mitigated.

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COLLAGEN HYDROLYSATE AS A FILLER FOR ELASTOMERIC BLENDS

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Keywords: *collagen, swim bladder, modification, elastomer, frost resistance*

The development and implementation of new, environmentally friendly polymer materials is the basis of the 17 Sustainable Development Goals, also known as the Global Goals, were adopted by the United Nations in 2015 [1]. According to this concept, there is a need to replace petroleum as raw materials for making polymers and their ingredients. Petroleum and its products negatively effects on the environment. This problem can be solved by using bio-based polymers produced from renewable resources. Bio based polymers not only can significantly reduce the consumption of petroleum for the production of synthetic elastomers but also provide new combinations of properties for new applications. There are significant number of scientific works devoted to the preparation of new polymeric materials filled with biologically active compounds such as keratin hydrolysate, collagen hydrolysate, technical protein, amino acids, lignin, rice husk, phospholipids [2-5]. One of the biopolymers is collagen, which is widely used in various industries. Collagen are treated with an alkali-salt solution, enzymatic hydrolysis that causes the protonation of collagen polypeptides and allows obtaining highly dispersed collagen hydrolysate.

In previous works, we modified elastomeric materials based on rubbers of different chemical natures with collagen hydrolysate. Synthetic polyisoprene rubber, epichlorohydrin rubber (GPCO) HYDRIN T6000 (Zeon, Japan), and nitrile-butadiene rubbers with different contents of nitrile acrylic acid were used as an elastomeric matrix. Collagen hydrolysate was obtained from the swim bladders of sturgeon (ACIPENSERIDAE), white fish (COROGENIDAE), pike (ESOX LUCIUS) of northern fish species with alkali-salt hydrolysis and enzymatic

hydrolysis followed by freeze-drying. The resulting collagen hydrolysate was studied using modern physicochemical methods such as Fourier-transform infrared (FTIR) spectroscopy, Dynamic Light Scattering (DLS), High-resolution chromatography of liquids (HPLC), atomic force spectroscopy. The vulcanization kinetics of elastomeric blends were determined by a rotorless rheometer D-RPA 3000 (MonTech, Germany). The mechanical properties of tested vulcanizates were tested according to GOST 270-93, determination of tear strength of composites were investigated according to GOST 262-93, compression set (CS) was measured according to GOST 9.024-74 at 100°C for 72 hours. Frost resistance was evaluated by the value of frost resistance coefficient on elastic recovery after compression (Kw) at -20, -30, -40, -50 °C. Frost-resistant rubber must have Kw at least 0.2 at a temperature of -50 0C. The density of the vulcanization network of the studied elastomers was determined according to the Flory-Rener equation by the method of equilibrium swelling of vulcanizates in chloroform. The supramolecular structure of hydrolysate and studied rubbers was studied using scanning electron microscopy JSM-7800F (JEOL, Japan).

The FTIR-spectra of collagen hydrolysate obtained from swim bladders of fish indicated Amid I, Amid II, Amid III bands that represent N–H bending vibrations and C–N stretching of the protein molecule [6]. The results obtained by HPLC showed that collagen hydrolysate mainly contains the following amino acids: glycine, alanine, proline, glumamic acid, asparagine that is in good agreement with the literature data. Collagen fibers were clearly visible in electron micrographs.

The results of studies showed that collagen hydrolysate interacts better with polar rubbers. The addition of the collagen hydrolysate promotes an increase in mechanical properties filled vulcanizates based on nitrile-butadiene rubbers. The strength increases to 37%, modulus at 100% 2.4 times with the addition of hydrolysate. The use of collagen hydrolysate as modifying additive of elastomer composites based on GPCO caused a reduction of the level of compression set accumulation. Based on studies that collagen hydrolysate clearly increases the cross-linking density of the vulcanizates based on polar rubbers. Another important result

is an increase in the value of frost resistance coefficient with the addition of collagen hydrolysate at -20 and -30 ^{0}C. This figure increases to 14% compared to control samples.

Thus, the experimental data obtained allow us to conclude that the development of rubber based on polar rubbers using collagen hydrolysate obtained from the swim bladder of northern fish species as an environmentally friendly modifier is promising.

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DEVELOPMENT OF CLIMATE CHANGE ADAPTATION MEASURES WITH REGARD TO THE PHYSICAL AND GEOGRAPHICAL CHARACTERISTICS OF THE REGION

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Keywords: *climate risks, climate adaptation, adaptation measures*

The Russian Federation has joined the global low-carbon development process. A number of recent national policy documents and regulatory legal acts make the climate agenda a priority for our country. The decarbonisation policy aimed at reducing greenhouse gas emissions through the implementation of mitigation measures and the development of adaptation measures will avoid economic, social and environmental risks for the population, various sectors of the Perm Territory economy and industrial enterprises.

The aim of the research work is to develop a draft plan of adaptation to climate change for the territory of the Perm region.

To achieve this goal, it was necessary to solve the following tasks:

1. To characterise the territory of the region and predict the most likely climatic changes for it.

2. Identify the prevailing socio-economic and environmental-economic trends and predict the possible consequences of climate risks for the region.

3. To develop a system of operational and long-term adaptation measures based on the collection of information from stakeholders and the selection of priority measures to reduce climate risks both in the region as a whole and in individual leading enterprises, as well as the expert ranking of adaptation measures in accordance with approved methodological guidelines.

4. Provide financial and economic justification for the proposed measures.

5. To formulate recommendations for the development of measures to reduce the socio-economic and environmental impact of climate change on the territory of the Perm region.

On the basis of the conducted research, a list of recommended measures was developed, taking into account the specifics of the region and the strategic goals of its development. The prepared draft of the Perm Region Climate Change Adaptation Plan is the result of the coordinated work of a wide range of stakeholders.

GLOBAL TRENDS OF THE DEVELOPMENT OF LOW-CARBON ENERGY AS THE LOCOMOTIVE TO THE GREEN ENERGY TRANSITION

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Keywords: *global energy consumption; fossil fuel reserves; low-carbon energy; non-carbon energy; renewables installed capacity; specific investments for energy unit; renewables technical potential*

Global energy consumption is accelerating over the past 50 years it has increased more than to 2.5 times, with an annual growth rate of 3.1%. This is primarily due to the surging rates of growth in energy consumption in the Asia-Pacific Region.

In 2022, global energy consumption exceeded 14.43 billion TOE, and almost 77% of energy consumed by the G20's countries, which allows us to conclude that the trends in this bloc determine the trend in global energy.

The analysis of retrospective dates allowed the authors to make a prediction involving three scenarios defining what the global energy consumption up to 2050 and 2100 will be even in the energy-efficient scenario, by 2050, energy consumption will already be 18 billion TOE, and by 2100 – 26 billion TOE, that is, it will actually be double the current level. In case of conservative scenario, the implementation of which is most likely, energy consumption by 2100 will be more than 36 billion TOE [1].

In 2022 there are five countries such as Russia, Canada, France, Great Britain and Argentina has leading position among G20's countries in the share of "low-carbon" energy more than 60% because natural gas in their Total Energy Consumption Balance prevail. Taking into account that more than 82% of 'global

energy consumption is satisfied by fossil fuel, the role of natural gas in ensuring the ecological sustainability of energy is now Key [2].

In 2022 share of low-carbon energy in global energy sector decreased of 0.5% compared with 2021, also in 11 from 19 countries (including all countries from Europe, including Russia)) from group of twenty share of low-carbon energy decreased also, but it was caused the beginning in 2021 of the restructuring of the energy market, especially natural gas market.

Now the proven Global reserves of fossil fuels a little bit more than trillion TOE and hydrocarbons a bit more than 400 billion TOE. Quantitative assessment of years of extraction fossil fuel almost 90 years, hydrocarbons more than 50 years, so there is a limited period in which we can produce and make widespread use of fossil fuels, particularly hydrocarbons. The reserves of fossil fuels are limited and the prospect of their exhaustion is unavoidable in the long term [3].

The sustainable development of global energy requires the well-balanced deployment of all currently known fuels and energy sources globally and a huge effort to find new types of energy that can meet humanity's needs in the long term. In particular, in the future, thermal renewable energy sources are likely to play a huge role, the industrial application of which will require enormous scientific, technical, and technological effort. At the nearest time hybrid energy supply systems, using thermal and renewable energy will be used widespread especially in distributed energy supply systems [4].

The growth in global renewable energy installed capacity is huge – for previous 20 years since 2000, it increased from 26.2 GW to 1,223 GW – a growth rate of more than 46 times. The share of wind energy is more than 50%, which increased by 36 times; the share of solar energy is almost 48%, which increased by 838 times; the share of geothermal energy is highly localized and does not exceed 1.2% [3].

Assessment of technical potential of solar energy in China may be estimated at ~192 billion TOE, in Russia ~289 billion TOE per year. The technical potential

of wind energy in Russia can be estimated at ~6.2 billion TOE; in China ~3.7 billion TOE per year [5].

Analysis of trends of development of various areas of the global energy sector over the previous 20 years shows, that both globally and G20's countries there is a steady trend of advancing development in renewables, first of all that is major investment in renewable energy rather than other sources is the driving force behind the accelerated global development thereof [6]. Lieders countries of the share of "Low–Carbon" energy among G-20 countries have excellent result due to widespread using of natural gas and non-carbon energy sources, such us nuclear energy and renewables. Taking into account that almost 82% of the global energy consumption satisfied by fossil fuel, the role of natural gas in ensuring the ecological purity of energy now is key.

In Russia, we have to develop huge reserves of fossil fuel, especially most environmentally friendly natural gas, at the same time develop renewables, which is economically feasible, especially at remote regions and facilities of the oil and gas industry, non-carbon hydro and nuclear power.

In the global energy sector has been formed steady trend of growth energy consumption from "low-carbon" environmentally friendly energy sources, such as natural gas, nuclear and hydroelectric power plants and renewables. The main reasons, in our opinion, are limited reserves and the growing environmental consequences of modern energy sector, based on fossil fuel.

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ENVIRONMENTAL MONITORING OF THE WATERS OF THE NORTHERN SEA ROUTE

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Keywords: *The Northern Sea Route, the Arctic, Arctic ecosystems, environmental safety, environmental monitoring*

The integrated development of the Arctic zone of the Russian Federation is one of the strategic priorities of the state. Increasing the volume of traffic along the Northern Sea Route (NSR) is of paramount importance for solving the tasks set in the field of transport and cargo delivery. The development of this logistics corridor is ensured through the establishment of regular cargo transportation, the construction of new nuclear icebreakers and the modernization of the relevant infrastructure. Enterprises of the State Corporation "Rosatom" take an active part in this work. The integrated development of the Arctic and the transformation of the NSR into a year-round transport and logistics route require ensuring safe and sustainable Arctic shipping, and the creation of a modern and efficient port infrastructure requires constant monitoring of the condition of the water and terrestrial Arctic ecosystems adjacent to the NSR.

The purpose of the study is to study a comprehensive program for monitoring the state of the environment and biodiversity in the NSR waters and evaluate its effectiveness.

The following methods were used in the study: analysis, synthesis, induction, deduction, study and generalization.

Ensuring the environmental safety of the Arctic is of key importance for the development of the region and is possible by applying a systematic approach, including both regulatory support and management, navigation and technological solutions, as well as operational interaction between authorities, natural resource users and the expert community.

One of the most effective mechanisms for obtaining the necessary information about the state of the environment in the Arctic region, its biodiversity and its changes is monitoring of the state of the environment, carried out on an ongoing basis with the greatest possible territorial coverage and the use of modern technologies. Measures to identify, prevent and eliminate security threats, localize and neutralize the consequences of their manifestation, including remote methods of environmental research, prepared in accordance with generally accepted international standards, help in making timely forecasts and in analyzing the situation in the northern seas.

To ensure the environmental safety of the region, taking into account global environmental changes, as well as the increasing intensity of navigation along the NSR, work is underway to create an extensive program of comprehensive and systematic environmental research.

As a result of the work, a comprehensive program for monitoring the state of the environment and biodiversity in the NSR water area was formed.

The program includes:

- A system of measures to monitor and control the state of the environment in the NSR water area, taking into account Russian government, commercial, scientific and non-profit organizations and the foreign expert community;
- Environmental monitoring subprograms with the definition of a set of mandatory objects, parameters, methods, frequency of observations and work areas;
- Test sites for monitoring and observing birds and marine mammals.

The project does not stop and will be implemented in 2024. In September 2023, within the framework of the Eastern Economic Forum (EEF), a document was signed on the continuation of cooperation between the Rosatom State Corporation and the Moscow State University Center for Research and Development.

In 2024, the system of state environmental monitoring of the NSR water area as an information basis for ensuring the environmental safety of navigation will be

included in the unified system of state environmental monitoring as a separate subsystem.

In 2024, environmental monitoring will be carried out in the port areas of the Northern Sea Route and satellite monitoring with the further development of digital service functions. Work will continue on a comprehensive monitoring program based on an analysis of the needs for monitoring results; approaches and methods of information support for environmental protection and ensuring environmental safety in the NSR water area will be developed.

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CONSTRUCTION AND APPLICATION OF TYROSINE-CONTAINING SHORT PEPTIDE SELF-ASSEMBLING MATERIALS

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Keywords: *peptide self-assembly, tyrosine, oxidative cross-linking, optical materials, elastomeric materials*

Self-assembled peptides have been attracting more and more attentions because of their excellent biocompatibility. They have become one of the hot spots in the fields of colloidal and interface chemistry and materials chemistry in recent years. Peptide molecules can form highly ordered self-assembly structures through weak interactions. Through rational sequence design and solution condition regulation, various self-assembled peptide materials could be fabricated. Tyrosine is easy to be oxidized for the sake of the phenolic hydroxyl on side chain. Various supramolecular structures can be constructed, including nanofibers, nanosheets, nanotubes, through sequence design. The aim of the study is to enhance the optical and mechanical properties of peptide-based nanomaterials through tyrosine-containing peptides (TCPs) sequence design and oxidation degree control, and could be used in functional materials development.

Tyrosine is a natural amino acid that is susceptible to be oxidized due to the phenolic hydroxyl on the side chain. The structures and properties of tyrosine-containing peptides (TCPs) supramolecular self-assemblies are affected by oxidation of different degrees. The oxidized products include dityrosine, benzoquinone, and melanin. [1, 2] Resilin, often found in the wings of dragonflies and legs of fleas, has a typical cross-linking of dityrosine, and the linking increases the stability of the molecular structure.[3]Ren et al. have prepared dityrosine-containing nanomaterials through oxidation under low-oxygen condition, and found that the fluorescence property and morphology could be further controlled by the solution pH, which made the nanomaterials suitable for the construction of stimulus-responsive systems.[1]In our previous work on cyclic dipeptides, we have also found

that tyrosine-containing cyclic dipeptides also formed products with dityrosine structure upon oxidation, which significantly improved the fluorescence intensity of the cyclic dipeptide aggregates. [4]Through isolating the aromatic amino acids phenylalanine and tyrosine, the mutual interactions between peptide self-assembly and oxidative crosslinking was controlled by rapid photo-crosslinking. The mechanical properties of peptide hydrogel awas improved due to the formation of tightly entangled dimeric fiber networks through the dityrosine bonds.[5]

Tyrosine is easy to be oxidized for the sake of the phenolic hydroxyl on side chain. Various supramolecular structures can be constructed, including nanofibers, nanosheets, nanotubes, through sequence design. (Figure 1). A variety of products can be obtained via different oxidation methods. It is found that tyrosine-containing peptide (TCP) has good fluorescence properties (Figure 2) and elastic recovery properties after oxidation.

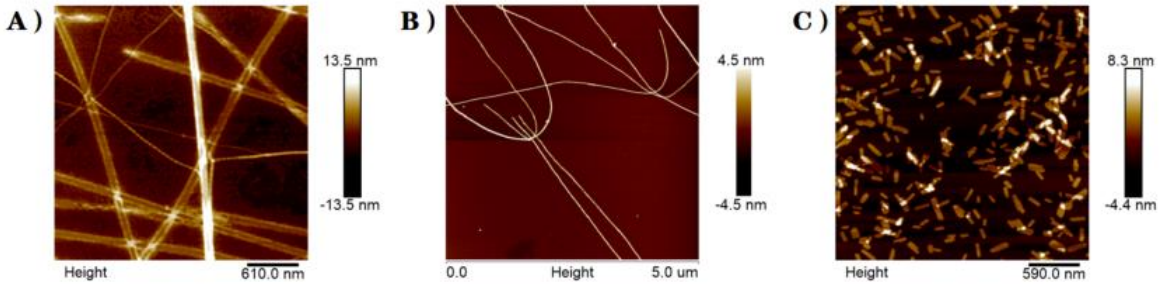

Figure 1 - Morphologies of tyrosine-containing peptide self-assemblies. A) nanotubes, B) nanofibers, C) nanosheets

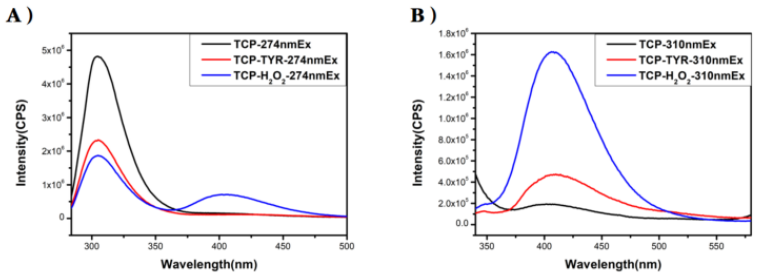

Figure 2 - FL spectra of TCP oxidized by Tyrosinase and H_2O_2. Excitated at A) 274nm B) 310nm

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RUSSIAN-CHINESE COOPERATION IN THE SPHERE OF ECOLOGY

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Keywords: *Russia; China; environment, projects, prospects*

Nowadays environmental issues have become the most popular topic for discussions, the world community has faced problems in protecting the environment and realized the human impact on nature. The most effective way to reduce ecological damage is to unite countries seeking to protect the environment through international organizations. In order to address those issues, China and Russia have established a set of cooperation mechanisms, such as the SubCommittee on Environmental Protection of the Regular Meeting of the Prime Ministers of China and Russia. There is currently a multi-level environmental cooperation system between the two countries. In recent years, China and Russia have strengthened their ecological cooperation and have achieved certain results in that sphere.

The purpose of the work is to analyze the past experience of cooperation projects between Russia and China and determine the prospects for their development.

Scientific novelty. In this article, from the methodological point of view of a systematic retrospective analysis, the political and economic base of the study, the main trends and problems, directions and specific projects of cooperation between Russia and China in the ecological sphere are considered.

Practical significance. The results of the work will be useful for analyzing projects in the field of ecological cooperation at the country level.

MODULATION OF METAL-SUPPORT INTERACTION FOR PROPENE EPOXIDATION WITH H_2 AND O_2 ON NI-TI BIFUNCTIONAL CATALYST

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Keywords: *epoxidation reaction, titanium containing carrier, rutile, metal carrier interaction, propylene adsorption*

A new strategy for eliminating rutile in titanium containing carriers during epoxidation reactions. This method is based on the metal-carrier interaction (SMSI) mechanism induced under reducing atmosphere. By constructing an M-TiO_x structure between the loaded metal M and rutile, adjusting the distribution of titanium species can promote the efficiency of epoxidation. This method has achieved the effect of turning stones into gold and is expected to further improve the performance of epoxidation catalysts.

The titanium carrier containing 4-coordinated framework (TiO_4) was used for the direct gas-phase epoxidation of propylene, H_2 and O_2 to produce epichlorohydrin (PO). The traditional strategy for synthesizing titanium carriers is to obtain a high content of 4-coordinated titanium species (TiO_4) and inhibit the generation of rutile TiO_2 [1]. Because the in-situ generated H_2O_2 was decomposed on rutile TiO_2, thereby reducing the efficiency of the epoxidation reaction. This work is based on the strong metal carrier interaction (SMSI) effect [2]. Under high-temperature treatment in a reducible H_2 atmosphere, the rutile TiO_2 in the titanium carrier forms an M-TiO_x interface structure with the loaded metal M, an innovative strategy for preparing high epoxidation performance carriers has been developed.

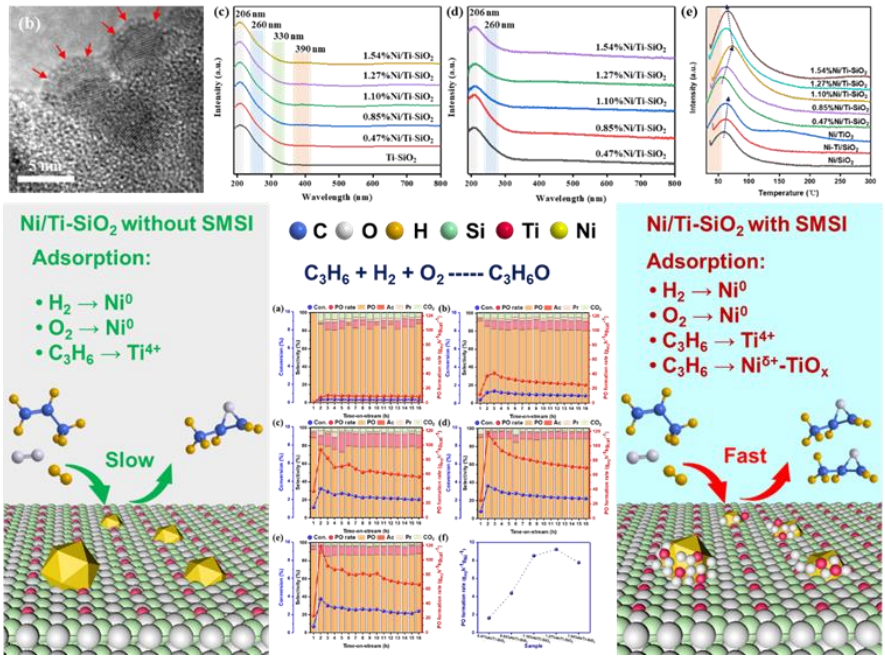

Figure 1 - Scheme showing the strategy for boosting propylene epoxidation reaction via SMSI on the Ni/Ti-SiO_2 catalyst

This method can reduce the content of rutile TiO_2, regulate the distribution of Ti species in the carrier, and improve the selectivity of epoxidation reaction; The interface structure of M-TiO_x can improve the electronic structure of active metal M, and The binding force between positively charged $M^{\delta+}$-TiO_x interface sites and electron rich C=C bonds is very strong, promoting the adsorption of propylene and increasing the formation rate of epoxidation. By changing the metal M content and reduction temperature, the M-TiO_x interface structure and Ti species distribution can be synergistically regulated, achieving synchronous enhancement of high activity and selectivity. This efficient and environmentally friendly method has achieved the goal of turning small stones into gold, breaking through the traditional view that rutile TiO_2 is not conducive to the gas-phase epoxidation reaction of olefins, and providing new ideas for the targeted construction of novel catalysts.

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DESULFURIZATION OF HIGH-SULFUR PETROLEUM COKE BY WET OXIDATION WITH OXYGEN (AIR) UNDER MILD CONDITIONS

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Keywords: oxidative desulfurization; petroleum coke; wet oxidation

High-sulfur petroleum coke, produced as a distillation by-product in production of motor fuels by delayed coking of heavy petroleum residues, is widely used in power engineering and in other practical applications. However, the large-scale use of petroleum coke in the energy and metallurgy industries is accompanied by significant emissions of sulfur compounds into the environment, which leads to high and very high levels of air pollution in cities where such production is localized. The sulfur content in the original coke (more than 1.5% for sulfur cokes and more than 4% for high-sulfur cokes) is determined mainly by the sulfur content in the feedstock, as well as the influence of technological parameters of the coking process. Sulfur is present in petroleum coke mainly (up to 98%) as part of organosulfur compounds and is represented mainly by thiophene, dibenzothiophene and their alkyl derivatives (~2% of sulfur is represented by inorganic compounds in the form of sulfates and sulfides of metals and elemental sulfur). The presence in the original petroleum coke of condensed compounds such as thiophene and other organosulfur compounds associated with the carbon skeleton of the coke makes it difficult to remove sulfur, and currently desulfurization of high -sulfur coke is a great challenge. No economical method has yet been found to achieve efficient and cost-effective desulfurization of high-sulphur petroleum coke on an industrial scale.

This project presents a new approach to creating an effective, environmentally friendly and economical process based on the use of the hydrothermal method of oxidative desulfurization of petroleum coke by oxidation with oxygen (air) in aqueous solutions at elevated temperatures (110-250°C). Hydrothermal oxidation

technologies allow complete oxidation of various sulfur compounds both without catalysts and, under milder conditions, in the presence of catalytic systems [1, 2].

The dependences of the degree of desulfurization on the parameters of the process were experimentally determined. The highest degree of desulfurization at an oxygen pressure of 5.0 MPa and 180°C was from 32.34 (at the petroleum coke particle size of 2 mm) to 39.68% (at the petroleum coke particle size smaller than 0.5 mm). The maximal degree of desulfurization, reached at an oxygen pressure of 5.0 MPa, 220°C, and petroleum coke particle size smaller than 0.5 mm, was 51.61%.

CONCLUSIONS

Our study proved the possibility of reaching high degrees of desulfurization (up to 50%) in a one-step oxidation process performed in an aqueous phase under excess pressure corresponding to or exceeding the saturated water vapor pressure. The desulfurizing agent in the process is atmospheric oxygen or pure oxygen under the conditions ensuring efficient mass transfer of the desulfurizing agent to the petroleum coke surface. The optimum parameters of the oxidative desulfurization are as follows: T = 180°C, P = 5 MPa, and coke particle size 1–2 mm.

The resulting low-sulfur desulfurization product can be used in the energy sector, in metallurgy, in particular, at coke-chemical enterprises in the composition of the charge for producing metallurgical coke.

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THE POSSIBILITY OF USING SORBENTS FROM PLANTS OF THE UMBRELLA FAMILY FOR WATER PURIFICATION

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Keywords: *plants of the umbrella family, invasive plant species, sorbing, filtering and marker materials, structure*

The most prominent representative of the invasive plant species of the umbrella family, which have become widespread in the territory of the Russian Federation, is Sosnovsky's hogweed. The problem of its spread remains at the moment.

The leaves and fruits of hogweed are rich in essential oils, touching plants can burn the skin due to the fact that they contain furanocoumarins — photosensitizing substances that, when they get on the skin, can increase the sensitivity of its cells to ultraviolet light. Photosensitizing substances are substances capable of reducing the resistance of cells to the adverse effects of light. The concept is most often used in relation to the ultraviolet range.

Sorbing, filtering and marker materials from Sosnovsky hogweed have been developed and have shown their high efficiency in the relevant technological processes. This proves that a dangerous weed - Sosnowski's hogweed - can be used to create various useful materials.

The authors carried out work to assess the effect of the type of sorbent from Sosnovsky hogweed and the size of its particles on the effectiveness of water purification in filters. The results can be seen in table 1.

According to the results of the study, it is clear that the carbonized sorbent shows better results in the efficiency of water purification from oil (396 mg of retained oil versus 249 mg), however, pressure losses in it are 28% higher than in non-carbonized, which is explained by the presence of a larger number of nanopores in which oil is retained.

Table 1 – Results of experiments with fillers

Parameter	**Non-carbonized filter sorbent**	**Carbonized filter sorbent**
Characteristic	Organic	Organic
Appearance	Light brown powder	Black Powder
Particle size, mm	0,5-5	0,3-3
Filler weight, g	100	100
Filtration rate, m^3/hour	375	278
Pressure loss, MPa	0,043	0,055
Oil content mg/l The original The final	 253 4	 401 5
Resource, l	4000	5000

Based on the results of the work, ways to improve production technology and sorption efficiency are proposed.

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ACTUAL AND PLANNED VOLUME OF COMMISSIONING OF WIND POWER PLANTS, SOLAR POWER PLANTS, SMALL HYDROELECTRIC POWER PLANTS BY CONSTITUENT ENTITIES OF THE RUSSIAN FEDERATION

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Keywords: *renewable energy sources, wind power plants, solar power plants, hydroelectric power stations, Russian economy*

The current situation in the global economy and geopolitics is adjusting the implementation of projects in the young, established renewable energy industry in Russia. In connection with the growing role of renewable energy sources in the development of the economies of the world, Russia is faced with new challenges associated with the need to speed up the formation of technological, scientific, and engineering competencies [1]. The base of the Russian renewable energy sector, created in previous years, allows the industry not only to continue the implementation of previously approved projects, but also to make long-term plans.

In total, as of July 1, 2023, the unified energy system of Russia implemented 70 solar power plants with a total capacity of 1,788.3 MW, operating in 14 constituent entities of the Russian Federation. The top three include the Orenburg region with a total installed solar generation capacity in the region of 370 MW, the Astrakhan region – 285 MW, and the Republic of Kalmykia – 234 MW [1,2]. In accordance with the results of competitions held in 2021 and 2023, significant volumes of solar energy commissioning are also planned in the Trans-Baikal Territory, Astrakhan Region, and the Republics of Dagestan and Buryatia. In the Trans-Baikal Territory, additional solar power plant projects with a total capacity of 1,042 MW will be implemented [2].

As of July 2023, there are 25 wind power plants operating in the electricity and power market in eight constituent entities of the Russian Federation with a total

capacity of 2,360.0 MW, of which the largest volume of implemented projects was recorded by the companies PJSC Fortum – 1,112.6 MW and JSC NovaWind – 940.0 MW; PJSC EL5-energo owns 292.4 MW, LLC VES Breeze – 15.0 MW. In total, within the framework of the program, 1,071 MW of wind power projects remain to be implemented, of which 252.5 MW are at JSC NovaWind, 747.7 MW at PJSC Fortum and 71.3 MW at PJSC EL5-energo [3]. Also, based on the results of selections held in 2021 and 2023, an additional 2,131 MW of wind power capacity is planned for implementation with planned commissioning in 2025–2029.

For today, the largest volume of wind power plants projects has been implemented in the Stavropol Territory, Rostov, and Astrakhan regions. Together, these three regions account for over two-thirds of the total installed capacity of wind power plants in the unified energy system of Russia. Commissioning is also planned in the Volgograd and Samara regions, the Republics of Dagestan and Tatarstan, etc.

As of May 2023, there are five small hydroelectric power plants operating with a total installed capacity of 70.7 MW [4], all facilities are located in the regions of the North Caucasus Federal District, where there are some of the most favorable natural conditions for the operation of small hydroelectric power plants.

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MODERN METHODS OF REDUCING GREENHOUSE GAS EMISSIONS INTO THE ATMOSPHERE DURING THE OPERATION OF OIL AND GAS PRODUCTION FACILITIES

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Keywords: *greenhouse gases, greenhouse gas emissions, methods of reducing greenhouse gas emissions, environment, oil and gas production facilities*

This paper examines methods for reducing greenhouse gas emissions into the atmosphere during the operation of oil and gas production facilities. Firstly, various technologies are considered to prevent such emissions or reduce the negative impact on the environment. Secondly, the areas of application of these methods are analyzed.

Currently, the problem of greenhouse gas emissions into the atmosphere has become one of the main environmental problems associated with the operation of oil and gas production facilities. Greenhouse gases such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and ozone (O3) have high global warming potential, which highlights the need to develop modern methods and technologies to reduce them.

To solve the current problem, modern methods and technologies are being developed that can reduce such emissions and reduce the negative impact on the environment during the operation of oil and gas production facilities.

One of the most popular methods of reducing greenhouse gas emissions into the atmosphere is the use of carbon capture and storage (CCS) technologies. This technology includes the process of carbon capture, which is carried out at an oil or gas production facility, and its subsequent storage in underground reservoirs. Thus, emissions of CO2 and other gases are significantly reduced. This method can significantly reduce the impact of oil and gas production facilities on the climate.

An equally important method of reducing greenhouse gas emissions is to improve gas combustion technologies. Instead of releasing gas into the atmosphere, it can be used to generate electricity or heat water. This makes it possible to reduce greenhouse gas emissions by significant amounts.

In addition, one of the main methods of reducing greenhouse gas emissions into the atmosphere is effective control and measuring equipment (KIA). Automation technologies and high-precision sensors make it possible to control the parameters and composition of gases released into the atmosphere at each stage of the oil and gas production process. This allows you to quickly identify and prevent leaks or deficiencies in equipment, which leads to a reduction in greenhouse gas emissions.

Another method important for reducing greenhouse gas emissions is the use of recycling and recycling technologies. Natural gas, which contains more methane than other emissions from oil and gas producing enterprises, can be converted into electrical energy or used as fuel for gas turbines. This not only reduces greenhouse gas emissions, but also saves energy used for electricity generation or for a compressor station.

There is also a method for reducing greenhouse gas emissions based on the use of carbon dioxide burial and separation technologies. The burial of carbon dioxide allows to prevent its entry into the atmosphere, and thereby reduce its impact on the greenhouse effect. In addition, the separation of carbon dioxide allows its use in other production processes or as a raw material for other chemical processes, which contributes to its utilization and reduces emissions.

Thus, modern technologies make it possible to reduce greenhouse gas emissions by optimizing production processes, reducing methane losses and using energy efficiently. For example, the use of gas collection and processing technology reduces emissions of methane, which is one of the most dangerous greenhouse gases. More efficient use of energy also reduces greenhouse gas emissions, as less energy is required for the production and transportation of oil and gas.

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DECARBONIZATION OF LNG: CHOICE OR NECESSITY?

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Keywords: liquefied natural gas, decarbonization, energy transition

Natural gas is considered to be the leading hydrocarbon fuel in the energy transition. The CO_2 emissions from natural gas combustion are about half that of coal, and the combustion of gas transported as LNG generates much less pollutants due to the pre-treatment of the gas before the liquefaction process.

Gas is increasingly becoming the focus of attention, and questions are increasingly being raised both about its ability to play the role of a "transition fuel" and about the long-term role of gas in the global energy mix. Of course, natural gas is less harmful to the environment than other traditional fuels, but it is a fossil fuel, and its use still contributes to climate change.

The prospects for natural gas in the global energy mix are quite stable when compared with other emitting fuels. LNG will be particularly in demand, with most of it buyers coming from Asia-Pacific countries, where domestic natural gas production is low and pipeline infrastructure is limited, which means that imported LNG is the main source of energy supplies. Demand for LNG is expected to grow until 2040, and by 2040 there will be a significant gap between supply and demand.

However, due to the presence of carbon dioxide emissions, the need to consider the environmental agenda is acute for participants in the natural gas and LNG markets. It is necessary to understand whether decarbonation of LNG is a choice of individual players or an integral need of the entire market.

Methods of analysis and synthesis, economic-statistical and system analysis were used to achieve the research objectives. The research is based on publications of foreign and domestic experts, official statistics, as well as reviews of the world's leading energy agencies and oil and gas companies.

There are several ways to produce and use natural gas and LNG in such a way as to reduce its harmful impact on the environment, such "decarbonized" liquefied gas has even been given the name "green LNG". These methods include:

- reduction of greenhouse gas emissions associated with natural gas production.
- capture and store volumes of CO_2 that occur during natural gas production, during liquefaction, and during regasification.
- compensation of CO_2 emissions throughout the entire LNG production chain.
- usage of alternatives to natural gas sources, such as bio-LNG and LNG mixed with hydrogen.

Of course, all of these methods are quite expensive and require additional investment from producers, for example, the $28.75 billion North Field Expansion Project in Qatar will include spending $200 million on emission reduction technologies that minimize emissions from gas production and processing by using renewable energy sources to power infrastructure. The project will also use CCS technology to minimize CO_2 emissions, which cannot be avoided during the extraction and liquefaction of natural gas. For companies that are ready for such investments, decarbonization is a strategic choice based on balancing environmental and economic factors. They recognize the need to reduce greenhouse gas emissions and introduce cleaner technologies in the production and use of LNG. In this case, decarbonization of LNG is considered as a strategy that provides a competitive advantage and meets the requirements of environmental responsibility.

However, in the context of global climate challenges and the pursuit of zero greenhouse gas emissions, decarbonization of LNG takes the form of an inherent necessity.

Decarbonization of LNG can be seen as a combination of strategic choice and necessity. Depending on the context and situation, different market participants may perceive LNG decarbonization differently, based on their interests and opportunities. But given the importance of achieving climate goals and the sustainability of the

energy system, the development of LNG decarbonization strategies must keep pace with the overall need for environmental sustainability.

Decarbonization of LNG is a significant challenge for producers and consumers. By weighing environmental requirements and economic factors, innovative approaches, technologies, and strategies need to be developed to ensure the transition to low-carbon LNG and achieve climate goals.

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A STUDY ON GREEN CONSUMPTION CHOICES AMONG DIFFERENT INCOME FAMILIES: A BEHAVIORAL ECONOMICS PERSPECTIVE

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Keywords: *green consumption choices, income families, behavioral economics, sustainable development, policy recommendations*

Nations worldwide are actively pursuing carbon neutrality, with a strong emphasis on promoting eco-friendly consumer behavior. Households play a pivotal role in achieving this goal through their adoption of green consumption practices. This study aims to investigate the behavioral disparities in green choices among families belonging to different income brackets. Employing quantitative methods, data was collected from diverse income groups and analyzed considering factors such as income levels, educational backgrounds, and environmental values. The findings underscore the significant influence of income on green preferences, revealing that higher-income households tend to prioritize high-value sustainable options while lower-income families place greater importance on affordability. Additionally, education and environmental awareness were found to exert notable impacts on individuals' decision-making processes regarding environmentally friendly alternatives. Several barriers were identified including information gaps, limited availability of green products, pricing concerns, and social influences affecting consumer choices. To address these challenges effectively, recommendations include diversifying the range of available sustainable products in the market along with enhancing educational initiatives and providing incentives for adopting greener lifestyles.

I. **Background**

With the exacerbating global environmental crisis, there is a growing recognition of the urgency to address climate change and protect the ecological environment. Currently, nations worldwide are vigorously pursuing carbon neutrality goals and acknowledging the necessity of fostering environmentally

conscious and sustainable consumer behavior. The Chinese government places great emphasis on ecological civilization construction, as highlighted in the 20th Party Congress report that advocates for green consumption and promotes green, low-carbon production and lifestyles. As environmental issues gain increasing prominence with strong governmental support, more domestic and international companies are incorporating green concepts into their products while actively researching and promoting green products. Despite widespread dissemination and recognition of the concept of green consumption due to growing emphasis on environmental consciousness, there still exists a significant gap between consumer attitudes towards purchasing green products and demand for such consumption that requires further stimulation. Therefore, from a behavioral economics perspective, analyzing household consumption behavior can facilitate better understanding of characteristics in the market for green consumption while providing guidance for relevant policy formulation.

II. Connotation of green consumption

Consumers with high environmental awareness are more willing to purchase green products and adopt green lifestyles. They play a crucial and active role in promoting the development of a green society. Green consumption, characterized by resource conservation and environmental protection, refers to consumer behaviors that minimize the negative impact on the environment during the purchase, use, or disposal of products. Green consumption possesses moral attributes and reflects consumers' sense of social responsibility.

III. The Significance of Behavioral Economics on Green Consumption

Behavioral economics combines theories of behavior analysis with the principles of economic operation and the field of psychology, aiming to rectify the shortcomings of mainstream economics regarding assumptions about human rationality and preferences. This study on household consumption behavior aims to empirically investigate the characteristics of consumer behavior by incorporating prospect theory and reference dependency theory from behavioral economics. Examining the behavioral differences in green consumption choices among

households with different income levels can enhance our understanding of the relationship between individual economic conditions and the willingness to engage in green consumption. Such understanding can facilitate the development of differentiated green consumption policies to better meet the needs of diverse income households and promote more widespread adoption of green consumption practices.

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NEW BILAYER MEMBRANE FOR FUEL CELLS, POLYMER SENSORS AND DIODES

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***Keywords*:** *bilayer MF-4SC/PTMSP composite membrane; asymmetry of current–voltage curve; membrane sensors and diodes; "fine porous membrane" model*

A novel bilayer cation-exchange membrane—consisting of a thick layer of a pristine perfluorinated membrane MF-4SC (Russian equivalent of Nafion®-117) and a thinner layer of the membrane on a base of glassy polymer of internal microporosity poly(1-trimethylsilyl-1-propyne) (PTMSP)—was synthesized and characterized. Using the physicochemical characteristics of one-layer membranes MF-4SC and PTMSP in 0.05 M HCl and NaCl solutions, the asymmetric current–voltage curves of the bilayer composite were described with good accuracy up to the overlimiting regime, based on the "fine-porous membrane" model [1]. The MF-4SC/PTMSP bilayer composite has a significant asymmetry of the current–voltage curves (CVC) that is promising for using it in electromembrane devices, such as membrane detectors, sensors, and diodes, as well as fuel cells.

The asymmetry of transport properties is an important attribute of bilayer membranes. When the direction of the driving force (pressure, concentration, or electric potential gradients) changes, the flux density of solvent, solute [2], and electric current [3–7] can change notably, so that an asymmetry of the current–voltage curves (CVC) is observed. It leads to a substantial difference in the limiting current density when the orientation of the membrane in the measuring cell changes. The asymmetry of the CVC was also detected at single pores of the track-etched membrane [8]. This feature can be promising for creating membrane diodes, when a bilayer membrane passes current well in one direction, and practically does not pass it in the contrary direction [9,10]. Membrane materials and processes are highly

environmentally friendly and contribute to the preservation of human and animal habitats.

The object of the present work is to establish and quantify the asymmetry of the current– voltage curve of a novel bilayer composite membrane, based on a thick layer (219 μm) of cation-exchange perfluorinated membrane MF-4SC and a thin (1 μm) non-conducting layer of a glassy polymer of internal microporosity poly(1-trimethylsilyl-1-propyne) (PTMSP), depending on the direction of the external electric field. Two reasons determined our choice of the PTMSP polymer—(i) its physicochemical properties are close to those of the MF-4SC polymer (porosity/free volume, hydrophobicity, degree of swelling, both polymers are stable in acid and ethyl alcohol) and (ii) PTMSP is practically non-charged. It was recently shown that the ζ-potential of the PTMSP membrane surface at the 0.5 g/L NaCl concentration in the ethanol. At the same time, we have theoretically shown that bilayer membranes with the highest difference in the modules of effective exchange capacities have the greatest asymmetry [2,3]. This means that one of the membrane layers must be neutral for reaching a maximum asymmetry.

According to the proposed model, the bilayer membrane under consideration should have an asymmetric current–voltage curve. As can be seen from Figure 1, the substantial asymmetry of the current–voltage curves is registered, depending on which side of the membrane faces the counterion flux, that means different values of the limiting current densities and all other characteristics of the CVC. Thus, one can see, with the orientation “w”, that is, by the MF-4SC layer faced the counterion flux, the value of the limiting current density is 2.5 and 2.8 times higher in the case of NaCl and HCl solutions, respectively. Therefore, the layered membrane composites with high asymmetry of current–voltage curves, such as MF-4SC/PTMSP, are important for potential applications, such as fuel cells, membrane sensors, detectors, and diodes [6,9,10]. We have recently received a Russian patent for the invention of such a membrane [11].

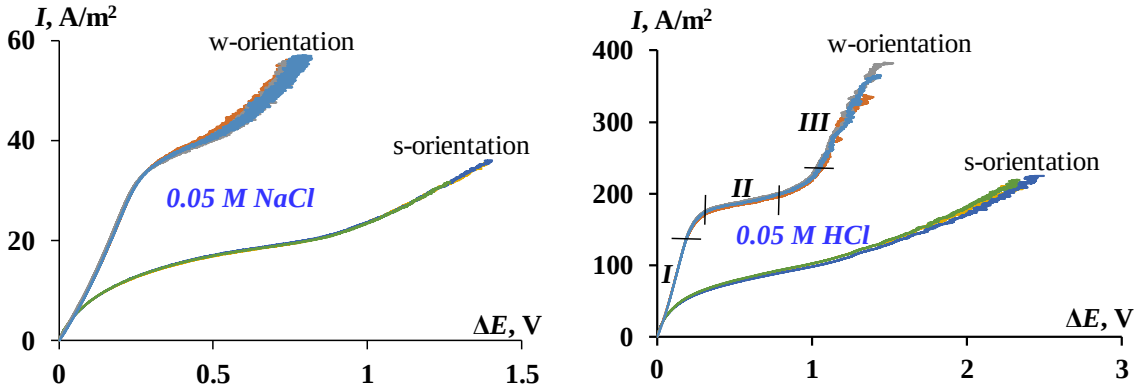

Figure 1 - CVCs of bilayer MF-4SC/PTMSP membrane in 0.05 M NaCl (at left) and HCl (at right) electrolyte solutions. s-orientation: thin PTMSP layer is oriented towards anode; w-orientation: thick MF-4SC layer is oriented towards anode; I-ohmic region; II-limiting current plateau region; III-overlimiting region (adopted from [1])

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REDUCTION OF GREENHOUSE GAS EMISSIONS AT GAS PIPELINE'S FACILITIES THROUGH THE USE OF RENEWABLE ENERGY SOURCES

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Keywords: *renewable energy sources, solar power plant, diesel power plant, gas pipeline's facilities, carbon dioxide emissions, low carbon technologies*

Purpose of the study. To analyse the environmental efficiency of using a renewable energy plant instead of a diesel power plant to supply power to the gas pipeline's facilities.

Materials and methods of the study. The following objects of the main gas pipeline are selected for the study: cathodic protection system, telemechanics system and equipment of crane units. The total power of the consuming objects is equal to 9.75 kW. The devices should function round the clock during the year. For power supply we propose an autonomous photovoltaic installation with energy storage and diesel power plant [1].

The autonomous photovoltaic installation includes photovoltaic panels with parallel connected inverter-controllers, as well as the necessary number of batteries for energy storage and operation of the installation in the dark. An emergency diesel generator is also provided, to be switched on during a failure of the main system, operating for several days until the failure is eliminated. Other than this, the use of an off-grid PV plant minimises greenhouse gas emissions from the site.

The diesel power plant consists of a main operating diesel generator and one standby generator. The fuel consumption of an installation with a capacity of about 10 kW at the diesel power plant is 67 litres per day, or 24.455 m^3/year, which corresponds to 20.297 t/year with a diesel fuel density of 830 kg/m^3 [1].

Based on the consumption of diesel fuel it is reasonable to calculate the annual amount of emissions from one diesel generator. Calculation of carbon dioxide emissions for diesel fuel is made according to the formula [2]:

$$E = M \cdot K_1 \cdot CNV \cdot K_2 \cdot \frac{44}{12}, \quad (1)$$

where

E – annual emission of carbon dioxide, t/year;

M – annual fuel consumption, t/year;

K_1 – fuel carbon oxidation factor, $K_1 = 0{,}99$;

CNV – calorific net value, $CNV = 43{,}02 \cdot 10^{-3}$TJ/t;

K_2 – carbon emission factor, $K_2 = 19{,}98$ t/TJ;

44/12 – carbon to carbon dioxide conversion factor (molar mass of CO_2 – 44 g/mol, molar mass of carbon – 12 g/mol).

Results of the study. Formula 1 is used to calculate carbon dioxide emissions for diesel fuel:

$$E = 20{,}297 \cdot 0{,}99 \cdot 43{,}02 \cdot 10^{-3} \cdot 19{,}98 \cdot \frac{44}{12} = 63{,}331 \text{ tonnes/year}.$$

Conclusions. Keeping in mind that there can be a large number of installations depending on the conditions of the trunk pipeline route, the use of renewable energy sources for power supply of facilities of the trunk pipeline compared to a diesel power plant is more favourable from the environmental point of view. The amount of carbon dioxide emissions calculated in this paper is comparable to the amount of greenhouse gas emissions from a passenger car with an internal combustion diesel engine travelling a distance of 250,000 km.

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QUANTIFICATION OF GREENHOUSE GAS EMISSIONS OF A CHEMICAL PROCESSING PLANT ACCORDING TO THE REQUIREMENTS OF GOST R ISO 14064-1-2021 (ISO 14064-1-2018)

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Keywords: *greenhouse gas emissions, quantification of greenhouse gas emissions, chemical engineering, direct and indirect greenhouse gas emissions, GOST R ISO 14064-1-2021 (ISO 14064-1-2018)*

Introduction

In 2021, the Russian Federation adopted the Federal Law "On limitation of greenhouse gas emissions" № 296-FZ dated 02.07.2021. [1]. Its goal is to create conditions for sustainable development of business activities with reduction of greenhouse gas (GHG) emissions. As of January 1, 2024, regulated organizations (with direct GHG emissions of more than 50,000 t CO2e) will be required to report their direct GHG emissions on a regular basis. Emissions are quantified according to the Methodology approved by the Ministry of Natural Resources of the Russian Federation (RF MNR) Order № 371 dated 27.05.2022 [2], and reporting is provided according to the form approved by the Russian Federation Government Decree № 707 dated 20.04.2022 [3]. The GOST R ISO 14064-1-2021 (ISO 14064-1-2018) standard [4] provides specifications and guidance for quantifying and reporting not only direct, but also indirect GHG emissions and removals at the organization level.

Quantitative assessment of greenhouse gas emissions and removals at FEFU Polytechnic Institute is implemented as part of expert, educational and project activities in Russian Engineering Center and in Department of Oil, Gas and Petrochemical Industry. The purpose of this paper is to quantify the direct and indirect greenhouse gas emissions (Scope 1 and 2) of a polymer chemical processing plant for 2022 in accordance with the requirements of GOST R ISO 14064-1-2021.

Research object and method

The object of the study is direct and indirect GHG emissions of polymer chemical-technological plant of III Category of negative impact on the environment with regional level of environmental supervision. The facility is in Vladivostok, commissioned in Q4 2021, and produces polymer products (plastic plates, pipe strips and profiles).

The complex consists of a technological site and auxiliary facilities: boiler house, logistic area, parking lot for passenger cars, area for garbage containers and production waste, as well as diesel fuel storage and local treatment facilities. The technological site consists of production areas for corrugated pipe, smooth rigid PVC pipe, as well as the production of metal trays by cold forming.

Two hot water boilers "Lavart R-700" with a capacity of 700 kW are used for heat supply of the building; two boilers operate in winter, in summer - one boiler at minimum load; diesel generator is considered as backup. The diesel generator is considered a backup heat source and was not used in 2022. The total natural gas consumption for the reporting year 2022 was 310 081.00 thousand m3 and the total electricity consumption was 504.124 MW.

The calculation of the carbon footprint in the paper was performed in accordance with the requirements of GOST R ISO 14064-1-2021 [4]. Quantification of direct GHG emissions is determined for natural gas burning in the boiler house in accordance with the Methodology approved by the RF MNR Order № 371 dated 27.05.2022. [2]. Indirect GHG emissions are determined according to the Methodology of the RF MNR Order № 330 dated 29.06.2017 "On Approval of Methodological Guidelines for Quantitative Determination of the Volume of Indirect Energy Emissions of Greenhouse Gases" [5] using Regional Method.

Results

In accordance with Paragraph 5 of the Methodology [2], flue pipes of the boiler house (Stationary combustion of gaseous, liquid, and solid fuels category) were attributed to the sources of direct GHG emissions. Based on the physical and chemical composition of natural gas, the CO2 emission factor (EFCO2,n.g.,2022) was calculated: 2.058 t CO2/thousand m3. The fuel oxidation factor, according to

paragraph 1.7 of the Methodology, was taken as 1.00. Thus, as a result of the consumption of 310,081.00 thousand m3 of natural gas, the direct GHG emissions of the boiler plant in 2022 amounted to 638.126 tons of CO2.

To calculate indirect emissions, the Regional Emission Factor for the second synchronous zone of RAO UES of Russia (443.266 kg CO2e/MW·h) was used [6]. The calculation showed that electricity consumption of 504.124 MW·h in 2022 resulted in indirect GHG emissions of 223,460.861 tons of CO2e.

Conclusion

The results of quantitative assessment of GHG emissions of polymer chemical-technological plant showed that direct greenhouse gas emissions (Scope 1) in 2022 amounted to 638.126 tons of CO2. Indirect GHG emissions from imported energy (Scope 2) exceed the direct by more than 350 times and amounted to 223 460.861 tons of CO2. The total greenhouse gas emissions of the facility under consideration amounted to 224 098.936 tons of CO2.

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TRENDS AND DYNAMICS OF TRANSFORMATIONS OF THE ENERGY COMPLEX OF THE ASIA-PACIFIC REGION UNDER THE CONDITIONS OF GREEN ECONOMY

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Keywords: *green economy, China, energy transition, renewable energy, sustainable development*

The global energy sector is undergoing major changes in the context of high geopolitical tensions and growing economic, environmental and technological challenges.

The transformation affects not only the global energy complex, but also the balance of power in the global political arena. The factors of military and economic power are gradually replacing in the international space by new structural factors of the world economy and politics, such as climate change, water and food shortages. In this context, the importance of strengthening partnerships with the growing Asian countries is only growing.

The Asian Development Bank forecasts the growth of the economies of developing countries in the Asia-Pacific region (APAC) by 4.8% in 2023-2024, which is significantly ahead of the growth of the economies of developed countries. The region is the center of global energy interests, demonstrating constant population growth, increasing demand for energy resources and high resistance to the negative consequences of the global economic crisis.

"APAC will play a critical role in the energy transition - it is the center of population growth in the world. APAC countries currently account for more than half of the world's energy consumption and about 40 percent of the world's total emissions. Many countries in the region have set themselves the goal of achieving zero emissions by the middle of this century. More and more countries are becoming leaders in the use of renewable energy in our region," Hongpeng Liu, Director of the

Energy Division of the United Nations Economic and Social Commission for Asia and the Pacific and an expert of the Global Energy Prize, told the Russian Energy Week [1].

Analyzing the prospects of energy transition in the region, its trends, innovative solutions and technical challenges is becoming an extremely urgent task both for energy exporting countries and for supporters of the global energy transition as a way to address global environmental challenges.

China's approach to the transition to green energy is fundamentally different from that of Western countries. For example, China imports a huge amount of gas. According to published data, in July China imported just over 12 billion m3 of gas through the gas transportation system. This is a new record for gas purchases.LNG purchases have also increased - in July 2023, deliveries rose by 33% to 8.2 billion m3 compared to the same month a year earlier. However, it is not "blue fuel" that is the basis of China's economy.

In 2022, coal, oil and natural gas accounted for 92% of total energy consumption in the PRC. In the structure of this indicator, coal accounted for more than 60%. Moreover, already in the first half of 2023, China has approved the construction of new coal-fired power plants with a capacity of 52 gigawatts (GW), which is more than all the permits issued in 2021.

These coal plant capacity expansion plans are in addition to the 136 GW of infrastructure already under construction.

The Chinese approach to the energy transition consists in a systematic and gradual increase in the share of renewable energy sources and in an annual increase in investments in "green" projects. For example, China annually implements and introduces new renewable energy projects into its grid, such as a wind turbine in the Taiwan Strait with an estimated capacity of up to 66 gigawatts per hour of electricity. The PRC is also expanding the share of nuclear power. By 2035, the share of nuclear power plants in China's energy balance will become twice as large, reaching 10%.Thus, by 2025, the installed capacity of nuclear reactors in China will exceed 70 million kWh.

In 2023, the capacity of renewable sources exceeded the capacity of coal-fired generation nationwide, indicating the promising development of the country's energy sector relative to the sustainable development strategy.

To summarize, China's current development model aims to achieve higher quality economic growth while reducing quantitative indicators. The main directions of this model include developing services and innovation, reducing social inequality and supporting environmental sustainability. The realization of environmental sustainability principles are closely linked to overall economic activity, industrial structure, development strategy and government policies on energy utilization. In China, the establishment of a green finance system has become a national strategy, reflecting the desire to reshape the financial system and support inclusive green development. China, unlike most Western countries, does not seek to abandon traditional energy resources abruptly in favor of renewable energy resources and to achieve carbon neutrality in the shortest possible time by all means, thus preventing the energy gap.

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APPLICATION OF EDDY COVARIANCE METHOD FOR CARBON FLUXES ESTIMATES ON A CONSTRAINED CROP FIELD

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Keywords*: eddy covariance, carbon flux, sequestration*

The measurement of carbon fluxes into ecosystems using the Eddy Covariance method is based on the fact that horizontal air movement in most cases consists of multi-scale eddies in the vertical plane, which allows by using simultaneous rapid measurements (10-20 times per second) of meteorological parameters and gas concentrations to assess the turbulent flux from the surface at the height of the equipment placement [1]. In the simplest case, this flow is estimated as a covariance of the fluctuations of the vertical air velocity and gas concentration. Of course, in order to obtain the necessary accuracy, many additional factors have to be taken into account, such as the concentration and vertical flux of water vapor, the thermodynamic state and the structure of the movement of the air layer between the surface and the measurement level of eddy covariances [2,3]. In addition, the projection area plays an important role, which depends on the wind speed and direction, the height of the equipment placement and the roughness parameter of the studied surface. It is ideal to place the equipment in such a way that, at any wind speed and direction, the projection area is located within the ecosystem under study, however, for a number of reasons this is not always possible. This paper describes a technology for estimating the carbon storage created in 54 days of growing technical cannabis in a 2-hectare field surrounded by arable land and vegetation with low carbon fluxes. The obtained eddy covariance estimate of 2.08 tons per hectare of pure carbon is in good agreement with the direct estimate of the carbon content in

the collected biomass at 2.09 t/ha. The details and uncertainties of the methods are discussed.

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SELECTIVE OXIDATION OF METHANE INTO OXYGENATES

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Keywords: *methane conversion, selective oxidation, oxygenates, green chemistry*

Photocatalytic oxidation of methane to produce oxygenates is one of the important ways of high-value utilization of methane. The difficulty in designing the active site of catalyst's structure restricts the efficient and controllable activation of O_2/H_2O_2 and the methane's C-H bond. The applicant has made the following significant progress in addressing this challenge: ① It was the first to construct an organic site to activate O_2 and methane efficiently. The mechanism of in-situ photoinduced formation of stable free radicals was elucidated for deep activation of O_2 and methane's C-H bonds. ② Dual carbon/nitrogen coordination sites were constructed to synergistically activate H_2O_2 and CH_4. It revealed the effect of electron spin state and electron density on the activation of H_2O_2. Methane was efficiently oxidized into formic acid. ③ Cu/Zn bimetallic sites were preferred to solve the problem that residual H_2O_2 is difficult to decompose and explosive under acidic conditions after methane is oxidized to formic acid.

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NIMBY RISK IN THE CONSTRUCTION OF LARGE-SCALE SOLAR: A LITERATURE REVIEW

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Keywords: *solar energy, nimby risk, public attitudes*

Reducing dependence on fossil fuels has never been more urgent. Comprehensively promoting the diversified utilization of solar energy is one of the important ways to develop renewable energy. However, there is a "NIMBY risk" that is difficult to ignore in the location of large-scale solar energy facilities. This abstract briefly reviews the relevant research in the fields of public attitudes, the construction of large-scale solar energy facilities, and NIMBY risk avoidance.

With the rapid development of human society, the rapid development of energy demand, and the increasingly serious environmental pollution and climate problems, reducing dependence on fossil fuels has never been more urgent. For the first time since the publication of the IPCC's Fifth Assessment Report (AR5) in 2014, the framework for the issue of "the end of the fossil fuel era" has been clarified. The white paper "China's Energy Development in the New Era" also shows that the development and utilization of non-fossil energy is the main way to promote the green and low-carbon transformation of energy. China has given priority to non-fossil energy in energy development, comprehensively promote the diversified use of solar energy. However, there is a "NIMBY risk" that is difficult to ignore in the location of large-scale solar energy facilities.

This abstract mainly uses the literature analysis method to read a large number of literature in the core database, and briefly reviews the construction of large-scale solar energy facilities, nimby risk avoidance, public attitudes and other fields.

The theoretical exploration of the conflict in the location of nimby facilities starts from public attitudes, and any improvement plan cannot avoid the basic

question of "what is the fundamental reason for the public's opposition to the location of nimby", so the study of public attitudes has always been at the core of the literature on the location of nimby. What factors shape the public's attitude towards risk? This issue has attracted scholars in many fields of research to gather under the umbrella of "risk perception" to publish a large number of research results.

The existing literature focuses on repositories of radioactive material, toxic and hazardous industrial projects, solid waste treatment facilities and other neighbor avoidance facilities. Early studies focused on practices in developed countries such as the United States, Europe, and Japan. Recent research has been extended to developing countries.

A 1990 study on risk perception was conducted by Kunreuther et al., one of the early large-scale empirical studies of public attitudes. In this paper, they used two different models to study public attitudes, the "cost-benefit model" and the "risk-perception model." The construction of these two models is based on theoretical analysis in economics and psychology. Frey and Oberholzer-Gee (1996) conducted a study investigating public attitudes towards nuclear waste siting. According to their research, public acceptance depends mainly on economic factors. Specifically, residents in the vicinity take into account the expected economic benefits. In the field of sociology, Kunreutheretal. (1993) conducted an empirical study to evaluate the practical effects of the whole set of "facility siting rules". Author investigated a total of 29 waste treatment facility site locations in the United States and Canada. Findings suggest that there are three key factors that influence site selection outcomes: social trust, sound design, and public participation. In the field of political science, one of the difficulties in siting a nimby facility is the widespread perception that the decision-making process is unfair.

Sandra George O'Neil (2021) explores the resistance of residents in one suburban, New England town, to a large-scale (2 MW), ground-mounted solar project in a residential neighborhood. This research indicates that environmental advocates and policymakers need to more fully incorporate both the meanings of, and connections to places, residents of a community hold.this case further highlights

the complexity of NIMBY thinking in renewable projects. Larson, EC, and Krannich, RS (2016) examined Utah residents' attitudes toward wind and solar energy, as well as differences in willingness to build utility-scale wind or solar facilities near where they live, through a Utah-wide survey of data. The possible implications of these findings are also presented. Research by Carlisle, Juliet E. (2016) and others synthesizes disparate factors such as distance, place attachment, socio-demographic characteristics, and project-related characteristics to research the visual impact of large-scale solar installations, and the impact of the distance between different types of land and the proposed solar facility on public support. Carlisle, Juliet E. (2015) and others examined public attitudes toward the construction of utility-scale solar facilities in the United States and the development of solar facilities in their counties, using data collected from a national sample of the United States and an excess sample of the southwestern United States. The findings are also meaningful for respondents outside the United States.

In summary, the theoretical exploration of the conflict in the location of nimby facilities in the academic community started from the public attitude, and the existing literature mainly focuses on the research of nimby facilities such as radioactive material repositories, toxic and harmful industrial projects, and solid waste treatment facilities. The research on the nimby risk of solar energy construction is mainly about exploring the causes of the formation of risks. As for reasonable solutions, there is still a broad scope for research.

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ENVIRONMENTAL PROTECTION INTERVIEW, GOVERNMENT-ENTERPRISE COLLUSION AND ANTI-STICKINESS OF ENTERPRISE ENVIRONMENTAL PROTECTION EXPENSES

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Keywords: *anti-stickiness of environmental protection expenses; environmental protection interview; Government-enterprise collusion*

Based on the panel data of A-share listed companies in China from 2010 to 2021 and using the ABJ model and Propensity Score Matching-Differences in Differences (PSM-DID) method, this paper finds that the anti-stickiness characteristic of " easy to fall and difficult to rise" are common in China's enterprises' environmental protection expenses, and the Environmental Protection Interview (EPI) policy can significantly decrease the anti-stickiness of environmental protection expenses. Further research shows that, the higher the likelihood of collusion between government and enterprises, the weaker the above effect of EPI on the anti-stickiness of enterprises' environmental protection expenses become.

Enterprises often significantly reduce their environmental inputs during periods of poor revenue for economic reasons. However, when enterprises' revenue increases, enterprises' environmental protection expenses do not increase with the same amplitude, leading to asymmetric environmental cost behavior of enterprises. To regulate corporate environmental protection behavior, the central government has introduced an environmental enforcement and monitoring mechanism represented by the environmental protection interview (EPI) policy to guide enterprises to increase their environmental protection expenses. From the perspective of anti-stickiness of enterprises' environmental protection expenses, this paper discusses the governance effect of EPI on the anti-stickiness of corporate environmental protection expenses, and the heterogeneity of this effect under the

collusion between government and enterprises. This is not only a supplement and enrichment to the existing research literature about EPI's implementation effect, government-enterprise collusion, and environmental protection investment, but also provides implications to break the chain of government-enterprise collusion so as to fairly transmit the pressure of environmental law enforcement and supervision to each regulated firms.

Based on the data of A-share listed companies from 2010 to 2021, the paper constructs the following basic model *(1)* by referring to the classical method of Anderson et al. (2003) to test hypothesis 1 that China's enterprises' environmental protection expenses have the anti-stickiness characteristic. The results are shown in the Panel A of Table 1. Then, based on the idea of sample pairing and double difference method, the EPI variable $Did_{i,t}$ is further introduced into the model *(1)* to test hypothesis 2 that EPI can decrease the anti-stickiness of enterprises' environmental protection expenses. The results are shown in the Panel B of Table 1.

$$\triangle LnEPE_{i,t} = \alpha_0 + \alpha_1 \times \triangle LnSale_{i,t} + \alpha_2 \times Dec_{i,t} \times \triangle LnSale_{i,t} + Controls + \sigma_{i,t} + \varepsilon_{i,t} (1)$$

Then, this study uses multiple data such as local government characteristics based on local officials tenure (in the Panel C of Table 1) and government quality (in the Panel D of Table 1), enterprise political characteristics based on property rights (in the Panel D of Table 1) and political connection (in the Panel F of Table 1) and local institutional environment (in the Panel G of Table 1) to measure the possibility of government-enterprise collusion, and further examines the mediating effect of government-enterprise collusion in the abovementioned governance effect of EPI. After adding control variables and conducting a series of robustness tests, the empirical results are basically consistent.

Table 1 - Multiple regression results

$\triangle$LnEPE$_{i,t}$						
Variables	Panel A	Panel B	Panel C		Panel D	
	Hypothesis 1	Hypothesis 2	Term of local officials		Government quality	
			(1)Short	(2)Long	(3)High	(4)Low

Continuation of the table 1 - Multiple regression results

$Dec_{i,t} \times \Delta LnSales_{i,t}$	0.470*** (2.62)	0.553*** (3.02)	2.397 (0.55)	2.132** (2.23)	1.612 (0.48)	2.191* (1.70)
$Did_{i,t} \times Dec_{i,t} \times \Delta LnSales_{i,t}$		-0.758*** (-2.89)	-2.042*** (-3.62)	-1.278 (-0.90)	-2.891*** (-3.74)	-0.657 (-1.40)
N	2 188	2 188	1285	903	1282	906
Variables	Panel E		Panel F		Panel G	
	State-owned attribute		Political connection		Marketization level	
	(5)Yes	(6)No	(7)Yes	(8)No	(9)High	(10)Low
$Did_{i,t} \times Dec_{i,t} \times \Delta LnSales_{i,t}$	-1.536 (-1.37)	-1.643*** (-2.91)	-0.103 (-0.05)	-1.203* (-1.90)	-1.377** (-2.28)	-1.913 (-0.47)
N	1067	1121	949	1239	1289	899

Note: * * *, * * and * respectively represent the significance levels of 1%, 5% and 10% and regression results for control variables are not shown.

Based on the above theoretical analysis and empirical test, the following conclusions are drawn. The anti-stickiness characteristic of " easy to fall but difficult to rise " are common in China's enterprises ' environmental protection expenses. As a new vertical management mode of environmental protection by the central government, EPI can significantly reduce the anti-stickiness of enterprises' environmental protection expenses. The greater the possibility of collusion between government and enterprises, the weaker the governance effect of EPI on the anti-stickiness of corporate environmental protection expenses. Long tenure and low government quality will affect the governance effect of EPI. State-owned enterprises and political affiliated enterprises are more likely to collude with local governments, thus alienating the implementation effect of EPI. The lower the level of marketization, the greater the possibility of government-enterprise collusion, and the worse the governance effect of EPI.

This paper reveals the governance effect of EPI on the anti-stickiness characteristic of enterprises' environmental protection expenses in Chinese listed

companies. In the future, the influencing factors of corporate managers and controlling shareholders can be further discussed.

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AI IN SMART GRID SYSTEMS AS AN IMPROVEMENT OF THE ENVIRONMENTAL IMPACT OF THE ENERGY INDUSTRY

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Keywords: *smart grid, AI, blockchain, energy, alternative energy*

Today, energy is one of the most capital-intensive industries, with the highest costs associated with maintaining the technical condition of equipment and ensuring reliable power supply to consumers.

The concept of the "Internet of Energy" is becoming a fundamentally new paradigm of generation, transmission and distribution of electricity.

The "Internet of Energy" is a concept that involves the creation of a local energy infrastructure (micro—energy system or microgrid), into which energy producers and consumers integrate and within which they can freely exchange energy [2]. The concept is based on a completely different architecture, which, unlike the traditional one, is a decentralized electric power system. It implements intelligent control of electricity flows, carried out through peer-to-peer energy transactions between its users. From what follows, the system is a technological integrator called Smart Grid. This is where artificial intelligence plays a key role. Intelligent systems and algorithms can significantly improve the efficiency of the usage of electric generating systems in various fields, as well as ensure the reliability and safety of its application [1].

The relevance of this study lies in the fact that currently the environmental agenda is increasingly influencing business development, as well as the environmental state of the world around us.

Thus, the usage of artificial intelligence is in order to optimize electricity consumption by both traditional and alternative energy sources. In the future, this may reduce the cost of both electricity production with the advent of new

manufacturers, as well as reduce the cost of manufacturing components for renewable energy sources.

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ENHANCING CITY ENVIRONMENTAL STRATEGIES THROUGH EFFICIENT WASTE MANAGEMENT

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Keywords: *resource optimization, waste management, life cycle assessment, city sustainability, power systems integration*

Importance: Resource utilization is key, enabling the recovery of energy, metals, and organic matter through recycling. This conserves raw materials and eases the strain on energy sources. Waste management plays a pivotal role in mitigating climate change, reducing greenhouse gas emissions through practices like recycling and energy recovery.

Well-handled waste directly impacts public health, making cities not just cleaner but safer. Economically, smart waste management creates jobs, fosters resource recovery, and minimizes costs linked to waste disposal. It's about sustainability, fiscal responsibility, and growth.

Compliance with waste management regulations is an ethical responsibility, crucial for sustainable and ethical city and industry operations. Tools like EASETECH in research underscore a commitment to enhancing waste management strategies, balancing environmental impact, economic viability, and societal harmony. Optimizing waste management isn't just about trash; it's about shaping a future where cities thrive sustainably, fostering resilience for generations to come.

Objectives: The task of my work was to design two waste management systems on example of Irkutsk city, decide which system is preferable and compare the negative impacts in 4 main categories: climate change, eutrophication, acidification and photochemical ozone formation. In order to complete this task, I used EASETECH [1]. For reference, it is a software the primary aim of which is to perform life cycle assessment (LCA) of complex systems handling heterogeneous material flows. EASETECH models resource use and recovery as well as

environmental emissions associated with environmental management in a life-cycle context.

Research methods: The initial Scenario 1 depicted the prevalent waste management practice in Irkutsk, where all waste was indiscriminately transported to an existing landfill merely 14 km from the city. This approach relied on refuse trucks with a 10-tonne capacity, consuming 3.27 liters of diesel fuel per ton of waste. However, this landfill lacked adequate facilities for gas and leachate collection during waste disposal, leading to uncontrolled gas emissions and leachate production.

Scenario 2 portrayed a more nuanced and segmented waste management strategy. The city authorities had established separate collection methods for various waste streams: paper, plastic, glass, and organic waste. Each stream underwent specific treatment processes, including recycling, biogas production, and responsible landfill disposal. Paper and plastic waste, collected separately with varying efficiencies, underwent recycling processes, significantly reducing the burden on landfills. Glass waste, collected with an 80% efficiency rate, awaited suggestions for local recycling initiatives, promoting a closed-loop system. Organic waste, collected with a 50% efficiency, contributed to biogas production, promoting renewable energy utilization. The residual waste, the inevitable outcome of all these processes, was transported to a new landfill equipped with gas and leachate collection systems. This ensured that gas emissions and leachate production were controlled and effectively managed, thereby mitigating environmental risks associated with traditional landfill practices.

The total amount of solid municipal waste in Irkutsk was taken approximately from different sources 624459.25 tonnes [2]. The fractional composition of waste was taken in accordance with the data provided in the book “Soft computing techniques in solid waste and wastewater management” by Rama Rao Karri, Gobinath Ravindran and Mohammad Hadi Dehghani [3].

Through the meticulous comparison of these scenarios, the research scrutinized and quantified the environmental impact, resource utilization, and

overall efficiency of these divergent waste management strategies. The findings derived from EASETECH's analyses provided tangible insights into the comparative advantages and shortcomings of each approach, illuminating pathways for more sustainable and efficient waste management practices within urban environments.

The results of the research: I got accurate numerical data on which substances pollute the atmosphere the most, in addition, which processes in my waste disposal system are eco-friendly and which are not, based on these data, I concluded that second scenario is preferable because it can reduce harmful emissions to the environment at all levels and reduce bad impact on human's health. The exceptions are eutrophication (terrestrial) and acidification. It happens due to the work of collection trucks, so if we will find different trucks with better catalysts in the exhaust system or less fuel-consumption, we can reduce the negative impact on these two categories.

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RESEARCH ON REGIONAL CARBON EMISSION REDUCTION AND PATH PLANNING UNDER SUSTAINABLE DEVELOPMENT

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Keywords: *dual carbon goals, relevant models, predictive models, pathway planning*

A mathematical model for predicting the impact of carbon emission is proposed to provide theoretical support for carbon emission reduction. Comprehensively analyze regional carbon emissions and their related economic, population and energy consumption, build correlation models and prediction models, and through scenario design, build carbon emissions accounting methods under multiple scenarios and determine the goals and paths of double carbon.

Introduction: To understand the relationship between regional carbon emission and economy, population and energy consumption, so as to better predict the future carbon emission trend and provide scientific basis for formulating carbon emission reduction strategies.

Relevance: The positive correlation between total population and economy and the negative correlation between total population and energy consumption structure are of great significance for the formulation of carbon reduction strategies and sustainable development goals. These relationships can help policymakers better understand the interactions between variables to develop more effective environmental policies and sustainable development strategies.

Methods and methodologies used, equipment, technologies: Spearman, ARIMA time series model, multiple linear regression model, scenario design, path planning.

Conclusion: Combining mathematical model prediction, multi-dimensional assessment and scenario design, this study provides solid theoretical support for China's carbon emission reduction work. The prediction models of carbon

emissions, economy, population and energy consumption were established through time series and multiple linear regression models, providing a scientific basis for the determination of carbon emissions peak in 2030 and carbon neutrality in 2060. Overall, the study provides a profound strategic plan for balancing economic growth and environmental challenges to achieve sustainable development, and provides a practical and feasible path for China to play an active role in the global response to climate change.

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ENERGY RIGHTS TRADING SYSTEM IN THE PROCESS OF CHINESE FACTOR MARKETIZATION:HISTORICAL EVOLUTION,ACADEMIC DEBATES,FUTURE PROSPECTS

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Keywords: *market-based allocation of factors of production, energy quota trading system, cap and trade, tradable white certificate*

The energy quota trading system is gaining prominence in national energy governance and legal research. This study utilizes a literature analysis method, comprehensively reviewing legislative documents and pertinent literature on China's energy quota trading system and its precursor, the energy-saving quota trading system. Aligning with the market-oriented reform in the resource and environmental sector, the study aims to offer insights into the future development of the energy quota trading system. Anticipated outcomes include enriching the theoretical understanding of the system and contributing to the realization of the "carbon peaking and carbon neutrality" strategic objective.

1.In the late twentieth century, China grappled with challenges such as limited energy consumption space, regional disparities, and the absence of a supervisory mechanism for enterprise energy consumption. While maintaining some command and control methods, the country actively investigated economic incentive approaches grounded in market regulatory mechanisms. The energy quota trading system, emblematic of current economic incentive governance, has shown commendable results in pilot practices. Nonetheless, it confronts challenges, including conceptual inconsistencies, unclear property rights attributes, and insufficient institutional systematization.

2.This study utilizes a literature analysis method, comprehensively reviewing and evaluating legislative documents and relevant literature concerning China's energy quota trading system and its precursor, the energy-saving quota trading

system. It summarizes theoretical debates on China's legal system regarding energy quotas, grounded in the practical requirements of market-oriented reform in resource and environmental elements. Drawing on the "rationalization of law" theory, the study outlines future prospects for the energy quota trading system.

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THE DRIVER OF POLLUTION CONTROL IN CHINA'S SUPPLY CHAIN: CUSTOMER RELATIONSHIP AND SUPPLIERS' ENVIRONMENTAL PROTECTION INVESTMENT

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Keywords: *customer relationship, environmental protection investment, informal institution*

In this paper, the dataset of Shanghai and Shenzhen A-share non-financial listed companies in China from 2010 to 2021 is analyzed using a multiple regression analysis. We find that customer relationship can improve the propensity of suppliers to invest in environmental protection, thereby assisting their customers to manage pollution across the supply chain. Further research find that customer relationship can mitigate suppliers' financial constraint, and the environmental protection investment driven by customer relationship can increase suppliers' value.

Investing in environmental protection is critical to ensuring long-term economic sustainability. Beside, the inherent incompleteness of formal institutions necessitates the supplementation with informal institutions. Due to the process of supply chain integration, customer relationship stands as an important informal institution in business research. However, there are few studies have examined whether the informal institution of customer relationship can motivate suppliers to invest in environmental protection in the supply chain. So, based on stakeholder theory, we find that the customer relationship can improve the propensity of suppliers to invest in environmental protection, thereby assisting their customers to manage pollution across the supply chain.

It is precisely because of China's unique institutional background that we use the dataset of Shanghai and Shenzhen A-share non-financial listed companies in China

from 2010 to 2021 to analyze. We construct a basic model[1] *(1)* by referring to the classical method of Zhang et al. (2019), Liu et al. (2022).

$$Epi_{i,t}=\alpha_0+\alpha_1 CRT_{i,t-1}+\alpha_2-\alpha_{11} Controls_{it-1}+\sum Year+\sum Ind \quad (1)$$

The empirical results are shown in Table 1, the findings are as follows: (1) Customer relationship has a positive effect on suppliers' environmental protection investment. (2) Unstable customer relationship can increase environmental protection investment of suppliers. (3) Customer relationship can mitigate suppliers' financial constraint. (4) Compared with SOEs, customer relationship enhances environmental investment in non-SOEs. (5) Customer relationship enhances environmental investment in highly-polluting companies. (6) Environmental protection investment driven by customer relationship can improve the corporate value of suppliers. The findings hold even when considering the endogeneity problem and sample subselection problem, altering proxies of customer relationship and the testing sample, and excluding alternative explanations.

Table 1 - Summary of regression results

	$Epi_{i,t}$				
Variables	Panel A	Panel B		Panel C	
	Customer relationship	Stability		Financial constraint	
		(1)Stable	(2)Unstable	(3)High KZ	(4)Low KZ
CRT_{it-1}	0.013*** (4.09)	0.008 (1.58)	0.014*** (2.68)	0.018*** (4.02)	0.006 (1.38)
N	7,449	2811	2782	3603	3235
	$Epi_{i,t}$				TobinQit
Variables	Panel D		Panel E		Panel F
	Property rights		Levels of pollution		Economic consequences

[1] Dependent variable: Environmental Protection Investment / Operating Revenue ($Epi_{i,t}$). Independent variable : Sales to top 5 customers(CRT_{it-1}). In the model the subscript "i " represents the firm, the subscript "t " represents the year and α1 represents our estimated effect of customer relationship.

Continuation of the table 1 - Summary of regression results

	(5)SOEs	(6)SOEs	(7)high	(8)low	(9)
CRT_{it-1}	0.003 (0.69)	0.018*** (4.28)	0.006 (1.35)	0.015*** (3.84)	0.198*** (2.60)
EPIit-1×CRTit-1					4.864* (1.85)
N	2908	4541	2984	4384	5,453

Note: * * *, * * and * respectively represent the significance levels of 1%, 5% and 10%.

Overall, our research contributes to the study of how informal institutions influence environmental investment and provides important insights for fostering green supply chain development.

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REDUCTION OF GREENHOUSE GAS EMISSIONS AT GAS PIPELINE'S FACILITIES THROUGH THE USE OF RENEWABLE ENERGY SOURCES

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Keywords: *renewable energy, heat pumps, solar collector, cooling PV panels*

Purpose of the study

Renewable heating capacities cover around 2 GW or 2% of total Russian heat capacities. Analysis of existing projects in Russia helps to evaluate efficiency of low-carbon heating and finds efficient typical solutions for district and individual heating for Russia.

Materials and methods of the study

The study carries out an analysis of biofuel-based heat supply projects in regions of Russia. It includes wood waste projects, biogas projects at water treatment plants, and municipal landfills. Due to the combined solution of two problems (waste processing/disposal and energy production), most projects are competitive with traditional energy resources (natural gas, electricity).

For example, Mosvodokanal (Moscow municipal water facilities company), by using anaerobic digestion of activated sludge on its wastewater treatment plants, not only increase in several times a speed of activated sludge treatment (this decreases territories for filter fields in city area) but also produce for own needs 25 % of total electricity and 50% of heat. Biofuel (wasted wood) usage instead of electricity on boiler-houses in Krasnoyarsk region decreases the cost of heat and reduces carbon footprint. The study cavers UK's and North European district heating heat pumps projects. These projects use sea water as a source of primary energy. Study also analyzes Murmansk’s 800 kW district heat pump project that use nearby lake's heat. The results obtained during the study are used when designing heat supply systems for Arctic regions’ projects.

The usage of solar collectors in combination with traditional diesel boiler houses in Arctic regions of Russia has a significant positive effect (particularly in summertime), helps to save tons of diesel fuel, decreases the cost of heat/hot water production, and decreases CO2 emissions. The study investigates existing solar collectors' projects in regions of Russia. Projects' analysis show that in Artic region in summertime, solar collectors allow to preserve diesel heat generation and provide heat and hot water supply from solar energy. That helps to save expensive external diesel and reduce CO2 emissions.

Based on cooled solar panels produced by Russian company New Polyus, a solar cogeneration unit was designed and tested. The unit consists of 1 cooling PV panel with heat load of 0,45 kW and power load of 1,2 kW. This unit successfully provided a 1 kW heat load with the required characteristics (water, 60 °C). On 2024, to continue our further research, we plan to assemble a new six PV panels unit.

Results of the study

Study shows that, for territories not connected to natural gas network, renewable heating using biomass, heat pumps, solar collectors is reasonable both in economic and ecological points of view. Heat pumps can be used even in Arctic regions of Russia, but in polar conditions they need sea or ice-free reservoir as a source of primarily heat. Cooling PV panels can produce twice more heat than power. In case of existence of a heat consumer, the total (heat and power) efficiency of cooling PV panel can exceed 60%.

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IMPROVING THE ENVIRONMENTAL SAFETY OF THE ATMOSPHERIC AIR AS A RESULT OF THE OPERATION OF THE GAS TRANSPORTATION ENTERPRISE

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Keywords: *environmental safety, atmospheric air, gas transportation enterprise, emissions purification, modern technologies*

Modern society is faced with the problem of atmospheric air pollution caused by various industrial processes. Gas transportation companies play a significant role in this process, as they are responsible for the transportation and distribution of natural gas. When transporting gas, the most constant sources of atmospheric pollution are compressor stations, gas distribution stations and linear parts of gas pipelines. They are sources of emissions into the air of large amounts of nitrogen oxide and dioxide, carbon monoxide. Reducing their content in the air is the main task in the gas transportation industry. A powerful fleet of GTE (gas transportation enterprise) and other installations participat in the overall contribution to air pollution and to changes in natural conditions.

One of the main ways to improve the environmental safety of gas transportation enterprises is the use of modern methods of cleaning emissions.

The main actions aimed at reducing emissions and losses of natural gas during combustion include:

- The use of mobile compressor units for purging of main facilities;
- Since natural gas is mainly released into the atmosphere as a result of depressurization of gas pipelines, destruction of its structure, it is necessary to use various sealing lubricants and pastes, and it is also necessary to conduct environmental monitoring of the condition of gas pipelines more often;
- Implementation of a purge system for devices and reduction of salvo emissions;

- Replacement of sewage treatment plants and installation of new filters on dust collectors.

Actions to reduce emissions into the atmosphere during the operation of facilities:

- Implementation of a waste-free device purging scheme;
- Reduction (elimination) of salvo emissions;
- Reduction of combustion product emissions;
- Installation of modern filters on dust collectors;
- The use of catalytic gas purification methods;
- Transfer of the GTE to an air launch.

One of the methods of reducing gas losses is also the utilization of secondary energy resources, which are used to supply heat to the gas transport facilities themselves and external consumers: residential settlements and greenhouse and vegetable plants. The heat of the exhaust gases of the GTE can be used to heat water or generate steam, and the exhaust gases of gas turbine plants can be used for carbon dioxide fertilization of plants, which significantly increases their productivity. In this case, the pollutants content is reduced by the method of catalytic reduction with reducing gases.

Improving the environmental safety of atmospheric air as a result of the operation of a gas transportation enterprise is possible through the use of modern emission purification technologies, air quality control and information work. The development of environmentally friendly methods of natural gas production and transportation is becoming increasingly relevant and necessary to preserve the health of the environment and ensure the well-being of future generations.

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LEGAL ASPECTS OF RUSSIAN FEDERATION CLIMATE AGENDA AND CLIMATE SUMMIT COP 28 OUTCOME

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Keywords: *international energy law, carbon units, private international law, climate change, sustainable development, climate agenda, green energetics*

The study is devoted to a legal analyses of modern national and global climate agenda regulation through comparative legal and system-logical research methods, that are used by the author in the research. The author identifies current strategic legal documents on climate policy of the Russian Federation, as well as modern international agreements and documents that are addressed the Paris Climate Agreement (2015) and determined the current prospects of legal regulation the climate agenda. The author concludes that the global nature of climate change and modern socio-economic consequences require full-fledged international cooperation the Russian Federation with other world countries on the principles of technological neutrality and balanced actions to ensure sustainable development.

In particular, a new Climate Doctrine of the Russian Federation in addressing climate change has formulated a unified state climate policy based on fundamental and applied scientific knowledge, focused on the long term, on issues related to climate change and its consequences. However, the Doctrine contains a number of new fundamental provisions, including: recognition of anthropogenic causes of climate change, setting quantitative goals for reducing greenhouse gas emissions and fixing the goal of achieving carbon neutrality (balance between anthropogenic greenhouse gas emissions and their absorption) by 20260, as well as the introduction of the concept of technological neutrality, which implies an impartial approach to the use of technologies that contribute to mitigation anthropogenic impact on the climate, based on the assessment of their economic, climate and environmental efficiency and expediency. In addition, the Doctrine develops provisions concerning

economic mechanism for reducing greenhouse gases emission, climate risks and declares the climate agenda development on a scientific base of climate sciences. The Russian Federation concerns related to climate change are not limited national territory and considered to be global. This is due to comprehensive climate change taking into account the diversity of climate impacts and the consequences of climate change in different regions of the world.

Climate change poses some threats to the Russian Federation national security, which should be responded to by means of providing the desired environmental and economic long term effects. There is a need to take into account the economic risks associated with the introduction by other States of measures to combat climate change affecting the interests of the Russian Federation, and reputational risks arising from the failure to take sufficient measures to combat climate change. Sovereignty in assessments and conclusions based on complete and reliable information about the ongoing and expected consequences of climate change for the Russian Federation and other states, the ability to meet their own technological needs to respond to threats related to climate change, as well as timely planning of measures to adapt to climate change at the sectoral and regional levels are of great importance (adaptation measures).

In September 2023 the United Nations published The Global Stocktake report, which represents the first comprehensive assessment of nearly 200 countries' efforts to tackle climate change since the adoption of the Paris Climate Agreement in 2015. The UN report underscores the need for nations to significantly enhance their clean energy ambitions and outlines that the world is rapidly approaching a critical juncture in the fight against climate change, and immediate action is imperative to achieve the Paris Agreement's objectives. The United Nations has reaffirmed that it is imperative for all stakeholders, including governments, non-party stakeholders, and the private sector, to significantly ramp up their climate efforts. The report outlines the necessity for stronger international cooperation, particularly in the areas of technology transfer, finance mobilization, and capacity-building.

The Paris Agreement (2015) set a target of keeping the global temperature increase to well below 2°C above pre-industrial levels, with the aim of achieving 1.5°C or less. On December, 19, 2023 the United Nations Climate Conference of Parties (COP28) to the United Nations Framework Convention on Climate Change (UNFCCC) marked the First Global Stocktake, at which the UNFCCC assessed its collective efforts and achievements in reducing greenhouse gas (GHG) emissions and adapting to the impacts of climate change. The First Global Stocktake agreement covers several thematic areas, including mitigation of greenhouse gas emissions, adaptation and resilience in the face of climate change, financing and means of implementation and support for climate projects, and loss and damage funding for climate-vulnerable nations. The agreement reinforced the 1.5°C goal and called for global efforts to transition away from fossil fuels (oil, coal and gas) in energy systems, accelerating action, so as to achieve net zero by 2050 in keeping with the science. This agreement is not legally-binding and seeks to support the transition by accelerating the adoption of technologies that have low or no GHG emissions, including emerging technological solutions such as carbon capture, which could help address emissions from sectors for which it will take longer to reduce fossil fuel reliance.

As described in the UN report, human-caused climate change impacts are being felt worldwide. The outcomes of COP28 demonstrate the importance keeping alive the Paris Agreement's goal of limiting temperature increase to 1.5 °C above preindustrial levels, that will require increased and sustained commitment and engagement from the public sector, the private sector, and civil society.

ASSESSMENT OF GEOECOLOGICAL RISKS ALONG THE RIGHT OF WAY OF THE TRANS-SAKHALIN PIPELINE SYSTEM (ON THE EXAMPLE OF THE MAKAROVSKY DISTRICT)

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Keywords: *geoecological safety, Trans-Sakhalin pipeline system, geohazards, emergency spills, database*

Sakhalin Island is a promising region for oil and gas production, which can become the most important point for providing the Far East. The Sakhalin Energy LLC (operator of the Sakhalin-2 project) was established here in 1994 and a production sharing agreement was signed, in 1999 the first oil production began, and after that gas. The Trans-Sakhalin pipeline system (TPS) was commissioned in 2005 and the first batch of Russian LNG was shipped in 2009.

The TPS has a length of 807 km and connects production platforms, the Onshore processing facility (OPF) and the Prigorodnoye production complex, where gas liquefaction and oil shipment take place.

Ensuring the safety of Sakhalin pipelines is an important task, since this facility is located in difficult engineering and geological conditions. The pipeline route crosses 19 tectonic faults, and the integrity of the pipeline is also affected by difficult climatic and geological conditions, which are often the cause of the formation of geohazards – landslides, mudslides, abrasions. [1]

Especially dangerous from the point of view of the risk of pipeline gusts is the Makarovsky district, through which the TPS runs. In this segment, the pipeline not only crosses 5 faults, 11 rivers of important commercial importance, but also passes through mountainous areas for which the risk of the formation of the above processes

is high. Therefore, the section of the Trans-Sakhalin pipeline system located on the territory of the Makarovsky district, as well as the right of way are the objects of study of this work.

Studies of the geohazards on Sakhalin, including on the territory of the Makarovsky district, were conducted by the FEB RAS. Then avalanche, mudslide, landslide and riverbed processes became dangerous processes identified at the site of the Trans-Sakhalin pipeline system. They were studied in the work of N.A. Kazakov and Yu.V. Gensiorovsky. [2]

The most important element of ensuring the safety of linear facilities, including pipeline systems, is the creation of a database containing information about geohazards that increase the risk of damage to pipelines and, consequently, lead to accidental leaks and spills. To create a database, it is advisable to use the ArcGIS software, a complex of geoinformation software products of the American company ESRI, containing tools that allow users to search, analyze and edit digital maps, as well as additional information about objects.

Initially, to create a database using SAS.Planet software was loaded with a mosaic composed of satellite images obtained through the Yandex portal for the area of interest. Then new layers were gradually added to the database: a digital relief model (DEM), earthquake epicenter data obtained from various sources, geohazards and monitoring sites, as well as spills detected during visual monitoring and described in reports.

The initial data for the assessment of slopes was the DEM obtained on the portal ALOS World 3D. Digital relief models are a special kind of three-dimensional mathematical models, representing the representation of the «relief» of both real and abstract geofields (surfaces).

After identifying the features of the relief of the studied area, including surface angles, slope exposures and surface curvature, in the online mode on the portal of the US Geological Survey (USGS) EarthExplorer, which provides access to Landsat-8 images, the right of way on the territory of the Makarovsky district was studied using the visual method for identification of exogenous processes. The

creation of an earthquake database for the period 03/15/1924-02/26/2022, which contains information about the time, intensity and coordinates of seismic events, was based on initial data obtained from open sources, such as the GS RAS, the USGS. When searching for oil leaks, preference was given to the visual method of detection using the portals of the US Geological Survey EarthExplorer and Sentinel Hub.

The result of the work carried out was the formation of a database of geohazards on the basis of the ArcGIS software, which included information not only about the areas of the UCP manifestation, but also monitoring points, as well as areas of development of slope processes and possible oil spills on the land acquisition strip identified during visual monitoring. (Figure 1)

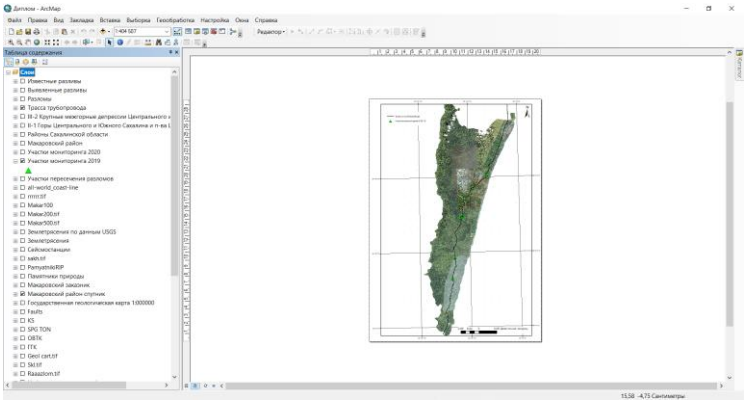

Figure 1 - Database in the ArcGIS software

In the process of a comprehensive analysis of the right of way passing through the territory of the Makarovsky district, the following was established:

1. Climatic features and relief (surface slope > 0.5 °) on the territory of the Makarovsky district are decisive in the formation of slope processes that are activated by movements in the Earth's crust in the zone of active faults. In this section, the pipeline crosses 5 faults.

2. The database of earthquake epicenters (from 1927 to 2022) showed that there are no epicenters of large earthquakes on the territory of the Makarovsky district, the magnitude does not exceed the value of 5. At the same time, the maximum earthquake strength for 200 and 1000 years for this area is determined at 8.5 and 9.8 points on the MSK-64 scale.

3. The most dangerous from the point of view of the impact on pipelines are landslide processes and river erosion, the areas of manifestation of which were identified along the right of way. As part of the visual inspection of the territory, 32 sites of the manifestation of erosion processes were found. Anti–erosion measures were used here – slope dividers, gabions etc.

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THE ENVIRONMENTAL AGENDA AS AN OBJECT OF PUBLIC LEGAL REGULATION

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Keywords: *control, supervision, environmental agenda, legal regulation, international administrative law*

As known, the right to a safe environment is an inherent right of every individual. The formal acknowledgment of this right is reflected both in state constitutions and in decisions of international organizations. However, the fuel and energy complex, despite stringent requirements for environmental safety, remains a powerful anthropogenic factor. Thus, a duality of regulation in the considered sphere is formed. On the one hand, business interests lie in the realm of constant profit growth from the production or transportation of energy resources. On the other hand, the state establishes requirements focused specifically on environmental safety.

Simultaneously, many foreign countries are pursuing carbon neutrality (decarbonization). In practice and in a legal context, the concept of carbon neutrality can be presented from several perspectives: it is both an indicator of the level of harmful emissions into the atmosphere (carbon dioxide), and a qualitative transformation of production processes that, in principle, excludes the creation of a carbon footprint. However, it is evident to us that the complete elimination of carbon traces from circulation is impossible and represents nothing more than political slogans. The combination of these factors leads us to the object of study - the examination of a set of regulatory acts regulating public relations related to decarbonization of the fuel and energy complex in Russia.

The methodological basis of the study includes systemic, historical, comprehensive, and target approaches to the studied group of public relations, as well as special methods of cognition: formal-legal and comparative-legal, as well as methods of modeling, analogy, and abstraction.

The analysis of the evolving model of regulating relations in the considered sphere allows us to conclude on the position of the domestic legislator regarding the environmental agenda - carbon neutrality is no more than an indicator of environmental safety, but not an end in itself. From this point of view, the law that came into force in September 2022, «On the Experiment to Limit Greenhouse Gas Emissions in Certain Subjects of the Russian Federation», and the order of the Government of the Russian Federation of August 5, 2021, No. 2162-r «On the Approval of the Concept for the Development of Hydrogen Energy in Russia» should be considered. Other normative acts also contribute to this perspective.

At the same time, if we analyze the prospects for the legal regulation of the decarbonization of the fuel and energy complex in Russia, we can note the following possible directions: the introduction of a carbon tax, the establishment in regulatory acts of methods for calculating and verifying the reduction of the carbon footprint of oil and gas companies, as well as the establishment of standards for the implementation of «green» technologies taking into account the factor of import substitution and the use of domestic solutions.

Moreover, the author consistently adheres to the position that the oil and gas industry, with compliance with already existing regulations, is sufficiently safe. However, directions such as environmental liability risk insurance, encouragement of conscientious behavior of business entities in the field of fuel and energy, the introduction of ESG policies, monitoring of environmental violations, including using digitalization means, improvement of the mechanism of administrative responsibility for violating mandatory environmental requirements, technical regulation and standardization based on the best technology, and others require further improvement of legal regulation. These directions are relevant not only for our country but also constitute the subject of the environmental agenda in the BRICS and the SCO.

REDUCING THE CARBON FOOTPRINT OF A GAS TURBINE POWER PLANT

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Keywords: *carbon footprint, gas turbine power plant, low carbon fuel*

Emissions from gas turbine power plants are not only a serious environmental, health and safety issue, but also a significant contributor to global climate change due to their carbon dioxide content. In the current situation, the reduction of CO_2 emissions has received much attention in recent years, both in scientific circles and in industrial production. The importance of the climate agenda, the development of industrial production and energy in Russia determines the high relevance of research on low-carbon fuels in the energy sector, optimization of combustion chamber designs and selection of optimal operating modes of power plants from the point of view of minimizing greenhouse gas emissions and efficient use of fuel, development of systems for capture of carbon dioxide generated during combustion of fuels.

The object of the study is a 25 MW gas turbine power plant.

The purpose of the study is to develop technical solutions to reduce the carbon footprint of gas turbine power plant operations.

To achieve this goal, the following tasks were solved:

1. Analysis of the technological characteristics of gas turbine power plants, determination of the qualitative and quantitative composition of emissions, compilation of the material and energy balance of gas turbine power plants, analysis of the risks and opportunities for reducing the carbon footprint;

2. Study of low-carbon fuels for gas turbine power plants, quantitative assessment of the carbon footprint of operating gas turbine power plants using different types of low-carbon fuels;

3. Development of solutions for improving the energy efficiency of gas turbine power plants, determination of optimum technological operating parameters, assessment of the possibility of introducing low-emission combustion chambers for gas turbine power plants.

4. Analysis of technologies to capture carbon dioxide from the flue gases of gas turbine power plants, determination of the optimal capture technology based on expert assessment, quantitative assessment of the carbon footprint of gas turbine power plants when implementing a carbon dioxide capture systems.

5. Development of a general energy-efficient and low-emission model of the technological scheme of gas turbine power plants.

During the research, scientific and technical information was collected, systematized and analyzed in the field of gas turbine power plant operation, low-carbon fuels, design features of low-emission combustion chambers, technologies for carbon dioxide capture and utilization. The selection of the optimal technological solution for the capture of carbon dioxide in the emissions of gas turbine power plants was carried out on the basis of the modeling of the life cycle of a gas turbine power plant at the operational stage.

Based on the research conducted, the following conclusions can be drawn:

1. In order to reduce the carbon footprint during the operation of gas turbine power plants, it is recommended to partially replace (up to 20% by weight) the actual fuel - dry stripped gas - with a low-carbon fuel with a smaller carbon footprint - hydrogen-containing fuel, biofuel.

2. The possibility of using low-emission combustors in gas turbine plants to reduce fuel consumption and emissions of nitrogen oxides, carbon oxides and carbon dioxide was evaluated.

3. During the analysis and expert evaluation of modern technological solutions in the field of CO_2 capture from flue gases, it was determined that the optimal capture technology for the gas turbine power plant under study is absorption using monoethanolamine as an absorbent. Based on available data, the technology is capable of effectively capturing up to 97% of the carbon dioxide in the flue gas.

4. An approach to assessing the full life cycle of a gas turbine power plant and analyzing its environmental impact based on the size of its carbon footprint is substantiated.

ANALYSIS OF EFFICIENCY OF METHODS FOR FORECASTING EMISSIONS IN THE OIL AND GAS INDUSTRY USING GEOINFORMATION TECHNOLOGIES

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Keywords: *GIS, environmental monitoring, remote sensing of the earth*

Goal: evaluation of the effectiveness of environmental monitoring using geoinformation systems to forecast emissions from oil and gas industrial enterprises.

Research methods: during the study, we conducted an analysis of the modeling and forecasting of emissions in the oil and gas industry using geoinformation systems. We reviewed all functioning environmentally oriented GIS systems that support environmental activities. We studied domestic geoinformation systems

Research results: geoinformation technologies combine traditional operations with databases, such as queries and statistical analysis, with the benefits of full visualization and geographic (spatial) analysis provided by maps. Using the significant indicators of GIS, automating the processes of data analysis and visualization, it is possible to more comprehensively assess the situation and reflect previously hidden emission trends and industrial area features, which were practically impossible to see in tabular data organization.

Regular monitoring of ecological parameters allows for identifying changes, correlating accompanying processes, and predicting future developments. Among the important capabilities are modeling the impact of continuous pollution and eco-disasters, both natural and man-made. GIS can be used to forecast greenhouse gas emissions in the oil and gas industry. Modeling can take into account various factors such as fuel type, energy use efficiency, geographical location, and climatic conditions. This enables companies to assess their emissions and develop strategies to reduce them.

The most popular types of software include: QGIS, MapInfo, ZuluGIS, and AxiomaGIS. The main requirements for the functioning of the analytical unit include using standard certified models of the spread of pollutants in the environment, taking into account natural and climatic conditions, urban development, and meteorological processes within it; interpreting measurements obtained using various instruments in the context of monitoring the level of environmental pollution.

As an example of the use of GIS in the oil and gas complex, we use the RAO «Rosneftegazstroy» project, which involves the construction of a 450 km main oil pipeline in the Nenets Autonomous Okrug. The project created a geoinformation space that provides a complete spatial data analysis when solving general and specific applied tasks at all stages of the case implementation.

The improvement of systems for predicting emissions of pollutants based on GIS should ensure the timely and regular receipt of high-quality data (i.e., complete, reliable, and accurate) for the timely and effective implementation of measures to protect the natural environment, prevent degradation and pollution of ecosystems, and model the consequences. Geoinformation systems contribute to the formation of spatial and temporal databases, which can not only accumulate information from research but also generate cartographic models for the analysis and forecasting of the geo-ecological situation.

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XI JINPING'S CONCEPT OF "GREEN MOUNTAINS AND EMERALD WATERS - PRICELESS TREASURES" AS A TOOL IN BUILDING AN ECOCIVILIZED AND HIGHLY DEVELOPED NATION

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Keywords: *ecocivilization, carbon neutrality, renewables, sustainable development goals, energy consumption, modernization*

In the 14th Five-Year Plan adopted in March 2021, China's major development challenges are labeled as "three hard battles" and are financial risk prevention, poverty alleviation and pollution control. In this regard, it is relevant to examine President Xi Jinping's concept of "Emerald Waters and Green Mountains - Priceless Treasure", which aims to build an eco-civilized yet highly developed nation.

The purpose of the study is to update and summarize the measures taken by China to achieve carbon neutrality and sustainable development goals in general through the prism of the idea of building an "ecological civilization", which implies the construction of a state with a "green" economy.

Through systematic comparative analysis, the author studied the "Energy Production and Consumption Revolution Strategy (2016-2030)" [1] and the White Paper on Clean Energy Development entitled "China's Green Development in the New Era", published in January 2023 by the Information Office of the State Committee of the People's Republic of China. [2]

The result of the study was the formation of a list of priority areas of China's green energy development within the framework of Xi Jinping's policy aimed at the socio-economic development of the state. The author also considered the possibility of applying the experience of Chinese partners for the development of green energy in the Russian realities.

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IMPLEMENTATION OF ENVIRONMENTAL STANDARDS IN OIL AND GAS ENTERPRISES AS A WAY TO REDUCE EMISSIONS AND IMPROVE THE ENVIRONMENTAL FRIENDLINESS OF THE RUSSIAN ENERGY INDUSTRY

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***Keywords**: environmental standards, oil and gas enterprises, environmental friendliness, energy industry, management system*

Russia has the largest energy reserves, which are extracted and processed by enterprises of the Russian oil and gas complex. At the same time, the enterprises' activities inevitably have an impact on the environment. The Russian oil and gas industry should be guided by the principles of optimal development and functioning in order to increase its efficiency and achieve its goals. Supporting the rational use of energy resources stimulates economic development and has a positive impact on environmental protection, improving the environmental friendliness of Russia's energy industry. This is especially relevant for the oil and gas industry, which plays one of the key roles in the Russian economy.

There are many challenges that need to be addressed and paid attention to in order for the Russian oil and gas industry to continue to function and develop further, including the profitability of enterprises, their business sustainability and efficiency, challenges related to human resources, work processes, production technology and the environment.

In a market economy, an important characteristic of an organisation's performance is its competitiveness. In order to gain market share, an organisation must strive to provide high quality products and services while continuously improving its environmental performance, reducing possible pollution and emissions.

One of the means to improve the environmental friendliness of Russian oil and gas enterprises can be standards that establish requirements for the environmental management system, which can improve performance indicators in the field of environmental protection.

The use of environmental management standards can help Russian oil and gas enterprises to comprehensively identify, manage, monitor and control their environmental problems, which in turn will enable organisations to improve their environmental performance through more efficient use of resources and waste reduction, and as a result, gain competitive advantage, stakeholder trust and economic benefits.

One of the advantages of environmental management standards is that they can be easily integrated into an existing management system operating in an enterprise. However, the use of these standards in their operation, as with all management system standards, involves the need for continuous improvement of the company's system and approach to environmental issues.

A strategic approach to improving their environmental performance by applying environmental management standards based on a process approach will improve the performance of Russian oil and gas companies and their economic efficiency by:

- compliance with current and future legal and regulatory requirements;
- increasing management and employee engagement;
- reputation enhancement;
- ensuring a competitive and financial advantage by reducing costs.

Oil and gas enterprises, by choosing the path of more efficient use of resources and waste reduction through the use of environmental management standards, will not only be able to improve their economic efficiency, but also lead to a reduction in emissions and increase the environmental friendliness of the energy industry in Russia.

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UTILIZATION OF MONI-BASED HOLLOW NANORODS FOR ENERGY-EFFICIENT HYDROGEN PRODUCTION VIA HYDRAZINE-ASSISTED SEAWATER ELECTROLYSIS

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Keywords: *seawater electrolysis, hydrazine oxidation reaction, hydrogen evolution reaction, MoNi-based*

Seawater electrolysis is an efficient avenue for generating carbon-neutral hydrogen; nevertheless, its advancement is hampered by the considerable energy costs involved and the challenge posed by chlorine evolution reactions. The thermodynamically more favorable hydrazine oxidation reaction (HzOR) supported water electrolysis proves highly efficient for energy conservation and the chlorine-free production of hydrogen. Therefore, the hollow nanorod arrays of $MoNi_4$ alloy particles loaded on MoO_2 nanorods were synthesized on foam nickel (NF) substrates (MoNi@NF). When coupling HzOR and hydrogen evolution reaction (HER) using MoNi@NF as both the anode and cathode in a two-electrode seawater system, a low cell voltage of 0.54 V is needed to reach 1 A cm^{-2}, and achieve long-term durability at 100 mA cm^{-2} for 100 h with nearly 100% Faradaic efficiency. This method conserves 2.94 W·h per liter of H_2 generated compared with alkaline seawater electrolysis, exhibiting a 37% reduction in energy equivalent input.

THE INTERNATIONAL EXPERIENCE AND PRACTICAL REFERENCE OF CARBON EMISSION TRADING MARKET

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Keywords: *carbon emission trading, carbon finance, low-carbon economy*

Carbon emission market trading is an inevitable requirement to promote the construction of ecological civilization, and it is also a long-term strategy to achieve carbon peak and carbon neutrality. Observation and practice show that some countries have established a comprehensive and multi-level trading system in terms of carbon emission trading policies and supporting mechanisms, the use of administrative means such as tax collection, and the pooling of resources to innovate low-carbon technologies. In view of the fact that China's carbon emission trading market is in its initial stage, it is necessary to learn from foreign experiences and lessons, build carbon market rules and stable regulation mechanism, and implant dynamic optimization genes for carbon market. Applying digital technology to strengthen carbon emission data analysis to improve market efficiency; We should design a carbon tax system reasonably and pay attention to key enterprises to release price signals.

Low-carbon economy is a new economic development model characterized by low emission, low consumption, low pollution and high efficiency, which is an inevitable trend of global economic development. As countries emit carbon dioxide, greenhouse gases soar, threatening living systems. Under this background, all countries in the world reduce greenhouse gases by means of global agreement, and China puts forward the goal of carbon peaking and carbon neutrality. To achieve carbon peak and carbon neutrality is a broad and profound economic and social systemic change, an inevitable requirement for ecological civilization, and an urgent need to promote the building of a community with a shared future for mankind. Since 2011, China has launched carbon emission trading pilot programs in seven provinces and cities, including Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei and

Shenzhen. On July 16, 2021, the national carbon emission trading market was officially launched, marking a new stage in China's carbon emission governance.

I. International experience in carbon emission markets

In order to promote the realization of the "double carbon" goal, countries and regions around the world, in order to reduce carbon emissions, build carbon trading market mechanisms, use social capital forces to achieve effective allocation of resources, control carbon emissions with the help of market forces, realize the internalization of the external cost of carbon emissions, and build a low-carbon economic pattern. Among them, the world's oldest and most mature carbon trading system, the European Union Emissions Trading System, was established in 2005 and is currently the largest, most liquid and most successful carbon emission trading system in the world.

1. Focus resources on the green transformation of the energy sector

Between 2009 and 2020, the EU carbon market has raised $80.737 billion for projects such as energy efficiency management, new energy investment and industrial decarbonisation. The EU has intensified its low-carbon transformation efforts, with the overall carbon emissions decreasing year by year and the energy structure transitioning to clean energy. The EU's climate targets have made European carbon emitters more aware of the scarcity of allowances, while incentivizing institutional investors to participate more actively in the carbon market, which is the main reason for the price increase in the EU carbon market.

2. Tax collection to promote the healthy development of the carbon emission market

The EU has actively introduced tax policies to improve the liquidity of the carbon emission trading market and ensure the fairness of the tax burden of carbon emitting entities. Member states have introduced carbon taxes. It has the advantages of quick effect, low implementation cost, stable tax rate and reallocation of income. The carbon tax as a supplement to the carbon emission trading mechanism has achieved a positive interaction between the two.

3. Complete policies and supporting mechanisms to improve the carbon financial market

Within the carbon financial market, financial institutions are widely involved in the carbon market, perfecting various forms and varieties of carbon derivatives and trading actively. The carbon market as an investment channel, mainly including brokers, traders, exchanges and clearing houses. Eu carbon derivatives mainly consist of EUA based products CER,EUAA and futures of carbon emission rights, Carbon index and other products. The market is rapidly growing and actively traded, with carbon derivatives contracts trading around six times more than spot in 2018, according to data from the European Energy Exchange .

Although the United States has not established a unified national carbon emission trading market, in order to control carbon emissions, it has mainly established regional carbon emission trading markets, including the regional greenhouse gas trading program and the California carbon emission trading market. As an early country in Asia to promote low-carbon development strategy, Japan's regional carbon trading system and joint credit mechanism (JCM) are the innovations of its carbon trading system, which are independent and linked to each other, fully realizing flexible compliance. South Korea's carbon trading system is relatively complete, the allocation method combining free and paid auction ensures the scarcity of quotas, the appropriate market reserve quota guarantees the stability of the market, and the abundant market players, diverse trading products and flexible implementation methods greatly enhance the vitality of the market.

II. Current situation and prospect of China's carbon emission market

The national carbon emission trading market has been in operation for one year since it opened on July 16, 2021. As of October 21, 2022, the cumulative trading volume of carbon emission allowances was 196 million tons, with a cumulative turnover of 8.58 billion yuan, and the market operation was generally stable and orderly. In general, after the construction and operation of the first compliance cycle, the national carbon market has established a basic framework system, opened up various key process links, initially played the role of carbon price discovery

mechanism, effectively enhanced the awareness and ability of enterprises to reduce greenhouse gas emissions and accelerate green low-carbon transformation, and achieved the expected goals.

It is to promote high-emission industries controlled by the carbon market to achieve green and low-carbon industrial structure and energy consumption, and promote high-emission industries to take the lead in reaching the peak; The second is to release the price signal for carbon emission reduction, and provide economic incentive mechanism, direct funds to the industry enterprises with high emission reduction potential, promote green and low-carbon technology innovation, promote cutting-edge technology innovation breakthrough and green and low-carbon development transformation of high-emission industries; Third, through the establishment of a national carbon market offset mechanism, promote the increase of forestry carbon sink, promote the development of renewable energy, help regional coordinated development and ecological protection compensation, and advocate green and low-carbon production and consumption methods; Fourth, relying on the national carbon market, we will provide investment and financing channels for the transformation of green and low-carbon development in industries and regions to achieve carbon peak and carbon neutrality. With the continuous advancement of the "double carbon" work, the development of the carbon emission market will receive more and more attention, and the development speed will also accelerate.

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ELECTRIC FIELD-ASSISTED PHOTOCURABLE 3D PRINTING TO ARRAY PEPTIDES SELF-ASSEMBLIES

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Keywords: *3D printing, short peptide self-assemblies, arraying, bio-inks*

A technique for organizing short peptides self-assemblies using three-dimensional (3D) printing is proposed in this study. We propose the design and development of short peptide self-assembled photocurable 3D printing inks, coupled with an electric field control module, to prepare a highly-organized and mechanically rigid short peptide self-assembled biomimetic spiral array structures. This innovative approach addresses the limitations of developing large-scale peptides arrays for diverse bio-nanotechnologies. In brief, this method offers a promising solution for arranging short peptide self-assemblies for practical applications.

Short peptides have a remarkable ability to self-assemble into one-dimensional polar nanostructures, driven by various non-covalent bonding forces including intermolecular hydrogen bonding, aromatic interactions, hydrophobic interactions, and electrostatic interactions *etc*. These nanostructures can entangle and intertwine to form three-dimensional network structures, thus giving rise to supramolecular structural systems [1] (Figure 1). As a result of this unique behavior, short peptides have found extensive applications in the field of biomedical fields.

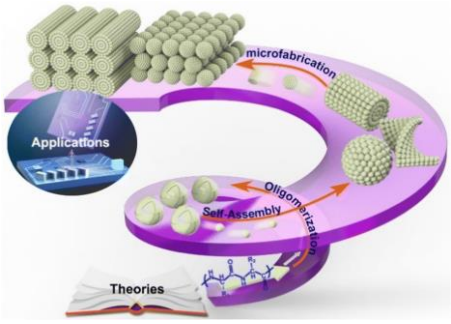

Figure 1 - Short peptide self-assembly forms various supramolecular structural systems for various practical applications [2]

The rapid advancement has allowed 3D printing a highly valuable and widely utilized tool for design and fabrication of various components [3]. However, currently there are relatively few biocompatible 3D printing ink materials available. To address this issue, our research aims to develop a novel biocompatible ink composed of short peptides and utilize 3D printing technology to construct various architectures with adjustable morphologies and properties.

The inherent polarity of short peptide molecules and the anisotropy of their self-assembled one-dimensional structures endow them with the ability to generate stimuli-responses to applied electric fields. Therefore, it is proposed to install an electric field control module in a photocurable 3D printing device, construct an electric field assisted photocurable 3D printing system by coupling the two technologies [4], thus developing short peptide self-assembled photocurable 3D printing inks to prepare a biomimetic spiral array structure of adjustable architectures and performances (Figure 2). The construction of a functional material system can ultimately achieve both biocompatibility and excellent mechanical properties.

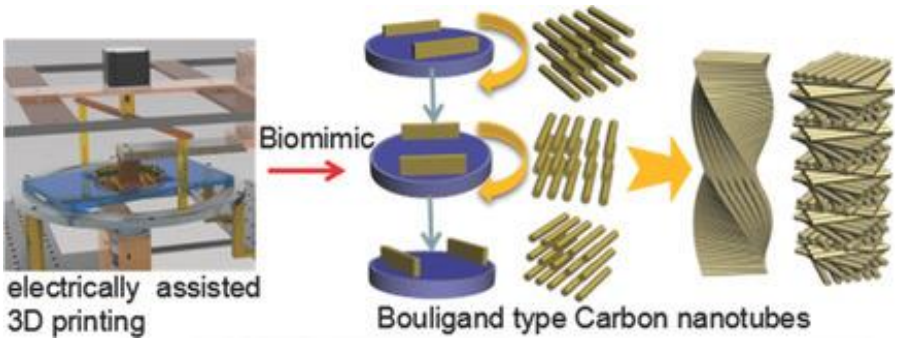

Figure 2 - Constructing a spiral array architecture for multiwalled carbon nanotubes through electric field assisted 3D printing [4]

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DIGITALIZATION IN DOWNSTREAM

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Keywords: *digital technologies, downstream, upstream, midstream*

The downstream chain involves processing and analysing the data obtained using specialised software. This allows geologists and other exploration specialists to obtain more accurate and complete information about mineral deposits, which can be used to make decisions about the next steps in mining and development.

The use of 4D drones in exploration has several advantages. Firstly, it reduces risks to workers as the drones can monitor and collect data in dangerous or hard to reach areas. Second, it increases the speed and efficiency of the exploration process, as drones can fly over large areas quickly and collect data in real time. Thirdly, it reduces the cost of reconnaissance, as the use of drones is usually cheaper than employing large numbers of personnel and equipment.

Thus, the downstream chain in exploration using 4D drones represents the future of the industry, providing more accurate data, increased safety and efficiency in the exploration process, and lower costs.

Development due to digital technology has a number of advantages over traditional development methods. Here are a few key differences:

1. Speed: Digital technologies enable faster development. Software and development tools can automate many tasks, which speeds up the product development process.

2. Flexibility: Digital technologies offer more flexibility in the development process. Changes and updates can be made easily and quickly, allowing you to adapt to changing customer or market requirements.

3. Quality: Digital technologies improve the quality of development. Automated testing, debugging and version control help identify and fix bugs and problems early in the development process.

4. Collaboration: Digital technologies facilitate collaboration and communication between developers. They can work remotely, share information and interact in real time, which facilitates more efficient and productive work.

5. Accessibility: Digital technologies make development more accessible. With open and free development tools, tutorials and online resources, people can start developing at minimal cost and access a global community of developers.

6. 6. Innovation: Digital technologies enable the creation of new and innovative products. They enable the use of artificial intelligence, blockchain, the Internet of Things and other advanced technologies to create new opportunities and solutions.

Overall, digital technologies are greatly improving the development process, making it more efficient, agile and innovative.

Resource extraction is an important sector of many economies and plays a key role in meeting the needs of mankind. With the advent of new technologies, the process of resource extraction has become more efficient and energy efficient, leading to significant changes in the industry. One of the major technological innovations in mining is the use of automation and robotisation. With the use of automated systems and robots, resources can be extracted at a deep level where previously it was impossible for humans to reach. This allows for increased extraction and improved worker safety. Also, new technologies allow for more accurate identification of resource deposits and more efficient exploration. Using modern geophysical methods and instruments, the presence of resources underground can be determined with greater accuracy, reducing drilling costs and increasing the likelihood of successful extraction. An important trend in the development of extraction technologies is the use of alternative energy sources. For example, solar and wind turbines can be used to power equipment in the field, reducing dependence on conventional energy sources and minimising environmental impact.

However, along with the benefits of new technologies, there are also a number of challenges and problems. For example, automation may lead to job losses as some

tasks will be performed by robots. This can cause social and economic problems in regions dependent on resource extraction.

In addition, the use of new technologies may require significant investment and staff training. It is necessary to provide specialists who will be able to work with the new equipment and software systems.

New technologies in resource extraction are driving change in the industry, improving the efficiency and safety of extraction. However, social and economic impacts need to be considered, and personnel need to be trained to deal with the new technologies.

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APPLYING THE RESOURCE AND ENERGY EFFICIENCY INDICATORS IN BEST AVAILABLE TECHNIQUES REFERENCE DOCUMENTS FOR OIL AND GAS INDUSTRY

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Keywords: *best available technologies, technological regulation, energy efficiency, resource efficiency*

In 2014, the main course of industrial development state regulation based on the best available technologies (BAT) principles was approved in Russia. The purpose of introducing BAT is to motivate industrial enterprises to consistent environmental and technological modernization, based on a balance of compliance with economic and environmental profits.

One of the elements of the new regulatory policy is the development and receipt of an integrated permit - a complex environmental permit (CEP), which determines the conditions for the operation of an enterprise for a period of 7 years (or 14 years for city-forming enterprises). The CEP establishes technological standards for permissible emissions and discharges of pollutants in accordance with the technological indicators of marker substances on an industry basis; the application of the negative impact of BAT at the object is confirmed. Technological indicators are determined as part of the Best Available Techniques Reference Documents development (ITS BAT).

The responsibility to obtain CEP applies only to objects of negative environmental impact of category I, characterized by significant emissions, discharges and waste generation. In total, by 2025, CEPs must be obtained for 7,000 objects of negative environmental impact of category I. If the CEP is not received on time, the enterprise faces extraordinary payments for negative impacts on the environment.

By 2024, the largest number of CEPs has been received by oil and gas enterprises by field of application:

– ITS BAT 28 Oil production – 106;

– ITS BAT 29 Natural gas production – 20;

– ITS BAT 30 Oil refining – 7;

– ITS BAT 50 Processing of natural and associated petroleum gas – 4.

One of the obligatory structural parts of the ITS BAT is the application "Indicators of resource and energy efficiency". It includes a brief description of the industry in terms of resource and energy consumption, a list of the best available technologies directed at increasing energy efficiency and resource efficiency, and targets set for these characteristics.

When classifying a technology as the best available, the criterion "Application of resource- and energy-saving methods" is also applied. The criterion is assessed on indicators such as specific consumption of energy, raw materials, water and auxiliary substances per ton of product. Technical solutions directed at increasing energy and resource efficiency, and environmental solutions themselves are considered one of the priorities when choosing the best available technologies for the fields of the ITS BAT application.

Technological processes of oil and gas industry enterprises are characterized by high resource and energy consumption. Resource capacity of production is an indicator that reflects the degree of efficiency in the use of enterprise resources in the production of a unit of product. This indicator applies to raw materials, energy, auxiliary substances, fuel, etc.

Table 1 provides a brief overview of the best available technologies directed at increasing resource and energy efficiency, established for oil and gas companies in the relevant ITS BAT.

Table 1 – Best available technologies directed at increasing resource and energy efficiency

BAT	Description
ITS BAT 28 Oil production	
BAT 2. Energy management systems	BAT includes tools to increase energy efficiency and reduce negative impacts on the environment
BAT 9. Use of associated petroleum gas to generate thermal energy	BAT is to use extracted and prepared associated petroleum gas to generate thermal energy for the enterprise's own needs
BAT 10. Use of associated petroleum gas to generate electrical energy	BAT is to use produced associated petroleum gas to generate electrical energy
BAT 11. Use of associated petroleum gas for injection into underground gas storage facilities	BAT is the use of produced associated petroleum gas for the injection of associated petroleum gas into underground gas storage facilities for the purpose of subsequent rational use
BAT 12. Use of associated petroleum gas for injection into the reservoir in order to maintain reservoir pressure	This technology includes the injection of prepared associated petroleum gas into an oil-bearing formation to maintain the level of reservoir pressure and, accordingly, the level of oil production in the field
BAT 14. Use of associated petroleum gas to transfer it to a gas processing plant (for processing)	BAT is to create a technological infrastructure for the transfer of associated petroleum gas to gas processing plants for the purpose of its deep processing
BAT 15. Use of associated petroleum gas for oil preparation	BAT includes the use of associated petroleum gas as fuel for oil treatment, using track heaters, oil heating furnaces, separators with built-in heaters
ITS BAT 29 Natural gas production	
BAT 2. Energy management systems	BAT includes tools to increase energy efficiency and reduce negative impacts on the environment

Continuation of the table 1 – Best available technologies directed at increasing resource and energy efficiency

BAT 8. Well gas flow stimulation technologies	BAT are technologies directed at intensifying gas flow, including during additional development of depleted fields, involvement in the development of hard-to-recover reserves, restoration of inactive and low-yield wells
BAT 14. Optimization of operation of booster compressor stations	BAT is to reduce emissions of pollutants into the atmosphere during compression of natural gas by optimizing the operation of the booster compressor station as a result of the use of one or more technological solutions
BAT 15. Technology for the production of liquefied natural gas (LNG)	BAT is to produce LNG using technological solutions that reduce emissions of pollutants into the air, including: – use of isothermal tanks for primary storage of LNG with removal and use of gas evaporation as fuel; – use of a flare unit at the LNG plant, which eliminates the release of unignited hydrocarbon gas into the air
BAT 16. Utilization of associated petroleum gas (APG)	BAT is the efficient use of APG: – at the gas processing plant to obtain various types of fuel and raw materials for petrochemicals; – to obtain electricity and heat; – APG consumption for own needs in the field development area; – APG injection into the reservoir
ITS BAT 30 Oil refining	
BAT 2. Energy management systems	BAT includes tools to increase energy efficiency and reduce negative impacts on the environment

Continuation of the table 1 – Best available technologies directed at increasing resource and energy efficiency

BAT 6. Use of alternative energy sources in the energy balance of oil refineries	BAT applies to the production of energy from alternative sources (solar energy, wind energy, water, geothermal sources, etc.) at oil refineries
BAT 14 Reduction of thermal energy consumption during the operation of main and auxiliary oil refining plants	BAT provides for the implementation of the following approaches and activities: – integration of heat flows, allowing to optimize the heat consumption required for various processes due to heat exchange between flows; – use of energy recovery devices, for example, waste heat boilers, turboexpander units, etc.; – use of highly efficient heat exchangers; – reduction of steam consumption by controlling the valves of the drainage system
ITS BAT 50 Processing of natural and associated gas	
BAT 1. Energy management systems	BAT includes tools to increase energy efficiency and reduce negative impacts on the environment

Rational use of resources ensures the achievement of maximum efficiency at the existing level of development of technology and equipment, taking into account the limited availability of their reserves and compliance with the requirements for reducing negative impact on the environment and other requirements of society.

PREPARATION OF METAL-ZEOLITE CATALYSTS AND THE PERFORMANCE IN CO_2 HYDROGENATION FOR METHANOL SYNTHESIS

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Keywords: *zeolite; metal encapsulation; hollow structure; green methanol*

Amidst China's dual-carbon strategy, a shift towards high-end, environmentally friendly development in chemical products is gaining momentum. The conversion of CO_2 into high-value chemicals holds paramount importance for enhancing energy efficiency and optimizing carbon resource utilization. Presently, green methanol stands as a globally acknowledged low-carbon fuel and raw material, with CO_2 hydrogenation serving as its pivotal technology. The sintering deactivation issue of metal components within CO_2 hydrogenation catalysts remains a persistent challenge in need of resolution. Our innovation involves the synthesis of a hollow-structured metal-loaded zeolite catalyst, effectively encapsulating ultra-small Cu/ZnO_x metal particles, and unveiling its evolutionary process. This breakthrough has significantly elevated the methanol production rate per unit of copper, surpassing industrial catalysts in the CO_2 hydrogenation process for methanol synthesis. This advancement paves a promising path for catalyst development.

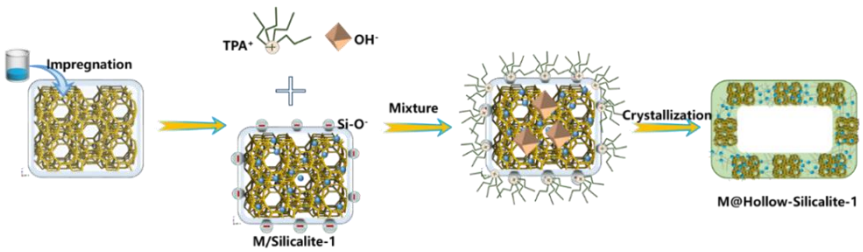

Figure 1

AUTOIGNITION STUDY OF SUSTAINABLE AVIATION FUEL BY HEFA PROCESS AT HIGH TEMPERATURES

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Keywords: *sustainable aviation fuel, jet fuel, shock tube, ignition delay times, high temperature*

The autoignition characteristics of sustainable aviation fuel (SAF) by HEFA process have been studied in a shock tube and are compared with its target Chinese No.3 jet fuel (RP-3). Experiment conditions covers temperature range of 1000-1400 K, pressure range of 10-20 bar, and equivalence ratio range of 0.5-1.5. The effect of pressure, fuel loading, and oxygen content on the ignition delay times of RP-3 and SAF have been investigated, and the overall trends are consistent between two fuels.

This study aims to extend understandings of SAF autoignition and provide fundamental experimental database for the future development of SAF kinetic mechanism.

1. Introduction

Developing the next-generation aeroengine for higher efficiency and lower emission is crucial in reaching the carbon peaking and carbon neutrality goals in China. As the development of SAF in replacement of conventional jet fuel is an important way in reducing both the carbon emission and the consumption of petroleum resources, and as the high-temperature experimental autoignition results of SAF produced by hydro- processed esters and fatty acids (HEFA) process are meager in literature, a good knowledge of the combustion characteristics of SAF can play a key role in the design and improvement of future aeroengine combustor.

2. Relevance

Ignition delay time (IDT) is one of the main combustion characteristics of fuels and is an important factor being considered in the design of aeroengine combustion chambers. The current work aims to provide experimental IDTs

database of “SAF produced by HEFA process” (referred as HEFA) in engine-relevant conditions, covering wide range of pressures, temperatures, and equivalence ratios. The comparison of experimental IDTs between HEFA and Chinese No.3 jet fuel (RP-3) can provide possibility of SAFs replacing conventional jet fuels in aviation. The new experimental database can guide the development of chemical kinetics mechanisms of HEFA, which can further facilitate high fidelity engine simulation as well as accelerate future HEFA-fueled engine design and optimization processes.

3. Methodologies

A shock tube facility in Beihang University has been used to measure the IDTs of HEFA and its target RP-3 jet fuel in this study, with covered temperature range 1000- 1400 K. Shock tubes are experimental facilities that are able to rapidly compress the premixed fuel/oxidizer mixture by shock waves so that the mixtures can reach pressures and temperatures high enough to trigger autoignition phenomena.

Homogeneous regime can be provided when the test mixtures are compressed by incident and reflected shock waves, which made the assumption of an ideal 0-D

homogeneous reactor applicable. As a result, the combustion processes of fuels in shock tubes are related to the ongoing reactions, which makes shock tubes suitable tools for high-temperature chemical kinetics studies. The experimental conditions of autoignition measurements for HEFA combustion in the current study were summarized in Table 1, which can show the effect of pressure, fuel loading, and dilution on IDTs, as well as the reactivity comparison between HEFA and RP-3.

Table 1 - Experimental conditions for HEFA combustion carried out in this work

ϕ	Xfuel (mol%)	XO2 (mol%)	XN2 (mol%)	XN2 /XO2	Pressure (bar)
0.5	0.48	20.91	78.61	3.76	15
1	0.96	20.81	78.24	3.76	15
1	0.46	10.04	89.5	8.91	15
1.5	0.45	6.55	93.00	14.20	15/20

4. Conclusion

Figure 1 is an example of the comparison between experimental results of IDTs for HEFA and RP-3, as well as the experimental measurements from Mao et al. [1] in literature. It shows that the reactivity between HEFA and RP-3 are close to each other, which can help us gain a preliminary understanding of the reactivities for both fuels, and it shows that HEFA can be a possible fuel to replace the conventional RP-3 jet fuel. In the next step, as suitable surrogate fuels are prerequisites for modeling real fuels, representative fuel components in major hydrocarbon classes of HEFA need to be selected based on the composition analysis, and surrogates of SAF can be further developed by matching the physical and chemical properties of their target fuel. The formation of HEFA surrogates is essential in the development of chemical kinetic mechanisms, and can further reduce the cost and amount of calculation in modeling the combustion process in real engine simulations.

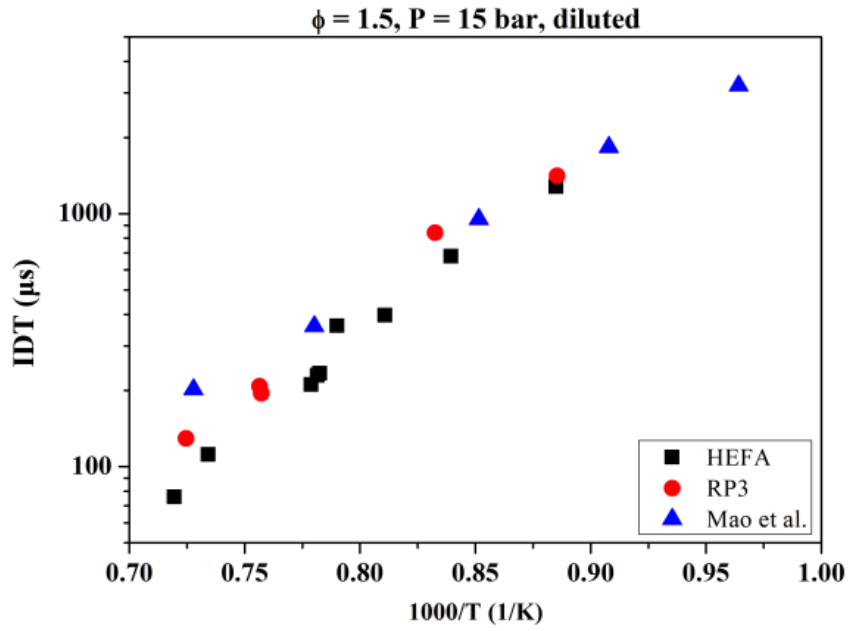

Figure 1 - Comparison of the experimental IDTs for HEFA and RP-3 in this study, and the ones for RP-3 from Mao et al. [1]

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INTEGRATED APPROACH TO OIL-CONTAINING WASTE RECYCLING WITH THE PRODUCTION OF SECONDARY MATERIAL RESOURCES

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Keywords: *waste, oil, petroleum product, refining, resource*

The topic of work is one of the priority areas in the field of environmental engineering and sustainable development. Oil-containing wastes generated as a result of operational activities of oil producing and refining enterprises are a complex mixture of hydrocarbons, often containing heavy metals and other harmful components. Processing of such wastes requires application of multilevel technological solutions aimed at maximum recovery of useful components and waste minimization. An important aspect is the development and optimization of processes that allow not only neutralizing harmful substances, but also transforming waste into valuable products such as fuel fractions, raw materials for the chemical industry and even construction materials [1]. Therefore, the aim of the work was to develop a project of integrated processing of oily waste with subsequent reclamation of the contaminated territory and obtaining secondary material commercial products.

Existing technologies for handling oily waste are divided into thermal, chemical, physical-chemical and biological methods, however, when solving large projects, for example, processing millions of tons of oily waste and reclamation of the area of their accumulation, the use of only one method is not cost-effective and technologically efficient [2]. Therefore, this problem can be solved only by an integrated approach using modern solutions of each of these methods. Integration of these methods into a single technological chain allows to create an effective processing system capable of adapting to different types of waste and changing

operating conditions. The key point is also the development of monitoring and control systems that ensure compliance with environmental standards and process optimization at all stages of processing.

The work shows the results obtained on the example of the object of oil-containing waste accumulation on the territory of the southern federal district of the Russian Federation, including engineering, environmental and geo-ecological surveys. The research on studying the complex chemical composition of oily wastes with selection of technical solutions for their processing has been carried out. A search for promising and realized technologies capable of processing these wastes into commercial products was carried out. Pilot tests of the technologies, which produced commercial products such as fuel oil and paraffin, were carried out. Physicochemical characteristics of the initial waste and the obtained secondary material resource are shown in Tables 1,2.

Table 1 - Results of complex-chemical analysis of the waste

Characteristics	**Result**
Top layer of the waste accumulation site 0-0.5 m	
Mass fraction of water %	80
Hydrocarbon phase, %	10
Mechanical impurities, %	10
Bottom layer of the waste accumulation site 0.5-2 m	
Mass fraction of water %	40
Hydrocarbon phase, %	20
Mechanical impurities, %	40

Table 2 - Results of complex-chemical analysis of the product composition

Characteristics	Result
Density at 20 °C, g/cm3	0,966
Solidification temperature, °C	50
Flash point in open crucible, °C	215
Boiling point, °C	300
Boiling end temperature, °C	360
Fractional content up to 360 °C, %	40

The obtained product is paraffin, which meets technical requirements and can be used as secondary material resources. Obtaining commercial products from oily waste opens new prospects for industry, allowing not only to reduce the environmental load, but also to obtain additional economic benefits. This stimulates the development of new technologies and approaches in the field of resource saving and waste recycling.

The project involves leading scientific and educational centers, as well as oilfield service companies of the Russian Federation implementing complex engineering environmental and technical solutions using interdisciplinary scientific interaction, including chemical engineering, ecology, materials science and energy. Only through joint efforts can significant progress be achieved in addressing the problem of oily waste and sustainable use of natural resources.

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METHODS OF MONITORING THE ENVIRONMENTAL SITUATION IN THE REGION OF OIL AND GAS PROJECTS

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Keywords: *remote sensing, satellite imagery, environmental monitoring, oil and gas industry*

This paper explores options for remote monitoring of the environmental situation in the implementation zone of oil and gas projects. Firstly, various satellite imaging options are considered, and secondly, the application scope of these methods is discussed.

The modern oil and gas industry, situated at the heart of the energy world, is confronted with the urgent task of refining its practices towards sustainable development and responsible environmental impact. Today, as environmental concerns take a prominent place in public consciousness, oil and gas companies strive not only to enhance their efficiency but also to minimize their negative impact on ecosystems.

At the core of this endeavor are monitoring programs, serving as a crucial tool in assessing and controlling the implementation of environmental programs in the oil and gas sector. These programs not only provide companies with the necessary information to reduce their ecological footprint but also lay the foundation for the sustainable development of the industry as a whole. In this work, we will explore the importance and prospects of monitoring programs in the context of the environmental sustainability of the oil and gas sector, highlighting their role in shaping a responsible approach to natural resources and ensuring an environmentally clean future for our planet.

Satellite monitoring of the environmental situation is an effective tool for obtaining comprehensive and up-to-date information about the state of the

environment. This method allows for remote tracking of changes in the natural environment, including areas affected by oil and gas activities.

Multispectral Sensing - Using satellites with multispectral sensors capable of recording information in different wavelength ranges. This enables the analysis of color data, which is useful for detecting changes in vegetation, water resources, and pollution.

Infrared Sensing - Recording infrared radiation to identify the thermal characteristics of the Earth's surface. This method can be used to detect thermal emissions, such as hotspots, and monitor temperature changes.

Radar Sensing - Applying radar sensors to penetrate through clouds and fog, providing the ability to monitor even in conditions of poor visibility. Radars can be used to analyze topography, determine soil structure, and detect changes in the landscape.

High-Resolution Imaging - Utilizing satellites with high-resolution cameras to obtain detailed images of the Earth's surface. This allows for the identification of changes in the landscape and detailed studies of specific areas.

In conclusion, the presented introduction underscores the relevance and urgency of ecological issues within the context of the modern oil and gas industry. The need to refine practices towards sustainable development and responsible environmental impact poses significant challenges for the industry. Monitoring programs, identified as a key tool, not only provide companies with essential information to reduce environmental impact but also serve as the foundation for shaping a responsible approach to natural resources.

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USE OF SHUNGITE AS AN ENVIRONMENTALLY FRIENDLY FILLER IN THE COMPOSITION OF ELASTOMERIC COMPOSITES BASED ON EPICHLOROHYDRIN RUBBER

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Keywords: *epichlorohydrin rubber, elastomeric composite, shungite, filler, carbon black*

Epichlorohydrin rubbers are often used in industry to create frost and hydrocarbon resistant products such as seals, hoses, gaskets and others. At the moment it is important to search for new fillers to reduce the cost of processing and improve the environmental friendliness of materials made of this rubber.

Shungite is a natural mineral, an intermediate product between amorphous carbon and graphite. Metal oxides, silicon oxides, silicates, carbon in the form of nanotubes, graphite and fullerenes are found in the composition of shungite. Finely ground shungite has bipolar properties, which makes it easily miscible with almost all substances [1]. It is also a promising environmentally friendly and cheap filler for elastomeric composites compared to traditional carbon black. It is considered that shungite is most suitable as a filler for polar rubber-based elastomers. It can act as a secondary vulcanizing agent [2] for polychloroprene and butadiene-nitrile rubber. At this point, it makes sense to consider shungite as a filler for epichlorohydrin rubber-based frost resistant elastomers, as it can exhibit the same compatibility.

The aim of this research is to evaluate the possibility of using the natural mineral shungite as an ingredient for frost-resistant rubbers based epichlorohydrin rubber.

The objects of the study are Hydrin T6000 Zeon epichlorohydrin rubber and natural shungite mineral from Zazhoginskoye deposit which was used as a filler. The

particle size of shungite was 5-90 microns. Hydrin T6000 is a copolymer of epichlorohydrin, propylene oxide and allyldiglycidyl ether, the rubber has a low glass transition temperature of -60 °C. On the basis of this rubber elastomeric composites containing carbon black and shungite fillers, dibutyl phthalate plasticizer, activators and accelerators of vulcanization, anti-aging agents, sulfur were prepared.

The vulcanization kinetics, physical and mechanical characteristics, compression set and glass transition temperature were determined in accordance with standard methods.

It was found that for Hydrin T6000-based elastomeric composites it is possible to replace a part of carbon black with shungite (up to 30% of the initial content), moreover, it allows to further significantly reduce the content of zinc oxide and more expensive magnesium oxide without significant loss of vulcanizates properties. Replacing 30 wt.% of carbon black with shungite leads to a 25% reduction in the time to reach the cure optimum, and the cure rate increases by 45%. This phenomenon allows to reduce energy and time consumption during vulcanization of materials based on the epichlorohydrin rubber. Also, the presence of shungite reduces the rubber content and also additionally allows to reduce the content of vulcanization activators and carbon black. Considering the price of the shungite, which is approximately 4 times lower than conventional carbon black in total it gives a noticeable economic effect

The investigation of glass transition temperatures of rubbers showed that the introduction of shungite practically does not worsen the frost resistance of materials.

From the analysis of our studies of the chemical composition of shungite and literature data it follows that due to the presence of various oxides in its composition, as well as the ability to form gels with chlorinated rubbers, the shungite can be used as an environmentally friendly, cheap filler and vulcanization activator for rubbers based on epichlorohydrin rubber Hydrin T6000.

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COMPARISON OF ENVIRONMENTAL STRATEGIES OF CHINESE AND RUSSIAN AND MAJOR OIL AND GAS COMPANIES

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Keywords: *China, oil and gas companies, green technology, sustainability, business development*

Nowadays, based on evaluation carried out by various analytical agencies, oil and gas industry accounts for around 9 [1]–15% [2] of greenhouse gas emissions globally. However, producers of hydrocarbons all around the world take effective steps to mitigate their hazardous influence towards environment through costeffective measures, which are comprised of lowering methane emissions, eliminating flaring, electrifying upstream facilities with low-emissions electricity, equipping oil and gas processes with carbon capture, utilization and storage technologies, and expanding the use of hydrogen from low-emissions electrolysis in refineries. Thus, oil and gas companies have an opportunity to continue operation with lower environmental risks.

China's rapid economic growth is closely tied to its energy demands. However, this growth has come with significant environmental challenges: China is one of the biggest green house gas emitters in the World. According to the estimations done by Energy institute, China accounts for 30.2% of global CO2 emissions, 30.7% of global emissions from energy sector and 28.5% of world methane emissions [3]. Oil and gas play a crucial role in fueling the nation's development: hydrocarbons make up nearly one third of China’s primary energy consumption, which means that oil and gas industry plays an inevitable role in improving the quality of the environment. In 2020 president of China Xi Jinping announced reaching the peak of carbon emissions in 2030 and carbon neutrality in 2060. This ambitious climate target requires a substantial change in the business development of China’s major oil and gas producers.

Oil and gas industry is a key sector of Russian economy. According to the Russian custom data, fuel comprised 65% of Russian export in 2022. Taxes from Russian oil and gas companies takes the biggest share in Russian government tax income – near 25%. Thus, oil and gas sector is paramount for the development of Russian economy and if trend on decarbonization changes the situation on world energy market, it will have significant influence on Russian economy. Therefore, ability of Russian oil and gas companies to change is of high importance.

Summing up these factors, research of influence, which green strategies impose on business development of Chinese and Russian major oil and gas companies, is highly topical. Purpose of this article is to analyze, how business activity of core producers of hydrocarbons in China and Russia changed after ecological issues became a key topic. The research analyzes sustainable reports and official announces of major oil and gas producers in China and Russia: CNPC, SinoPec, CNOOC, Gazprom, Lukoil and Rosneft for the period of 2020-2024.

A deep decarbonization became of paramount importance for oil and gas companies after the announcement made by Xi Jingping. Moreover, China's economic development and environmental risks impose high pressure on oil and gas industry: China faces the daunting task of meeting the energy and petrochemical materials demands of its 1.4 billion population while addressing environmental issues. The Chinese government plays a significant role in shaping the environmental strategy of major Chinese oil and gas companies. It has strengthened regulations, set ambitious emission reduction targets, and introduced policies to promote cleaner energy. Companies face strict penalties for non-compliance, which further incentivizes them to prioritize environmental sustainability.

There are three main actors on Chinese oil and gas production market: China National Offshore Oil Corporation (CNOOC), China National Petroleum Company (CNPC), and China Petroleum and Chemical Corporation (Sinopec), which are the National Oil Companies that follow the central governments' targets and shape global oil markets. After 2020 new low-carbon energy resources and energy innovations became key priorities of development of China's oil and gas companies.

To mitigate the environmental impact, Chinese companies are exploring alternative energies like wind, solar, and hydrogen power. For example, CNPC is actively expanding business connected with hydrogen, Sinopec is emphasizing on hydrogen and geothermal energy, CNOOC utilities carbon capture technologies and green electricity supply on its offshore production facilities.

Companies continue to expand main hydrocarbon business to assure country's energy security. Interestingly, natural gas is categorized as low-carbon energy resource and is addressed as a bridge from fossil fuels to green energy resources because of its stable supply chains and low level of emissions compared with green and fossil energy sources correspondingly. Thus, companies continue to increase production of tight gas, coal bed methane, shale gas and traditional natural gas. Gas comprised 52% of CNPC's hydrocarbon production in 2022. Massive investments are being made in research and development to improve energy efficiency and reduce emissions. Companies are implementing advanced monitoring systems, modernizing infrastructure, and employing advanced drilling techniques to minimize waste and reduce the ecological footprint. Main feature of Chinese approach is harmony between fossil fuels and new energy resources.

Russian companies are also adapting their strategies to the challenges of low-carbon development. Gazprom is proactively developing the new park of vehicles, which are fueled with gas. In cooperation with Kamaz, Gazprom has constructed new autobuses and trucks, which can be fully fueled with low-carbon gas energy. Rosneft is increasing the share of natural gas in its production, sets goals of achieving zero routine methane flaring and methane emissions. Company is on the way to change the corporate transport to low-carbon and electric vehicles. Lukoil is also adopting its strategy to new trends in the world energy market. Lukoil has improved its documentation in the aspect of cooperation with contractors, that should comply with ESG-requirements. In addition to that, Russian and Chinese oil and gas companies are establishing effective communication and cooperation in low-carbon projects, connected with gas-supply, especially liquified natural gas.

In conclusion, the environmental strategies of major Chinese and Russian oil and gas companies reflect their recognition of the urgent need to address environmental sustainability. Necessity of urgent change shapes their approach, requiring a delicate balance between fossil fuels and new energy resources. By investing in green technologies, adopting traditional business to new requirements, and complying with stringent environmental regulations, these companies are taking steps towards a more sustainable future for China, Russia and the world. Collaboration and technological advancements hold the key to overcome challenges and ensure a smooth transition towards a greener energy landscape in the years to come.

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CREATION OF AN ECOCLIMATIC ATLAS FOR THE ZONE OF POTENTIAL ENVIRONMENTAL IMPACT OF OIL AND GAS INDUSTRY FACILITIES

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***Keywords**: analysis, inventory, monitoring, risk, environment*

The analysis of the potential impact of inventoried controlled technological and economic facilities of the oil and gas industry on environmental components assumes the timeliness of expert and analytical assessments.

The slow speed and lack of modern decision-making is explained by the complexity of identifying environmental and climate risks and zoning areas of relative actual and potential impacts of the oil and gas industry. At the same time, it is necessary to take into account a number of features of the territory (relief, climate, soils, etc.). To solve such problems, it is necessary to create a single geoinformation space for the accumulation of statistics and retrospective analysis and forecasting of the potential impact of these objects on environmental components.

The creation of an ecoclimatic atlas for the zone of potential impact on environmental components (Atlas) allows you to visually display temporal and geospatial data of multi-level environmental monitoring and evaluate organizational and technical measures for adaptation to climate change.

The creation and testing is based on a specialized methodology that implements a unified approach to organizing and conducting an assessment of climate and environmental risks

The Atlas interactive expert consulting hardware and software complex is created on the basis of updated databases based on cataloged cartographic and normative reference information, as well as a database of geospatial data, aerial and satellite images.

The operating environment of the ecoclimatic atlas should provide visualization of geo-spatial data and ensure the processing of digital cartographic information as part of a management decision support system for the assessment and rehabilitation of polluted components of the natural environment and improvement of environmental conditions.

The effectiveness of the Atlas is determined by a combination of management and environmental effects with the ability to control the timing of planning, environmental protection and adaptation measures. It is expected to reduce the time and labor costs for the preparation of routine and operational reporting on the impact of controlled facilities on environmental components.

FINE-TUNING THE CU-ZNOX INTERFACE VIA CONTROLLED CU SUBSTITUTION IN BASIC ZINC CARBONATE FOR ENHANCED LOW-TEMPERATURE METHANOL STEAM REFORMING

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Keywords: *low-temperature; methanol steam reforming; cationic substitution; Cu-ZnOx surfaces*

The conversion of methanol steam reforming to hydrogen offers a clean and viable solution for fuel cell applications, addressing the requirements of energy storage and efficient utilization. Herein, the Cu/ZnGaOx catalysts with abundant Cu-ZnOx surfaces have been produced. The degree of substitution of Cu^{2+} in zinc carbonate hydroxide can be precisely regulated by modulating the basicity during the co-precipitation process. It is discovered that mild substitution promotes the establishment of the Cu-ZnOx interface. The optimized catalyst exhibits ~50 % CH_3OH conversion with a corresponding H_2 production rate of 180 mmol g_{cat} h at 200 °C for a feed of CH_3OH/H_2O (1/2, mol/mol).

With the proposal of the "carbon neutrality" goal, hydrogen energy is expected to replace fossil energy as the backbone of economic and social development, playing an important role in energy, environment and chemicals. However, due to the difficulties in storage and transportation of hydrogen, its practical application has been hindered. Compared with gaseous hydrogen storage, low-temperature methanol steam reforming for hydrogen production is an economical and effective way to produce hydrogen. It is characterized by its relatively mild conditions for hydrogen production and the high hydrogen storage rate.

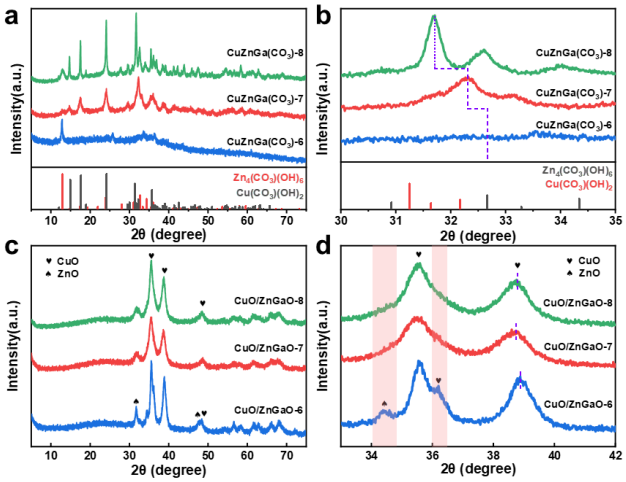

Figure 1 - (a b) XRD patterns of precursor (c, d) XRD patterns of CuO/ZnGaO-6,7,8

The Cu/ZnGaOx catalysts were prepared via a co-precipitation method, followed by the subsequent roasting and reduction processes. Basic zinc carbonate hydroxide was generated first during the co-precipitation procedure. As the pH of the solution increased, Zn^{2+} were gradually replaced by Cu^{2+}, forming bimetallic basic carbonate (Aurichalcite) in Figure 1a[1]. The generated basic carbonate's XRD diffraction peak is between that of basic copper carbonate and basic zinc carbonate in PH-7 (Figure 1b). The catalyst is a composite oxide of copper oxide and zinc oxide after air roasting, and the diffraction peak of copper oxide shifts to lower angles due to the strong interaction between Cu-ZnOx in Figure 1c, d.

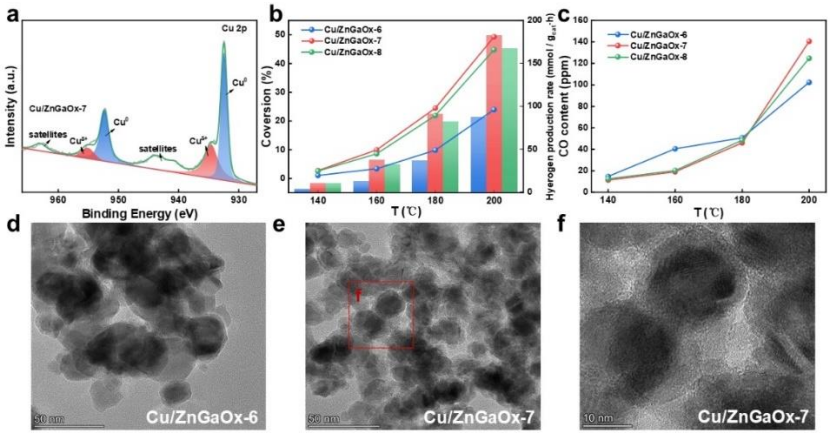

Figure 2 - (a) XPS of Cu/ZnGaOx-7, (b, c,) H_2 production rate, CH_3OH Conversion and CO content of CuZnGaOx-6, 7, 8, (d-f) TEM or HR-TEM of CuZnGaOx-6 and CuZnGaOx-7

The Cu 2p3/2 XPS spectra demonstrate that the Cu/ZnGaOx-7 catalyst exhibits both a zero-valent state and a partial positive-valent state, which can be attributed to the presence of the Cu-ZnOx interface (Figure 2a)[2]. Remarkably, the Cu/ZnGaOx-7 catalyst surpasses other catalysts in terms of its performance in low-temperature methanol steam reforming for hydrogen generation (Figure 2b). At a temperature of 200 °C and a feed ratio of CH_3OH/H_2O (1/2, mol/mol), the Cu/ZnGaOx-7 catalyst achieves an impressive ~50% CH_3OH conversion rate, accompanied by a H2 production rate of 180 mmol gcat h. Furthermore, the concentration of CO in the product gas remains below 150 ppm (Figure 2b, c). TEM analysis reveals the presence of abundant and distinct Cu-ZnOx contacts in CuZnGaOx-7, while such contacts are absent in Cu/ZnGaOx-6 (Fig. d-f). These observations align with the results obtained from XRD and XPS investigations. Overall, this discovery offers valuable scientific insights into the co-precipitation method for low-temperature methanol steam reforming.

In conclusion, the co-precipitation approach is a widely employed method in industry for manufacturing CuZnAl catalysts. However, its reaction activity at low temperatures is currently limited. To address this issue, this research has successfully controlled the creation of the Cu-ZnOx interface by modifying the metal's basic environment during co-precipitation. As a result, the hydrogen generation activity of CuZn-based catalysts at low temperatures has been significantly enhanced. Furthermore, advanced characterization techniques such as XRD, XPS, and TEM have been utilized to fully elucidate the precursor formation process in the co-precipitation process of CuZn-based catalysts. These findings shed light on the mechanism of the Cu-ZnOx interface and provide valuable theoretical guidance for the co-precipitation preparation of CuZn-based catalysts.

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DEVELOPMENT OF A METHODOLOGY FOR CALCULATING METHANE DISPERSION BY PIPELINE TRANSPORT FACILITIES

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Keywords: *blowing, methane, dispersion, methane emission, vent pipes*

Sources of methane emissions at gas industry facilities, in particular, at gas transport facilities, have features that determine the difficulties associated with the mathematical description of such sources of emissions and the application of traditional dispersion models to them.

One of the important features of such sources is that gas emissions are carried out at temperatures well below ambient temperature and even below 0 °C. Most existing models describing emissions of pollutants into the atmosphere or dispersion of pollutants are unable to process such sources.

Another important feature is the dynamic nature of the emission, that is, at each new moment in time, the emission source has new parameters – emission temperature, mass flow rate, and emission velocity. In addition, during the ejection process, there is a change in the gas flow mode from sound to subsonic, which leads to a change in mathematical expressions that should be put into the formation of a mathematical model.

The aim of the work is to develop a model of the source of emission and dispersion of hydrocarbon emissions, which allows to increase the reliability of the calculated results and ensure comparability of the initial data when calculating the dispersion of gas mixtures from multiple emission sources, as well as to create a unified methodological approach for calculating atmospheric air pollution by emissions of gas mixtures during technological operations of purging and venting gas from high-pressure apparatuses and pipelines to gas transportation facilities.

The work is based on the results of the analysis of scientific and technical literature, experimental data obtained during field experiments at gas transport

facilities, as well as calculated data obtained as a result of the development of mathematical models. The research was carried out on the basis of an experimental work plan developed on the basis of methodological recommendations for field studies.

The results of the study were

1. Development of a time-dynamic source model that allows calculating the parameters of the pollutant emission source at any given time. The source model takes into account the change in the expiration mode from critical to subcritical.

2. An integrated model of pollutant dispersion based on the Gaussian outflow model has been developed, which includes both the dynamic parameters of the emission source and the direct dispersion of pollutants.

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UPSCALING MODELING OF CARBON FLUXES IN THE NORTHERN HEMISPHERE USING MACHINE LEARNING AND MULTISPECTRAL REMOTE SENSING DATA

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Keywords: *machine learning, multispectral data, carbon sequestration*

Whereas terrestrial ecosystems are considered as one of the major carbon sinks on the planet, the existing numerical estimations of carbon budget of different territories still contain large uncertainty and need improvement. To fix this problem many researchers have tried to upscale *in-situ* measurements of CO_2 fluxes globally fusing machine learning approaches and remote sounding observations. Many publications were focused on application of classical algorithms such as Random Forest (RF) [1], Artificial Neural Networks (ANNs) [2], Support Vector Machine (SVM) [3] and others [4], when the models were fed with data acquired by different orbital instruments. However, while these research demonstrated relatively fair accuracy in predictions, good scalability and significantly outperformed process-based approaches in terms of time, there are still issues related to errors and uncertainty as well as explainibility of the models.

The current work aims to propose a new dataset, NorthFlux, comprising carbon fluxes estimations in the northern hemisphere. By combining a unique set of pre-processed features derived from MODIS Terra and Aqua product MOD09 CMG and MCD12C1 and climate reanalysis ERA5 on single levels an ensemble of machine learning models, in particular, ANN, RF, Extreme Gradient Boosting (XGBoost) and Adaptive Boosting (AdaBoost), was trained. As target parameters time series of Gross Primary Production (GPP), Ecosystem Respiration (RECO) and Net Ecosystem Exchange (NEE) were provided by FLUXNET and AmeriFlux networks for training and validation purposes.

When validating the training results, it was demonstrated that, in general, all four types of models were fairly accurate in evaluating GPP, RECO and NEE, however, the median ensemble prediction always had the lowest mean squared error (MSE) and the highest coefficient of determination (R^2): for GPP MSE = 2.012 $gCm^{-2}d^{-1}$ and R^2 = 0.884, for RECO MSE = 0.837 $gCm^{-2}d^{-1}$ and R^2=0.883, for NEE MSE = 1.454 $gCm^{-2}d^{-1}$ and R^2 = 0.773.

Acknowledgments: The study was supported by the Ministry of Higher Education and Science of the Russian Federation (Project No. FEUZ-2024-0011).

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NUCLEAR-HYDROGEN PRODUCTION VIA MODULAR HIGH-TEMPERATURE STEAM ELECTROLYSIS POWERED BY VVER-1000

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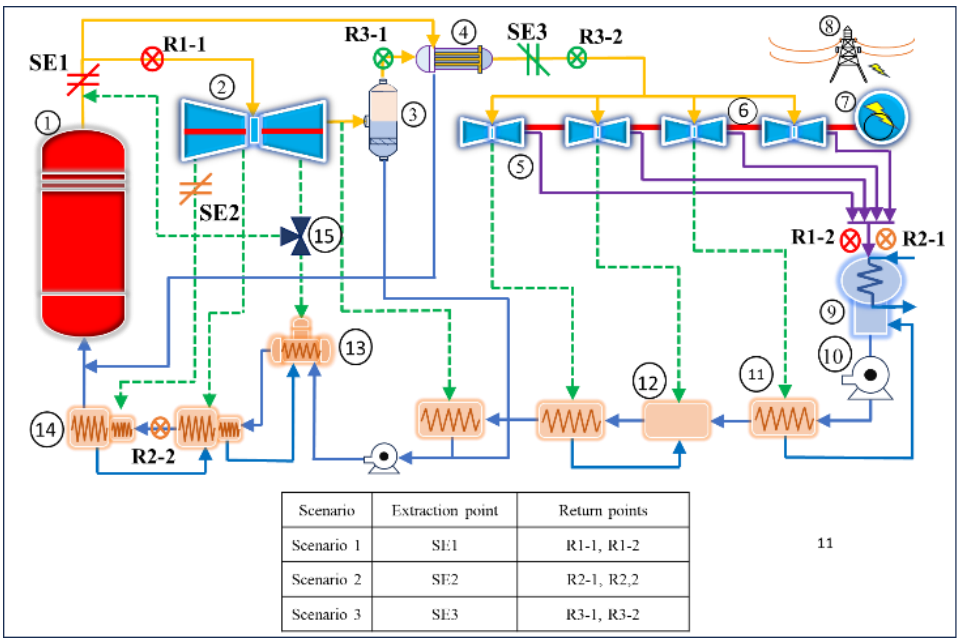
Keywords: *clean energy; nuclear hydrogen production; nuclear cogeneration; high-temperature steam electrolysis*

The generated heat by a nuclear cogeneration plant can be used in hydrogen production plants. The major aim of this study is to perform a techno-economic evaluation of integration of a modular high-temperature steam electrolysis (HTSE) plant into a light-water reactor. According to the obtained results, the total efficiency of the cogeneration plant increases by 5% for large-scale HTSE plants.

Methodology:

Technically, any type of nuclear reactor can be used in nuclear cogeneration plants [1]. In this work, a water-cooled reactor of VVER-1000 is introduced as the driving energy source of the HTSE plant. Potentially, there are three points in the second cycle of the nuclear power plant, which can be used for steam extraction process. In Fig. 1, the general scheme of the second cycle of NPP including the possible steam extraction points and return points are shown [2].



Scenario	Extraction point	Return points
Scenario 1	SE1	R1-1, R1-2
Scenario 2	SE2	R2-1, R2,2
Scenario 3	SE3	R3-1, R3-2

Figure 1 - Pictorial representation of three scenarios based on the second cycle of VVER-1000 nuclear power plant: 1- steam generator, 2- high-pressure turbine, 3- moisture, 4- reheater, 5- low-pressure turbine, 6- turbine shaft, 7- generator, 8- grid, 9- condenser, 10- pump, 11- preheater, 12- open preheater, 13- deaerator, 14- two-stage pre-heater, 15- regulating valve

Results:

One of the most significant results of the technical analysis is the efficiency of the power system. In Fig. 2, the electrical efficiency of the nuclear power plant (NPP) after extracting a certain amount of heat is presented and compared with the total efficiency of the cogeneration plant. As can be seen, although the electrical efficiency of the NPP decreases by increasing the hydrogen capacity, the total efficiency of cogeneration (thermal energy utilization) increases.

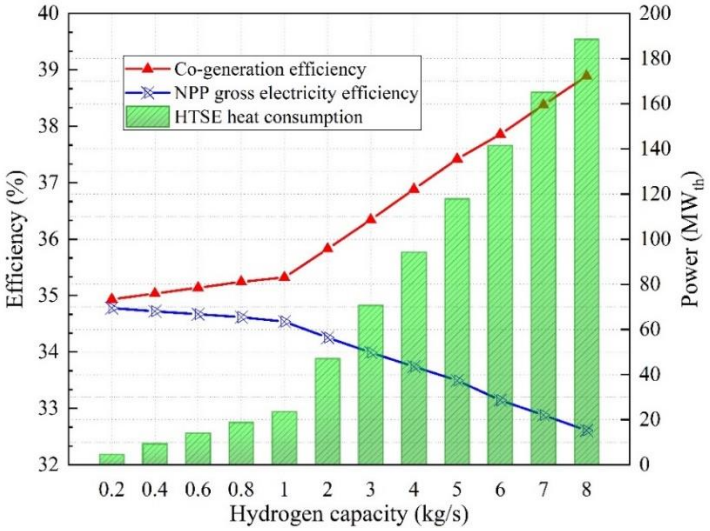


Figure 2 - Comparison of electricity efficiency and cogeneration efficiency of the system under different values of extracted heat

The results of the economic evaluation of the HTSE plant driven by VVER-1000 are shown in Table 1. The levelized cost of hydrogen (LCOHY) is made up of three major components, which are reported in this table.

Table 1 - Economic results of HTSE plant driven by NPP

H_2 Capacity (kg/s)	Capital $_{total-cost}$ (M$)	Annual $OM_{total-cost}$ (M$)	$Decomissiong_{cost}$ (M$)	LCOHY
0.2	26.711	18.592	2.069	4.168
1	129.848	92.116	10.058	4.122
2	255.640	183.861	19.802	4.109
4	502.738	368.165	38.942	4.107
6	746.514	551.969	57.824	4.101
8	988.180	737.295	76.544	4.105

Acknowledgment

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INTEGRATED ASSESSMENT OF THE ENVIRONMENTALLY FRIENDLINESS OF TECHNOLOGICAL PROCESSES OF MACHINING

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Keywords: *technological process. environmental impact. numerical estimation. integral environmental indicator*

The goal of the work is to develop a unified methodology for numerical estimations of the negative impact of technological processes of machining on the environment and humans for each specific implementation, that will enable evaluation of the negative impact and compare various technological processes machining for their environmental friendliness, as well as to formulate ways to reduce this negative impact.

The research method is based on the energy representation of technological processes of machining, which, with all their diversity [1] and different implementation conditions, can be described in terms of two processes: the process of converting electrical energy into mechanical energy and the process of transferring mechanical energy to the processing area.

Electrotechnical systems of process equipment carry out the first processes, technological equipment kinematics carry out the second process [2].

With this approach, the technological process of machining can be represented as the energy diagram shown in Fig.1. Energy diagram of the technological process,

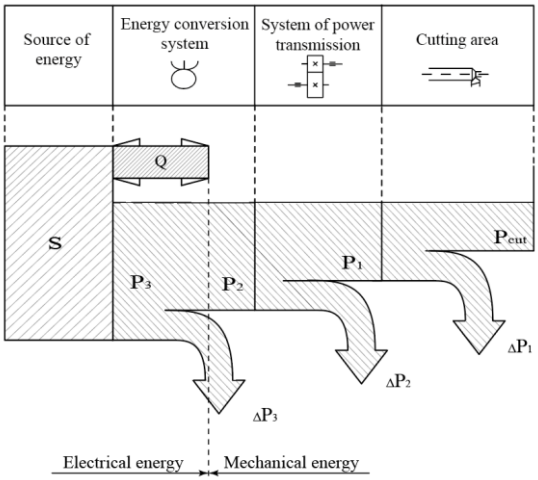

Figure 1 - Energy diagram of the technological process: where P_{cut} – cutting power, ΔP_1– losses in the cutting zone, ΔP_2 – mechanical energy transmission losses, ΔP_3– losses during the conversion of electrical energy into mechanical energy, P_1, P_2, P_3 – active component of power consumption, respectively, during transmission and conversion energy, Q – reactive component of power consumption, S – power consumption

Losses of the active component of the consumed power directly or indirectly determine the negative impact of the implemented technological process on the environment and humans, considering the state of the equipment and the presence of disturbing factors, and the reactive component of power consumption determines the excessive energy consumption during the implementation of this technological process, which is also an environmental factor.

$$S = \frac{P_{cut} + \sum_{i=1}^{3} \Delta P_i}{cos\,\varphi}$$

Where $\cos\varphi$ - phase angle of the electrical system (primarily the electric motor), P_{cut} -cutting power calculated by the technologist.

Energy analysis allows to formulate approaches to reducing energy consumption when implementing technological processes of machining and succeeded in numerically evaluating the complex effect of these processes on the environment and humans for each specific implementation, and their environmental friendliness [3].

This numerical estimate can be implemented by comparing of cutting power (P_{cut}) and power consumption (S) when implementing the technological processes of machining. Relation of the P_{cut} to S completely characterizes the negative effects and call it the integral environmental indicator I.

Research results has shown evident of the integral environmental indicator for the numerical assessment of the negative of technological processes of machining on the environment and humans.

In addition, two technological processes: hole boring process and drilling process the same hole were compared with this indicator in the conditions of production experimentally. These studies have shown that the drilling process in preferred by a factor of 1,44 in terms of ecology.

Integral environmental indicator can be increased by reducing losses and underloading of the machine tool.

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APPLICATION OF MECHANISMS FOR ZEROING GREENHOUSE GASES IN THE SAKHALIN REGION

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Keywords: *alternative energy, traditional energy, solar panels, wind power plants, environmental management, geothermal power plant, combined energy, resource conservation*

In the report, the analysis presents an analysis of the main trends in the development of ESG policy on the example of zeroing greenhouse gases in the Sakhalin region. The program to minimize emissions is based on the introduction of emission quotas for large oil and gas companies, as well as the transition of public transport to gas fuel, and personal transport to electricity. This approach to solving the problem will reduce the negative impact on the environment. Regulatory documentation in the field of environmental protection has been studied, as well as the program of decarbonization of the economy. The purpose of the work was to study the possibility of zeroing greenhouse gas emissions using the example of the Sakhalin region.

In the modern world, society has increasingly begun to think about the concept of sustainable development as part of the economic, social and environmental policies of countries, regions and companies. Despite the fact that sustainable development, as one of the ESG's agendas, has only recently begun to sound in the development programs of the regions of the Russian Federation, it is already possible to notice the potential of this program. That is why the Sakhalin Region has chosen the implementation of ESG goals related to resource conservation and environmental protection as one of the main directions of its development. Within the framework of these agendas, the program of decarbonization of the economy is being implemented. Since 2021, the government of the Sakhalin Region has begun to conduct an experiment to improve accounting and quotas for greenhouse gas

emissions into the atmosphere. This program is of an interdepartmental nature and is aimed at reducing greenhouse gas emissions and improving the environmental and social situation of the region by 2028. As part of this experiment, the largest industrial enterprises of Sakhalin and the Kuril Islands will reduce greenhouse gas emissions. which in turn will lead to their complete zeroing. In addition, the number of boilers running on coal and fuel oil on the islands will gradually be reduced and the transition to alternative energy sources will be made. The islands will also partially switch to cars, gas stations and buses powered by electricity. These innovations will not only reduce emissions, but also solve the problem of the lack of public transport on the skeletons, and, consequently, improve the state of the technosphere of the region.

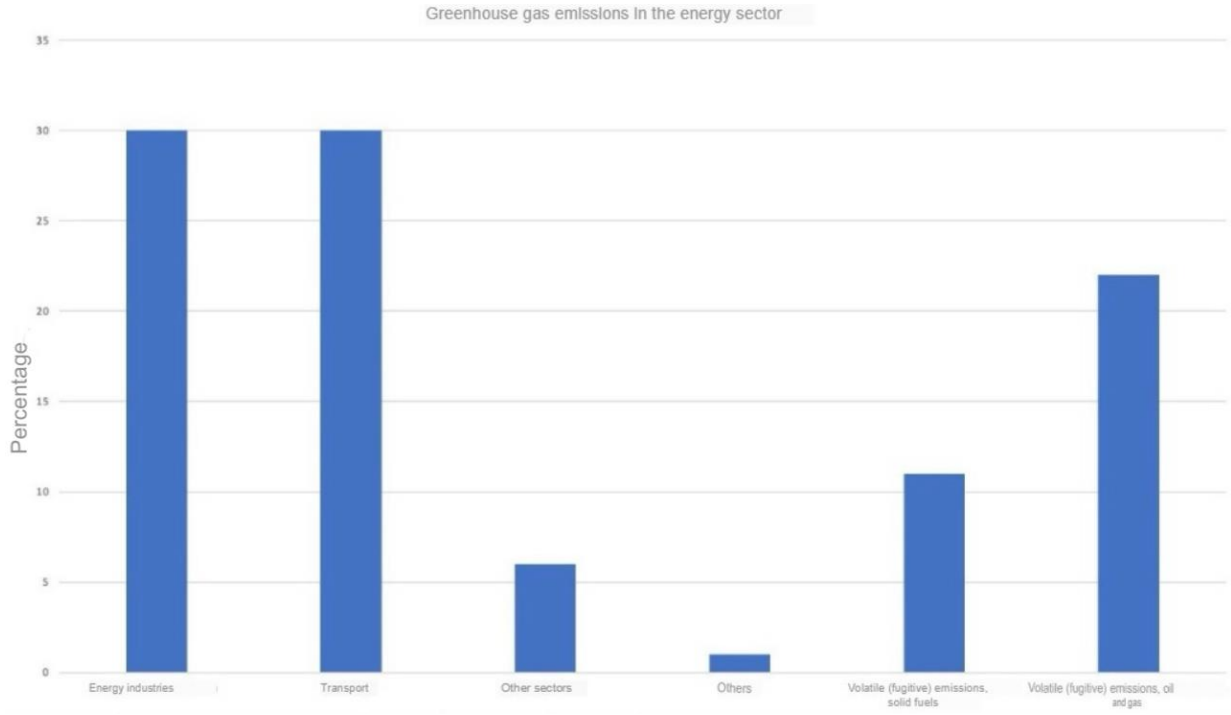

Figure 1 -Greenhouse gas emissions in the energy sector for 2022

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CREATION OF CARBON POLYGONS: ENVIRONMENTAL AND LEGAL ASPECTS

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***Keywords**: environmental protection, emissions regulation, legal regulation, carbon landfill, international cooperation*

In this research the authors analyze and evaluate the prospects for the formation and development of legislation of the Russian Federation in the field of creation and operation of carbon landfills. The purpose of the work is to characterize the legal aspects of the creation of carbon landfills.

The authors used the following methods to achieve the purpose of the research:

— legal analysis: research of legal acts and legislation regulating the creation and operation of carbon landfills;

— comparative analysis: a comparison of the practices of creating carbon landfills and their environmental and legal regulation in different countries and regions.

Carbon landfills are unique territories with certain natural and climatic conditions, where measures are being taken to determine the volume of greenhouse gas emissions and absorption. Currently, there are 18 carbon landfills in the Russian Federation, located on a total area of 39157.3 hectares.

The legal regulation of the creation and operation of carbon landfills is carried out in accordance with the general provisions of the first-level strategic planning documents:

— The Strategy of Scientific and Technological Development of the Russian Federation, approved by Decree of the President of the Russian Federation dated December 01, 2016 No. 642, regarding the need to conduct research on processes

occurring in the field of interaction between society and nature, the development of nature-like technologies, management climate and ecosystems, etc.;

— The Climate Doctrine of the Russian Federation, approved by Decree of the President of the Russian Federation No. 812 dated 10/26/2023, according to which state support measures are provided in the Russian Federation to ensure systematic climate observations in accordance with international standards; fundamental and applied research in the field of climate and related fields of science; application of research results to assess the risks and benefits associated with the consequences of changes climate change, as well as the possibility of adaptation to these consequences.

One of the main problems is the lack of a single clear legislative regulation of the activities of carbon landfills and farms. Currently, there are no special laws or regulations governing this area in Russia, which leads to some legal uncertainties in the implementation of such projects.

Based on the analysis, it can be concluded that territories and water areas with different legal regimes are provided and used to create carbon landfills. However, the legal regime of carbon landfills is not defined in the current legislation, since it is not clear by what criteria land plots from different categories of land, forest plots, water bodies or parts thereof are provided, as well as whether specially protected natural territories can be included in these lands and what is the legal regime for their use and protection. The procedure for the use of natural resources and facilities on the territory of carbon landfills has not been defined. The question is also open whether it is possible to conduct economic or other activities on these lands and whether this will interfere with the achievement of the goals of creating a carbon landfill.

However, in recent years, certain steps have been taken in Russia to strengthen the legal regulation of carbon landfills and farms. A number of laws and regulations aimed at strengthening control and supervision of these facilities have been developed and put into effect.

Additionally, it is necessary to mention the weak information support for projects of carbon landfills and farms. Insufficient information transparency and low public awareness can lead to distrust and resistance towards these projects.

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ON THE RIGHT TO USE ENERGY FROM THE PERSPECTIVE OF HOHFELDIAN THEORY OF LEGAL RELATIONSHIP

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Keywords: *the right to use energy, Hohfeld's theory of rights, legal relationship, theoretical construction*

As the cornerstone of energy economy,it has not been confirmed by Chinese law.The academic research on the related topic is still in the initial stage.Hohfeld's theory of rights is influential in the field of rights analysis.In this system,the right subject of personal information should belong to energy using company;the object of right is energy index;the content of the right to use energy is a rights collocation.When the subject of energy-using units enjoy right,privilege,power and immunity,the government bears the corresponding duty,no-right,disability and liability.

In 2015,the " Overall Plan for the Reform of the Ecological Civilization System "first proposed the term " the right to use energy " and proposed the implementation of energy use right transactions based on the total energy consumption management.However,the legal concept of the right to use energy is controversial.Only by clearly defining the legal concept of energy use right can we promote the further development of energy use right system.

The legal concept of the right to use energy is defined by Hohfeld theory.Which means,the right to use energy consists of eight parts.Energy-using units have the right to obtain the right to use energy through the initial allocation of the government.Meanwhile,it have the freedom to dominate the right to use energy which can be traded in the market,and subjects outside the energy-using units have no right to claim or interfere with the transaction.The government has the power to allocate the index to the energy-using units and an obligation to save energy.Subjects other than the government have no power to interfere with energy-using units.

Therefore,the legal concept of the right to use energy:under the background of realizing the total energy consumption control,the annual comprehensive energy use right index obtained by the energy-using units through distribution or transaction is allowed to be used.

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ECONOMIC ASSESSMENT OF DECARBONIZATION PROJECTS IN THE OIL AND GAS SECTOR

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Keywords: *low carbon development, emission reduction, oil and gas sector, economic efficiency indicators, decarbonization projects assessment*

According to scientific research, sustainable development strategies, and environmental reports, published by oil and gas companies, many of them have set targets to reduce greenhouse gas (GHG) emissions [1] to meet the United Nations Sustainable Development Goals (SDGs) and mitigate global warming and climate change[23]. To achieve the long-term goal known as "net zero emissions" and "carbon neutrality" by 2050, the targeted emission levels should be reached by 2030 at the latest. There are numerous decarbonization options [2] available, each with varying emission reduction impacts and capital and operating costs. Therefore, the decision-making process and prioritization of decarbonization efforts pose challenges for oil and gas companies. They need to assess the expected GHG reduction volume, compare it with the decarbonization costs, calculate the economic efficiency and decide what the decarbonization portfolio of a particular oil and gas company should look like: What kind of emission reduction projects should be implemented to achieve the decarbonization targets while avoiding or minimizing negative impacts on economic and other (environmental, social, etc.) parameters of the company's activity.

This research aims to define an appropriate toolkit for assessing decarbonization projects (DP) economically. In this article, we define "decarbonization projects" as projects or a group of measures that aim to reduce or

[2] Paris Agreement. URL: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

[3] Kyoto Protocol to the United Nations Framework. URL: https://unfccc.int/resource/docs/convkp/kpeng.pdf

avoid GHG emissions or increase CO2 absorption while meeting the criteria of emission reduction projects[4]. The DP results should be measurable by absolute indicators (amount of GHG emissions, tonnes of CO2 equivalent) or specific, relative indicators, e.g., carbon intensity (tonnes of CO2 equivalent per barrel of oil equivalent, TJ, etc.).

Additional stages of the decision-making process may also include technical evaluation, sustainable development assessment, health, safety and environmental assessment, and DP's risk assessment. These tools can be used to exclude unsuitable projects not in line with the company's strategy or policies from the list of potential projects. The regular economic evaluation of DPs should include an analysis of inflows and outflows [3].

A DP could not only influence the company's GHG emissions level but also reduce or increase other parameters such as materials and energy consumption; it could also change the overall environmental impact (pollutant emissions, waste generation, wastewater discharges, etc.). To proceed with the complex analysis of DPs and choose the most appropriate option, it is recommended to evaluate all kinds of changes brought about by these projects and extend the approach developed for the economic assessment of DPs [6]. For example, if we install a Carbon Capture, Utilization and Storage (CCUS) unit to reduce direct GHG emissions (Scope 1), we should consider the resulting growth in energy consumption and corresponding emissions (Scope 2) and calculate the additional GHG emissions as well as the increase in operating costs. Furthermore, the decarbonization equipment maintenance could also be a source of additional waste generation and pollutant emissions that companies must pay for according to the environmental tax rates. To obtain the most accurate evaluation results possible, the economic assessment toolkit should include a quantitative financial analysis of all changes. Table 1 provides examples of categorizing the major changes in operating expenses "inside" and

[4] ISO 14064-2:2019. Greenhouse gases. Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. URL: https://www.iso.org/standard/66454.html

"outside" the DP, which can be considered as the difference between positive and negative impact.

Table 1 - Examples of operating expenses increase and reduction caused by a DP

№	Category, indicator	Expenses growth example (E_G)	Expenses reduction example (E_R)
1	Environmental impact: waste generation, discharges, pollutant emissions (ΔEnv_i)	Blue hydrogen production process (stream methane reforming) increases CO_2 emissions, wind turbines generate a significant amount of waste after their service life is over	Reducing the flaring of associated petroleum gas lowers pollutant emissions
2	Consumption of materials and resources used "inside" and "outside" the DP project (water, sand, chemicals, metal, fuels and lubricants, etc.) (ΔMR_i)	The installation of new equipment (e.g. CCUS) could entail additional fuel and lubricant consumption	Modernizing equipment could reduce the cost of ongoing maintenance and repair work and require fewer chemicals
3	Services used "inside" and "outside" the DP project (transportation) (ΔS_i)	The installation of new equipment could require additional transportation of materials and personnel	Modernizing equipment could reduce the cost of ongoing repair and transportation of materials and personnel
4	Energy resources used "inside" and "outside" the DP project (electricity, heating, steam, cooling) (ΔEn_i)	Direct air capture technology requires additional electricity consumption (for pumps and other equipment)	Heat insulation measures could reduce heating energy consumption

Source: compiled by the author

Using the approach described above, the formula for the cash flow of a decarbonization project (DCF) [6] could be modified and extended as follows (1):

$$DCF = ER \cdot P_{CU} + Q_{new} \cdot P_Q - CAPEX - (\Delta Env_i + \Delta MR_i + \Delta S_i + \Delta En_i) - (E_0 - E_q - ER) \cdot T_e, \quad (1)$$

where:

DCF – decarbonization project cash flow, RUR,

ER – emission reduction, tn.CO2-eq,

P_{CU} – price of carbon unit, RUR/ tn.CO2-eq,

Q_{new} – new production quantity, units,[5]

P_Q – price per one unit of new product, RUR/unit,

CAPEX – capital expenses, RUR,

$\Delta Env_i, \Delta MR_i, \Delta S_i, \Delta En_i$ – difference between environmental taxes, materials and resources, services and energy operating expenses reduction and growth, RUR[6],

i = (R, G): R – reduction, G – growth,

E_0 –baseline GHG emissions, tn.CO2-eq,

E_q- GHG emissions allowances, tn.CO2-eq,

T_e – GHG emissions tax, RUR/ tn.CO2-eq.

The criteria of the most effective and appropriate DP is: $DACF \rightarrow max$. Ranking and prioritizing DPs is a pivotal stage of sustainable and low-carbon development of oil and gas companies. To make the most accurate and appropriate decision, it is recommended to consider all factors affecting the company's operating costs, both «inside» and «outside» the decarbonization project.

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[5] as a result of the decarbonization project, if applicable

[6] in brackets, the growth in expenses is shown with a plus sign, and the reduction in expenses with a minus sign

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CHIRAL-SELECTIVE CATALYSIS IN DOPA OXIDATION BY HEMIN-PEPTIDE CO-ASSEMBLED ARTIFICIAL PEROXIDASES

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Keywords: *peptides, artificial peroxidases, hemin*

In this study, we have engineered an artificial peroxidase through the co-assembly of amphiphilic short peptides and hemin, aiming to achieve chiral selectivity in catalysis, a hallmark of natural enzymes. The peptides, Ac-I3LH-NH2 and Ac-I3DH-NH2, form right- and left-handed helical nanofibers, respectively. These co-assemble with hemin via coordination between the histidine's imidazole group and hemin's Fe(III) center, preserving their helical structures. The catalytic efficiency and chiral selectivity of these artificial peroxidases were evaluated using L- and D-DOPA as substrates, with results indicating distinct activity preferences based on the handedness of the peptide nanofibers. This suggests that the imidazole conformation and nanofiber chirality influence the enzyme's chiral selectivity, transferring these properties from the peptides to the catalytic performance of the co-assemblies.

Peptides, bridging the gap between amino acids and proteins, are pivotal biomolecules characterized by their simplicity, modifiability, and excellent biocompatibility. They readily form supramolecular assemblies driven by hydrogen bonding, hydrophobic interactions, aromatic stacking, and electrostatic forces, making them a hot topic in molecular assembly research. Over recent decades, researchers have designed various peptides with diverse biological functions and self-assembly characteristics through rational design and random evolution. Incorporating other biomolecules into peptide supramolecular systems not only influences peptide assembly but also endows these structures with new biological functions. Among these, peptide-porphyrin co-assemblies have garnered significant attention.

Porphyrins and their derivatives play crucial roles in physiological functions within biological systems. Hemin, extensively utilized in the design of artificial enzymes, has been proven to exhibit enzymatic functions when co-assembled with peptides or amino acid derivatives. Different types of peptides, including α-helix, β-sheet, β-hairpin, lipopeptides, and modified amino acid derivatives, have been explored for co-assembly with porphyrins, providing spatial structures akin to natural enzymes. Furthermore, hydrogels formed from peptides and peptidic materials can reduce the dimerization of hemin molecules and degradation during catalytic processes, offering a stable microenvironment essential for the reactive centers.

Chirality selectivity, a vital feature of natural enzymes, is a key focus due to the expensive and unstable nature of natural enzymes. Hence, constructing controllable chiral-selective artificial enzymes is an attractive alternative. Previous studies, such as those by Korendovych[1] and colleagues, have demonstrated the creation of mimetic enzymes through the co-assembly of short peptides with hemin chloride. These enzymes efficiently catalyze reactions with high enantiomeric excess (ee) values. Liu[2] and others have shown that the chirality of amphiphilic histidine derivatives influences the rate of catalysis of the same chiral substrates by hemin chloride. Research involving G-quadruplex DNA and copper ions in mimetic enzyme construction revealed that a change in the DNA conformation from anti-parallel to parallel structures reversed the ee values in catalyzing Diels-Alder addition reactions, indicating that the spatial structure of the reaction center can create an environment conducive to selective catalysis.

In our study, we designed an amphiphilic short peptide, I3H, featuring a hydrophobic tail composed of three isoleucine residues and a hydrophilic histidine head. Inspired by previous research, altering the chirality of the hydrophilic histidine end allowed us to construct nano-helical structures of varying orientations. By titrating with hemin chloride, we investigated its impact on the assembly process of the histidine-containing short peptides. Moreover, we co-assembled short peptides with different chiral hydrophilic end residues with hemin chloride to construct

mimetic enzymes with varied chiral microenvironments. Dopamine (3,4-dihydroxyphenylalanine) exists in two enantiomers: L-DOPA, used in treating Parkinson's disease and hepatic encephalopathy, and the biologically inactive D-DOPA. To explore the selectivity differences of the mimetic enzymes for different chiral substrates, we used L-DOPA and D-DOPA as substrates, oxidizing them to dopachrome under the catalysis of mimetic enzymes with different chiral structures.

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DEVELOPMENT OF A METHODOLOGICAL AND HARDWARE TOOL FOR TOXICITY CONTROL WITH THE POSSIBILITY OF ASSESSING THE TOXICITY OF POLYMER COMPONENTS OF SOLAR PANELS

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Keywords: *polycrystalline solar panels, ethylene vinyl acetate, polyvinyl fluoride, biotesting, paramecium caudatum, extraction medium, extract temperature, extract holding time, computer vision*

Currently, there is an urgent question about the sufficiency of approved sample preparation methods for the case of compounds that are sparingly soluble or completely insoluble in distilled water. One example of such chemical compounds is the components of polycrystalline solar panels. Today, the final stage in the life cycle of approximately 90% of all solar panels is disposal. However, some components, such as photovoltaic cell, frame, can be reused [1, 2] It can be concluded that the study of the toxicity of components of solar panels, such as EVA and Tedlar®, is extremely relevant in the context of their widespread use and little knowledge.

Assessing the state of the environment using instrumental biotesting based on the interaction of microorganisms with limited sample volumes is a promising method. This approach, taken together, provides a comprehensive response that allows the overall environmental impact to be assessed, taking into account cumulative effects and complex interactions.

As part of the work, the preliminary stage was research related to the selection of a test object that will be the most sensitive when conducting experiments with polymer films included in polycrystalline solar panels, EVA and Tedlar®. The most common instrumental biotesting methods in environmental laboratories include

methods with the following test organisms: ciliates Paramecium Caudatum, algae Chlorella vulgaris beijer and bacteria Escherichia coli.

To determine the most sensitive test organism, studies were carried out to determine the toxicity of the polymer components in accordance with accredited methods for each test object. According to the results of the experiment, the greatest sensitivity is observed in the ciliate Paramecium Caudatum, since the results of the biotest analysis were closest to the threshold value, which corresponds to inhibition of the test function of the system, therefore, the manifestation of a pronounced toxic effect. Currently, there is an approved method for using this test of the organism using the Biotester 2M measuring device.

The stages of the study were determined: determining the influence of physicochemical factors on the sample preparation procedure for polymer materials included in solar panels during biotest analysis, assessing the possibility of reducing the time of the experiment by using a different extractant, testing the developed analysis model and the possibility of its application.

At the first stage of the study, the dependence of changes in the toxicity of EVA and Tedlar® materials on three factors was determined - the size of the fraction of components of used solar panels, exposure time and ambient temperature. As a result, it became clear that when materials are kept in distilled water for a long time, the toxicity of the solution changes, which leads to the assumption that it is necessary to develop a special method for recycling complex technical devices that contain these materials. One of the factors influencing the complexity of studying polymer components is the long time it takes to extract pollutants into the environment. To increase the rate of extraction of pollutants from poorly soluble polymer materials, it was proposed to use a 1% solution of acetone in distilled water. Studies with ciliated microorganisms have shown the resistance of the ciliate Paramecium Caudatum to low concentrations of acetone [3, 4]. Changes were made to the standard sample preparation procedure, which made it possible to evaluate in detail the influence of physicochemical factors on the formation of the system response and significantly reduce the time required to conduct the experiment.

Biotesting methods based on photometry have become widespread, but they are subject to certain disadvantages that affect the accuracy of the research results. First of all, this concerns the limited volume of the liquid being tested, since the sample is probed with a beam, which makes it difficult to accurately measure the number and speed of cell movement, and also involves a significant amount of manual labor during sample preparation.

To simplify research, reduce the amount of manual labor and increase the reliability of assessing the toxicity of the aquatic environment, it was proposed to develop hardware that would allow monitoring changes in the state of the entire cell population. To solve this problem, it was proposed to use a method based on computer vision technology. This system uses a digital camera as a sensitive sensor, which records changes in the distribution of the entire cell population throughout the entire volume under study, and also makes it possible to study changes in the speed of cell movement over time.

A functional prototype of the system was developed, which includes a digital camera, a backlight module and special containers for analysis. The device connects to a personal computer using a USB interface. The chemotactic reaction is recorded using special software. Then the resulting video materials are processed by a program written in Python and using the OPENCV library. During processing, many factors are taken into account, such as cell distribution, movement speed, etc. Expanding the range of monitored factors makes it possible to more reliably judge the toxicity of the test sample and give a more accurate conclusion.

The results showed that the use of modern technologies and modernization of biotesting methods can significantly expand the range of studies, simplify, speed up and increase the reliability of the results.

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DEVELOPMENT OF A METHODOLOGY FOR CALCULATING OIL AND PETROLEUM PRODUCT SPILLS FOR UNDERGROUND STORAGE SYSTEMS WHEN DEVELOPING PLANS FOR THE PREVENTION AND ELIMINATION OF OIL AND PETROLEUM PRODUCT SPILLS AT OIL AND GAS FACILITIES

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Keywords: *industrial safety, oil and petroleum product spill, emergency, underground reservoirs, calculation method*

One of the most important issues of emergency prevention, including those caused by oil spills, petroleum products, chemically hazardous substances and fires, is timely and adequate planning of measures to prevent them, as well as the readiness and sufficiency of response forces and means.

Given the importance of ensuring an adequate level of environmental protection in the implementation of projects related to the activities of enterprises in the Russian Federation, there is a need for an integrated approach to solving problems of ensuring industrial and environmental safety, including at oil and gas production facilities.

To implement the state policy in the field of public protection, reduce the risks associated with oil and petroleum product spills, ensure industrial safety of enterprises, including fire extinguishing, as well as eliminate the consequences of accumulated environmental damage, in order to restore natural systems previously exposed to negative anthropogenic and man-made impacts.

As part of the research and development, an important aspect is the effective management of risks associated with the spill of oil and petroleum products in underground reservoirs. However, at the moment there is no comprehensive calculation methodology that would help assess the likelihood and consequences of such spills.

The need for such a technique is related to the increased interest in the exploration and exploitation of oil fields, as well as the growing number of oil loading transit stations and oil depots in various regions. In this regard, there is a need for accurate and reliable calculations of oil and petroleum products spills in underground reservoirs, which will allow predicting possible consequences and taking appropriate precautions.

Given the complexity of this problem, it is necessary to conduct a series of comprehensive studies that include an analysis of various factors affecting the spill of oil and petroleum products in underground reservoirs. This approach will help us better understand the physical, chemical and geological processes, as well as the conditions in which a spill may occur.

The result of this study will be the development of a methodology for calculating the spill of oil and petroleum products for underground reservoirs, which will effectively manage risks and minimize the possible consequences of a spill. Providing evidence-based data and recommendations in this area will be useful for the industry and will allow making informed decisions in the field of oil production safety and transportation and storage of oil and petroleum products.

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THE USE OF THE NDVI INDEX TO STUDY THE STATE OF VEGETATION COVER ON THE TERRITORY OF PETROCHEMICAL ENTERPRISES IN KSTOVO

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Keywords: *petrochemistry, vegetation analysis, remote sensing, geoecological problems of petrochemistry, oil refinery*

Due to consumer, transport and a number of other factors, large industrial enterprises are located near residential buildings, as well as valuable ecosystems. This condition creates an immediate geoecological threat not only to the life of the population, but also to the neighboring natural systems of the territory. The city of Kstovo is located in the Nizhny Novgorod region, on the right bank of the Volga River and occupies a large area, there are several villages and villages nearby, other settlements, as well as agricultural land. The vegetation cover of the territory consists of spruce and pine, mixed forests [1].

In the southwest of the residential development of the city there is a large cluster of petrochemical enterprises, the largest enterprises - LLC Lukoil-Nizhegorodnefteorgsintez and LLC Sibur Kstovo, as well as waste disposal facilities

The proximity of a large oil refinery and chemical plants, as well as waste disposal facilities that are part of each other's sanitary protection zones, primarily leads to the effect of summation of pollutants from these enterprises, which affects the vegetation cover of the territory. The Landsat 8 satellite system was selected for its evaluation [2].

To compare and interpret the results, a vegetation map was compiled by tree species and correlated with the values of the NDVI index by territory. (Figure 1). The analysis of the studied area was also carried out using NDVI index calculation methods (Figure 2).

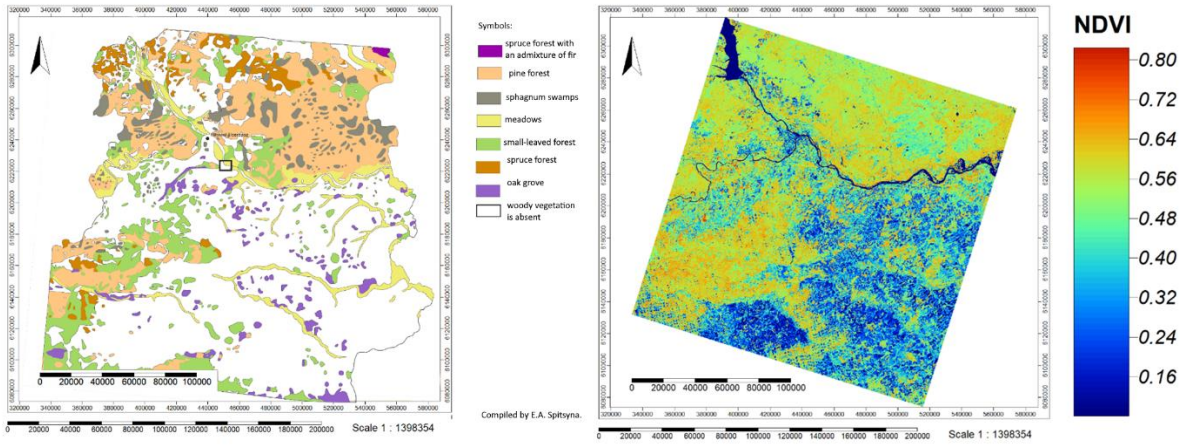

Figure 1 – comparison of the vegetation map of the Nizhny Novgorod region with the values of the NDVI index for the territory

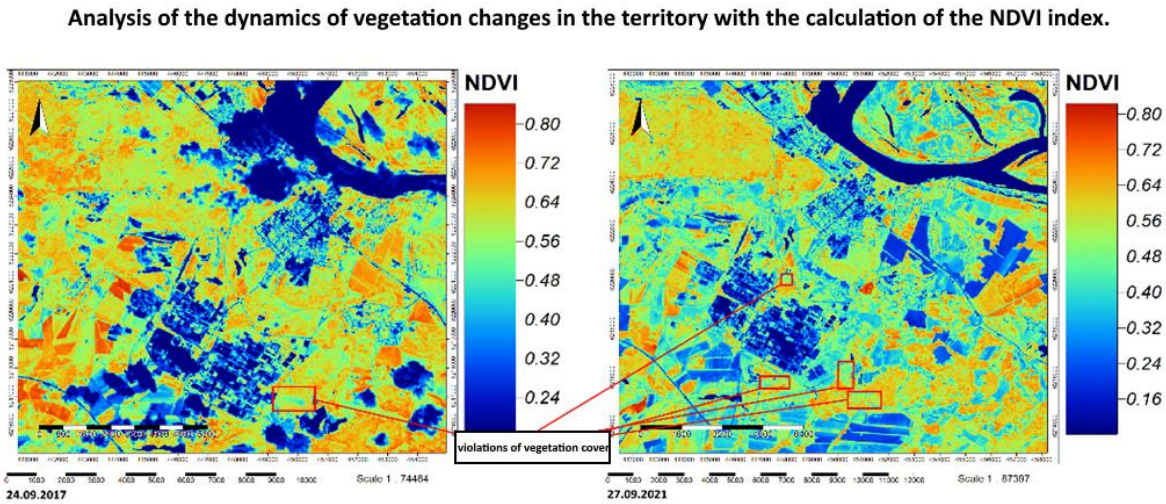

Figure 2 – analysis of the dynamics of vegetation changes in the territory with the calculation of the NDVI index

Thus, vegetation disturbances corresponding to the direction of the winds have been established on the territory, which may indicate environmental degradation due to the functioning of a large industrial cluster, during the planning of which the CVD facilities were violated.

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SELECTIVE HYDROGENOLYSIS OF FURFURYL ALCOHOL TO 1,5-PENTANEDIOL OVER MOF DERIVED CO-BASED CATALYST WITH CO-AL_2O_3 SITES

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Scientific adviser: Doctor of Chemical Engineering and Technology, Lecturer Dandan Liu

Keywords: *biomass, furfuryl alcohol, 1,5-pentanediol, hydrogenolysis*

Based on the cobalt-based MOF, we design and prepare high-performance catalysts with efficient Co/Al_2O_3 active sites, high specific surface area and stable structure for the synthesis of 1,5-pentanediol by hydrogenolysis of furfuryl alcohol. The synergistic effect and relative position are crucial for the ring-opening process of furfuryl alcohol. In addition, the high surface area could also promote the reaction.

1,5-Pentanediol (1,5-PDO) is an essential monomer for the synthesis of polyester, polyurethane and pharmaceutical intermediates[1], in addition it could also act as an important intermediate or green solvent in chemical synthesis. With the constant development of social economy, the industrial demand of 1,5-PDO is growing rapidly, and the low production capacity through C5 petrochemical products resulted in the high price of 1,5-PDO. Therefore, the development of green, and low-carbon synthesis of 1,5-PDO through biomass route, furfural hydrogenation, has a wide development prospect and application value[2,3,4,5]. In this study, we synthesized a difunctional sites $Co\text{-}Al_2O_3/C$ catalyst though Co-MOF, and the obtained catalyst could realize the adsorption-hydrogenolysis of furfuryl alcohol (FOL) through $Co\text{-}Al_2O_3$ active sites. The large specific surface area inherited from MOF precursor, could provide more accessible sites for the reaction, which resulted in a highly selective conversion to 1,5-pentanediol.

Cobalt nitrate and 2-methylimidazole was fully dissolved in methanol separately. Then the two solutions were mixed and remained at room temperature for 24 h. The mixture was filtered, washed, and then dried to get Co-MOF precursor.

The aluminum nitrate was introduced by incipient impregnation to obtained Co/Al-MOF, followed by pyrolysis at specified temperatures.

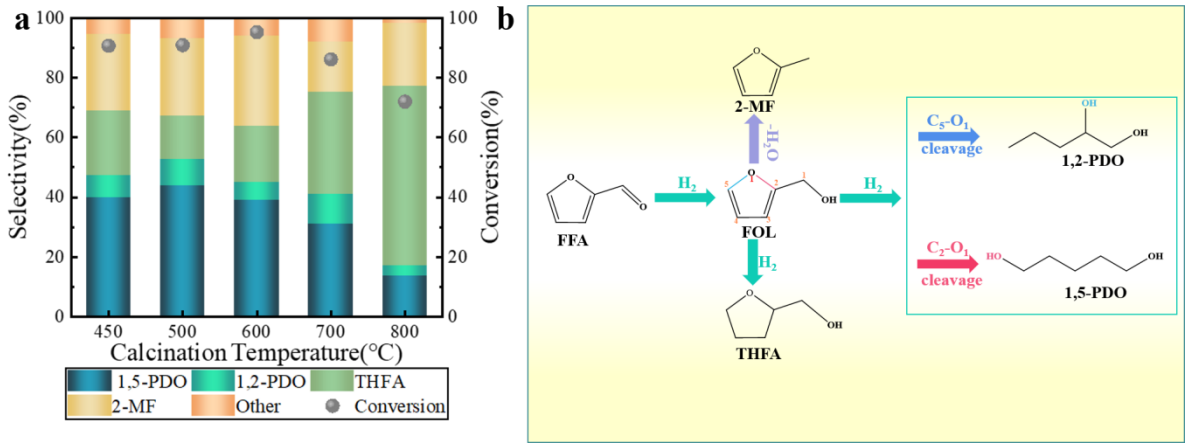

Figure 1 - a Catalytic performance of catalysts derived from Al/Co-MOF at different calcination temperatures, b Hydrogenation pathway of furfural and its derivatives

The performance of the samples was tested in a stainless-steel batch reactor using FOL as reactant. From Figure 1, the conversion of FOL could reach 90 % when using catalyst obtained below 600 ℃, then the conversion was decreased to 72 % at same reaction condition when the temperature raised to 800 ℃. The selectivity of 1,5-PDO presented similar tendency. The optimized selectivity of 1,5-pentanediol could reach 43.8 % when using catalyst obtained at 500 ℃, which was well-matched with the reported literature. Combined with the characterization results, during the decomposition of Co-MOF, Co^{2+} was reduced to metallic Co with high dispersion, and aluminum nitrate transformed into amorphous alumina. The acidic site could anchor and activate furfuryl alcohol through hydroxyl groups, and then the hydrogenation site attacked the C_2-O_1 bond, realizing the formation of 1,5-PDO. In addition, the high specific surface area inherited from MOF is facilitate for the mass transfer, enhancing the reaction efficiency than traditional transition metal catalyst. The catalyst obtained at high temperature possessed agglomerated Co nanoparticles, which is favor for the hydrogenation of furan ring.

Table 1 - Comparison of the performance of various catalysts

Sub.	Catalyst	Conv. (%)	Sel. (%) 1,5-PDO	Sel. (%) 1,2-PDO	1,5-PDO Productivity ($mmol \cdot g^{-1} \cdot h^{-1}$)	Ref.
FOL	Cu@MgO-La_2O_3	94.9	18.8	63.7	0.4	2
	1Ni11CoAl	99.6	42.5	12.2	1.8	4
	Cu-Mg_3AlO_4	63.1	30.5	50.0	0.5	6
	Co-Al_2O_3/C	91.7	43.8	8.9	3.3	This work

In summary, compared with the traditional transition metal catalysts, the catalysts derived from MOF could realize the order combination of adsorption and hydrogenolysis sites in microcosmic. Thus promoting the conversion of FOL to 1,5-PDO and provide significant advantages compared to reported catalysts (Table 1). This work offers a new strategy to obtain efficient metal-acid sites bifunctional sites for the formation of 1,5-PDO through FOL route, and deepen the understanding the mechanism of transition metal catalysts.

This work was supported by the National Natural Science Foundation of China [grant number 22005342].

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MODERNIZATION OF COMBINED HEAT AND POWER PLANTS AS A CONDITION FOR INCREASING ENERGY INTENSITY AND ENVIRONMENTAL FRIENDLINESS DURING THE ENERGY TRANSITION

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Keywords: *EV, natural gas vehicle fuel (NGV), motor fuel, comprehended natural gas (CNG), liquefied natural gas (LNG)*

The position of replacing internal combustion engines with electric vehicles is becoming more and more realistic every year. The growth in electricity production indicates a growing demand for environmentally friendly fuel. One of the most important principles of the new energy paradigm is safety, environmental friendliness and independence of countries from external energy supplies. Electric cars answer many challenges of modern society: they are environmentally friendly, since they do not emit carbon dioxide, consumers do not depend on exported motor fuel, since electricity can be generated from renewable energy sources, but the electricity can be from thermal power plants. This raises the question, is energy clean? Is the request for environmental friendliness fulfilled if the electricity was generated at a coal-fired power plant?

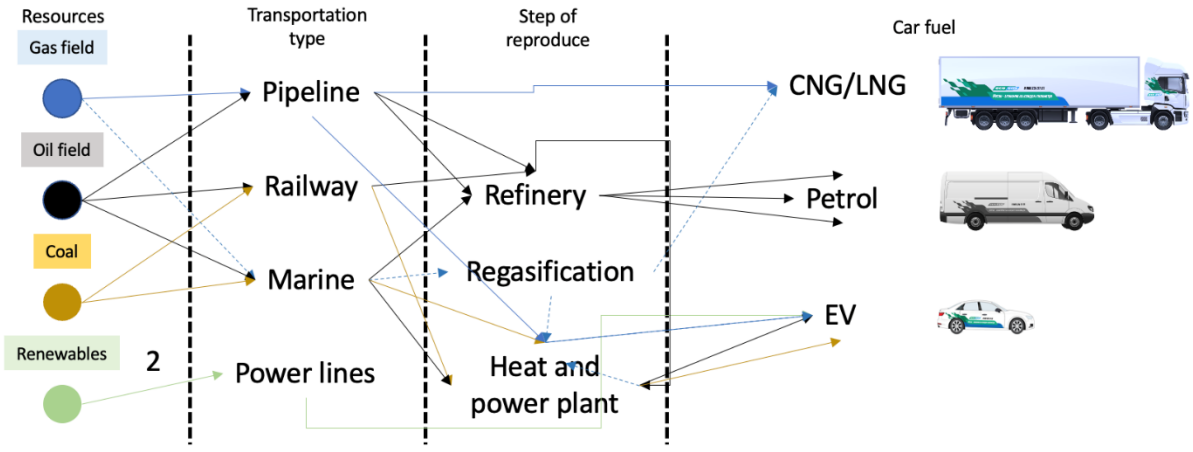

Figure 1 - Producing a fuel chain

The possibility of total electricity generation only from renewable energy sources in the near future is not a realistic goal, but the replacement and modernization of outdated thermal power plants with non-environmentally friendly fuels is a fairly realistic goal.

Technical projects for the modernization of energy enterprises that generate heat and electricity recommend the widespread use of natural gas as a process fuel (since, firstly, natural gas is characterized by a higher calorific value compared to coal, and, secondly, the use of gas accompanied by a number of other positive operational benefits).

COMPETITIVE ADVANTAGES OF SMALL-SCALE LIQUEFIED NATURAL GAS PRODUCTION PROJECTS

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Keywords*: sustainable development, liquefied natural gas, competitive advantage, gas market, environmental safety, energy security, LNG projects, small-scale LNG production*

The purpose of the study is to determine the competitive advantages of small-scale production of LNG (liquefied natural gas) at the current stage of development of the gas market.

The work substantiates the competitiveness of LNG as one of the promising environmentally friendly types of energy carriers.

The advantages of LNG production and transportation are considered.

The role of small-scale LNG production in the socio-economic development of Russia has been determined.

An analysis of the factors determining the state of the domestic liquefied natural gas market was carried out.

When conducting the study, methods of observation, comparison, analysis and description were used.

The relevance of the study is due to the fact that with the introduction of sanctions, the directions and volumes of interregional trade in energy resources have changed, and the risks of untimely commissioning of production capacities have increased.

The global LNG industry includes large-scale, medium-scale and small-scale production. The goal of large-scale production is to ensure supplies of LNG to world markets. Small-scale production ensures interregional trade and meets demand in the domestic market.

The small-scale production segment of liquefied natural gas consists of plants with a production capacity of up to 10 tons per hour (about 125 million cubic meters per year). Small-scale production of LNG is carried out at local installations located near gas pipelines, with delivery to consumers for use as gas motor fuel, as well as to replace diesel fuel or heating oil in enterprises with energy-intensive technology. The creation of mini-plants in conditions of economic crises makes it possible to solve problems associated with the use of resources from small gas fields, the connection of which to the main pipe is unprofitable. Mini-plants help solve the problems of gasification in remote regions. Switching part of the transport to gas helps reduce costs and expand the domestic natural gas market.

The small-scale LNG segment refers not only to LNG production facilities, but also to gas storage and distribution facilities.

The competitive advantage of small-scale production of liquefied natural gas is the ability to fill market niches that are economically unprofitable for large-scale production and network gas (autonomous energy supply, decentralized gas supply, mobile energy, freight transportation, quarry equipment, bus services, harvesting equipment, bunkering).

The main competitors of small-scale production of liquefied natural gas in the domestic market are pipeline gas, coal, petroleum products (diesel fuel, fuel oil), electricity, renewable energy sources (biofuels, wind power, geothermal energy).

Liquefied natural gas allows you to diversify the directions of gas supplies. This smoothes out uneven gas extraction and ensures peak demand.

The main limiting factors for the development of the domestic market are: low demand (small number of vehicles consuming natural gas motor fuel), imperfection of the regulatory framework, and problems of import substitution. The development of the domestic liquefied natural gas market is possible by increasing the number of vehicles using natural gas motor fuel, reducing capital costs for the construction of factories and gas stations, and increasing the production volume of equipment for mechanical engineering infrastructure.

The economic and synergistic effects of the development of the liquefied natural gas market and the introduction of LNG mini-plants were: the creation of new jobs at production and sales facilities, an increase in the tax base through the creation of value-added products.

Natural gas suppliers get the opportunity to diversify gas supplies, enter new markets, expand the product line, the ability to quickly respond to the demands of gas consumers thanks to the mobility of liquefied natural gas supplies, no need to connect to the gas distribution infrastructure, and directly enter the retail gas market and end consumers of gas.

The attractiveness of small-scale liquefied natural gas production projects is increasing in the context of falling prices for oil and natural gas. Capital investment in small-scale liquefied natural gas production is significantly less than in a large-scale plant. The construction period for a small-scale plant ranges from one to three years, while the average construction period for large-scale plants is 5 years. The payback period for small-scale projects is shorter than for large-scale projects.

Industry problems and risk factors in the gas industry are the increase in costs in the production and transportation of gas to the domestic and world markets (reduction of highly productive and shallow reserves in development, transition to the development of fields with difficult climatic and geological conditions, remoteness of new production areas from gas consumption centers).

The objectives of the gas industry to meet the needs of the socio-economic development of the Russian Federation include: improving the domestic gas market and effectively meeting domestic demand for gas; development of production and consumption of liquefied natural gas, development of production and increase in consumption of gas motor fuel (using liquefied natural gas).

A set of measures to ensure the solution of these problems includes the development of the production of small-scale liquefied natural gas and the formation on its basis of a domestic market for liquefied natural gas as a tool for ensuring the energy security of territories remote from the Unified Gas Supply System.

LNG allows consumers to obtain energy cheaper than classic petroleum fuels - diesel fuel and gasoline. LNG has a price discount to diesel fuel. This competitive advantage is used to promote LNG in the motor fuel segment. In order to attract buyers, the price of LNG is set at a discount to diesel fuel.

LNG has commercial, environmental and energy advantages over traditional fuels (reducing the amount of harmful emissions into the atmosphere, lower fuel costs and savings on fuel costs, increased equipment life due to fuel purity). Natural gas is liquefied at a temperature of minus 162°C, with no emissions into the atmosphere. The transition to the use of liquefied natural gas as a gas engine fuel leads to a significant reduction in emissions of pollutants into the atmosphere. The transition to the use of LNG as a bunker fuel allows us to solve the problems of emergency spills of marine fuel, as it eliminates the risk of emergency oil spills, the consequences of which are difficult to eliminate.

LNG production in Russia is a strategically important direction for the development of the gas industry. Large-scale plans for the construction of small-scale plants in Russia are based on expectations of the cumulative effect from the development of the small-scale LNG industry.

In conclusion, small-scale LNG production projects provide consumers with access to environmentally friendly energy, strengthening environmental safety, socio-economic development of regions, and, consequently, sustainable development of energy in general.

METHOD OF NEURAL NETWORK CALCULATION OF CONCENTRATIONS GREENHOUSE GAS CARBON DIOXIDE FOR THERMAL POWER ENTERPRISES

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Keywords: *thermal power facilities, greenhouse gases, receipt, neural network calculation of concentrations*

Currently, carbon dioxide is the leading cause of climate change due to the constant increase in the volume of fossil fuel combustion [1]. At the same time, in our country, measurements of carbon dioxide concentrations have significant spatiotemporal limitations. Carbon dioxide concentrations in the Nizhnekamsk region are measured at one automated observation post in Nizhnekamsk. Currently, information on greenhouse gas emissions across the territory of the Republic of Tatarstan is available from the industry sector rather than from individual enterprises and emission sources. Calculating carbon dioxide concentrations using regulated calculation methods is impossible since inventory data of emission sources and input parameters for dispersion calculation methods are unavailable. The use of neural network approaches to calculate the concentrations of impurities in the surface layer of atmospheric air makes it possible to take into account all the difficult-to-model hidden dependencies between the factors that form the level of pollution of the surface layer of atmospheric air [2]. In this regard, a fundamentally new approach was developed, based on calculating CO_2 concentrations taking into account the chemical transformation of impurities in atmospheric air, described in more detail in [3].

The task of designing a neural network model was set to calculate emissions of the greenhouse gas carbon dioxide from the Nizhnekamsk Thermal Power Plant, which dominates emissions. The fact that in the experimentally measured automated post concentrations of carbon dioxide, in addition to those entering the atmospheric air with emissions from stationary sources, there is a proportion of carbon dioxide formed during secondary reactions from carbon monoxide can serve as a basis for using CO concentrations as initial data for calculation of CO_2. In this case, the model must take into account the processes of transformation of substances in the atmosphere.

To calculate the surface concentrations of CO coming from the emissions of the Nizhnekamsk CHPP, the "Ecolog-Gorod" program version 4.70 was used. The maximum one-time concentrations of impurities corresponding to the design parameters of emissions from the thermal power plant using the software package were calculated at points in the residential area.

To determine CO_2 concentrations, the CO concentrations calculated by "Ecolog-Gorod" were used as a predictor in the developed neural network model of the multilayer direct propagation perceptron type. After entering the initial data into the Loginom neural network generator, the system automatically selected the optimal model architecture: the number of input neurons – 6; number of output neurons – 1; number of hidden layers -1; number of neurons in the hidden layer – 4; activation function of hidden layer neurons – hyperbolic tangent; the activation function of the output layer neuron is linear.

To implement a computational neural network block of values in CO_2 software, it is necessary first to implement an auxiliary block statistical calculation of the QD transformation coefficient based on the measured values of nitrogen oxide and nitrogen dioxide, which we described in detail in [4].

The average model error across the entire data set was less than one percent—0.87%.

The final scenario, corresponding to all stages of the construction and use of a hybrid intelligent model for calculating carbon dioxide concentrations in

atmospheric air, is implemented in the program (certificate of state registration of the computer program No. 2022618230 “Program for neural network calculation of greenhouse gas concentrations” authors: Novikova S.V., Tunakova Yu .A., Shagidullin A.R.).

As a result of our research, we have developed a method and program for obtaining calculated values of carbon dioxide concentrations without information about the parameters of the sources of emissions of this greenhouse gas. Computational experiments demonstrated the high accuracy of the proposed approach.

The work was carried out with financial support from the Ministry of Science and Higher Education within the framework of the “Priority 2030 program”.

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INTERNATIONAL LEGAL ISSUES OF ENVIRONMENTAL PROTECTION DURING SUBSURFACE USE IN THE CASPIAN SEA

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Keywords*: Caspian Sea, environmental protection, hydrocarbon production, international legal regulation*

The Caspian Sea is the world's largest inland water reservoir, a unique natural object with a high resource potential. So, about 120 species of fish live in its waters, there is a global gene pool of sturgeon, whose production accounts for about 90% of their total world catch [3, 141]. The mineral resource base of the Caspian region is also significant. According to experts, the size of the Caspian oil and gas reserves varies from 26 to 40 billion tons. There is active exploration and development of oil and gas resources at the bottom of the sea, the implementation of industrial projects on the shelf, for example, the Trans-Caspian gas pipeline project.

The basics of subsurface use are characterized, as a rule, by the legal regime for the use of a natural object. Both in international and national law, the definition of the legal status of the Caspian Sea is very ambiguous. The reason for this is "the lack of explicit parameters that would allow us to uniquely identify it as a sea or lake" [4, 11]. If it is a sea, then it is subject to the norms of international maritime law based on the principle of freedom of the seas, and if it is a lake, then it can be divided between States on the basis of their agreements.

For a long time, the legal regime of the Caspian Sea was contractual in nature, based on agreements of the Caspian states. In 2018, with the development of the Convention on the Legal Status of the Caspian Sea, the international legal regulation of the development of its seabed and subsoil became clear to the oil and gas companies of the participating countries, which stimulated their economic activities.

November 2023 marks the 20th anniversary of the signing in Tehran of the Framework Convention for the Protection of the Marine Environment of the Caspian

Sea – the Tehran Convention – by five Caspian littoral States: the Republic of Azerbaijan, the Islamic Republic of Iran, the Republic of Kazakhstan, the Russian Federation and Turkmenistan. This Convention is also of great importance for ensuring environmental safety in the region.

Despite the companies' statements about the use of "zero discharge" technologies, the environmental burden on the vulnerable ecosystem of the Caspian Sea is significant, especially in connection with cuttings discharge and oil spills during transportation. The increased environmental requirements for subsurface use in the Caspian basin cause the need of the international legal regulation of its protection and international cooperation of the Caspian countries.

This study is devoted to the analysis of the existing international legal system for ensuring environmental safety in the production of hydrocarbons in the Caspian Sea and the development of a number of proposals for its improvement.

It is planned to analyse the provisions of international conventions on the Caspian Sea, bilateral agreements of states from the perspective of their environmental significance. It is also necessary to investigate the specifics of international legal cooperation of the Caspian littoral states in the field of protection of the Caspian environment during oil and gas exploration.

The methodological basis of the research is the methods of analysis, synthesis, induction, formal legal and comparative legal methods. Extensive normative material has been analysed.

The provisions of the 2003 Framework Convention for the Protection of the Marine Environment of the Caspian Sea and its protocols, which enshrine the application of the fundamental principles of international environmental law in the extraction of hydrocarbons, are considered.

The articles of the Convention on the Legal Status of the Caspian Sea of 2018 on the lawful types and principles of activity in its basin and other novelties of legal regulation introduced by it are analysed. Bilateral agreements between the states regarding the regulation of the protection of the Caspian ecosystem were considered.

The study revealed a number of gaps in the international legal regulation of environmental protection of the Caspian Sea. Thus, in the Framework Convention of 2003 there are no provisions defining the implementation of the "polluter pays" principle. Regulation of the solution of the issue of anthropogenic impact on the ecosystem of the Caspian Sea during the development of oil and gas resources seems insufficient.

The problem of the lack of systematization of the international legal framework for regulating cooperation between states in the field of ensuring environmental safety in the production of hydrocarbons in the Caspian Sea is revealed.

The Caspian littoral countries are actively cooperating in the field of reducing pollution of the Caspian ecosystem. Agreements are being adopted, summits of heads of state are being held, national legislation is being improved, interstate structures for monitoring the environmental situation are being organized. However, this activity is uncoordinated.

As a way to solve the identified problem, it is proposed that the Caspian states develop a universal international act to ensure the environmental safety of the Caspian region. Such a document could, firstly, codify the norms contained in the agreements already adopted, secondly, supplement the provisions of the 2003 Framework Convention, taking into account the determination of the legal status of the Caspian Sea in 2018, and thirdly, propose specific legal mechanisms to control the implementation of hydrocarbon production and the application of liability measures for environmental violations.

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ETHYLENE GLYDOL REGENERATION ENERGY CONSERVATION SIMULATION OPTIMIZATION IN NATURAL GAS TREATMENT PROCESS

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Keywords: *ethylene glycol, regeneration process, energy, simulation optimization*

Ethylene glycol is often used as hydrate inhibitor in natural gas treatment process. And after mixted with water, ethylene glycol rich liquid should be regeneration and recycle used. A method to reduce regeneration energy consumption is proposed. The method is based on Aspen HYSYS simulation and analyze, find more optimization process parameters to reduce energy consumption. After optimization, the energy consumption is significantly reduced compared with the original design.

In natural gas extraction process, Hydrate is easily formed, Hydrate inhibitor must be used in natural gas extraction process for Prevent hydrate formation，and ethylene glycol is often used as a hydrate inhibitor in industry. The energy consumption in the process of ethylene glycol rich liquid regeneration mainly comes from the regeneration tower, so use Aspen HYSYS simulation to reduce the operating cost and respond to the goal of energy conservation and emission reduction.

The results show that when the mass concentration of glycol lean liquid after regeneration is 89.00%, the feed temperature is 95℃, and the reflux ratio is 0.21. And the energy reduce about 730kW. The fixed cost is increased by about 100,000 yuan, but the operating cost can be saved by about 690,000 yuan per year.

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LAW GUARANTEE OF COLLABORATIVE GOVERNANCE OF POLLUTION REDUCTION AND CARBON REDUCTION FOR THE 'DUAL CARBON' GOALS: AN ANALYTICAL PERSPECTIVE OF STRUCTURAL FUNCTIONALISM

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Keywords: *pollution reduction and carbon reduction, collaborative governance, structural functionalism, system, 'dual carbon' goals*

It is reasonable and scientific that "taking the realization of pollution reduction and carbon reduction as the overall focus". With the help of AGIL schema analysis, we will comprehensively examine the problems such as the lack of architecture, discrete functions and insufficient power in the collaborative governance of pollution and carbon reduction from the perspectives of vertical differentiation and horizontal exchange. And then this paper tries to integrate the separated social entities in the collaborative governance of pollution reduction and carbon reduction. On the basis of clear principles, we should establish a legal and policy system for coordinated governance of pollution reduction and carbon reduction; perfect the law enforcement mechanism of combing hardness with softness; promote the grid based multi governance pattern.

The carbon peak and neutrality have became an important goal of our economic development and social transformation. Meanwhile, it also puts forward new requirements of our national governance system and governance capacity. Because of the certain homology and current ecological environment and economic development. Form the perspective of structural functionalism, the legal protection of coordinated governance of pollution reduction and carbon reduction involves four dimensions: value concept, legislation, law implementation and multiple participation. This article focuses on the 'double carbon' target and the realistic state of Chinese collaborative governance of pollution reduction and carbon reduction.

Meanwhile, the applicability of structural functionalism analysis method is fully analyzed in this research. Starting form the normative logic of law, this paper takes the structural functionalism analysis method as the approach and emphasizes the systematic idea.

Compared with previous studies, this article innovates in the following three aspects. Firstly, the research focuses on the legal guarantee of the collaborative governance of pollution reduction and carbon reduction under the background of ‘dual carbon’ goals. Based on the synergistic mechanism of pollution reduction and carbon reduction, it also pays attention to the trend of our economic development and environmental rule of law. Then, the structural integration of pollution reduction and carbon reduction can be used to optimize the corresponding system functions. Secondly, innovation of the research perspective. In this paper, the structural functionalism analysis method as the approach, with the help of AGIL schema analysis, we try to explore the concrete path to promote the legalization of the collaborative governance of pollution and carbon reduction. Thirdly, the systems thinking. This paper abandons decomposition rationality and bases on systematic thinking. It emphasizes the consideration of ‘position-role’, and then the paper systematically analyzes the structure and function of each element in the legal guarantee system of the collaborative governance.

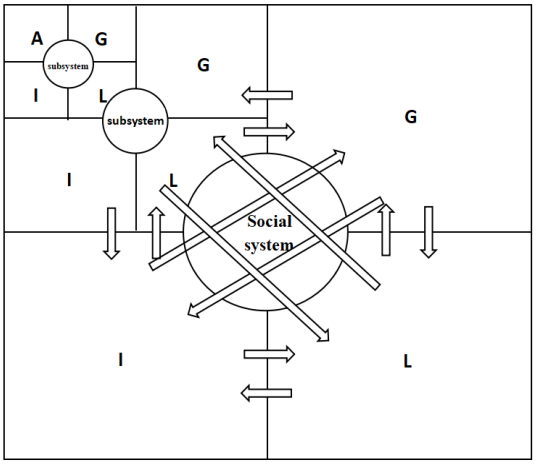

Figure 1 - Vertical Differentiation of Social System and Horizontal Exchange

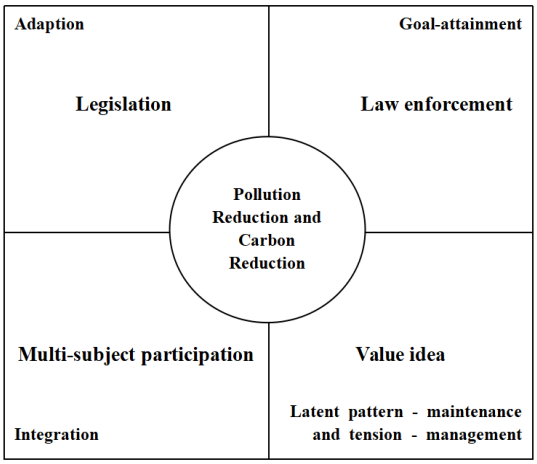

Figure 2 - Reducing the Carbon Reduction of Collaborative Governance AGIL System Structure of the Rule of Law Guarantee

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RESEARCH ON THE EFFECT OF AMIDE ADDITIVES IN HYDROGEL ELECTROLYTES ON THE PERFORMANCE OF ZINC-ION BATTERY

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Scientific adviser: Doctor, Professor, Huang C.

Keywords: *aqueous zinc-ion batteries, zinc metal anode, electrolyte engineering, amide*

Aqueous zinc-ion batteries (AZIBs) have broad application prospects in the field of large-scale energy storage and flexible wearable electronic devices. However, zinc anode suffers from issues such as dendrites and hydrogen evolution during long-term cycling, due to the high activity of water molecules and the unstable interface between the electrolyte and the electrode. Therefore, optimizing electrolytes and constructing stable electrode/electrolyte interfaces are worthwhile optimization strategies to explore. This paper designed a hydrogel electrolyte with amide additives. By adjusting the solvation structure of Zn^{2+}, the stability and reversibility of zinc deposition in the anode were effectively improved.

AZIBs are a promising class of energy storage devices due to their simple preparation, low cost, safety and environmental friendliness [1-3]. In aqueous batteries, hydrogels can be used as carriers for the aqueous solution electrolytes. Hydrogel is a flexible polymer with a three-dimensional network structure, with excellent water absorption and retention capacity and soft texture, which can be used to prepare solid-state flexible batteries. However, dendrite growth, water decomposition-induced parasitic reactions, and low coulombic efficiency of zinc anode in aqueous electrolytes have become thorny issues limiting the practical application of AZIBs.

In this paper, polyacrylamide (PAM) hydrogel was prepared as a carrier for the $ZnSO_4$ electrolyte solution and the effects of two additives, acetamide (AA) and propionamide (PA), on the performance of AZIBs, were researched. The details are as follows: (1) Calculations based on the density functional theory (DFT) method

were used to investigate the solvation conformation of Zn^{2+}. (2) Zn/Zn symmetric cells were assembled and the effects of the addition of amide additives on the electrochemical performance of the cells and the microscopic morphology of the zinc anodes were investigated.

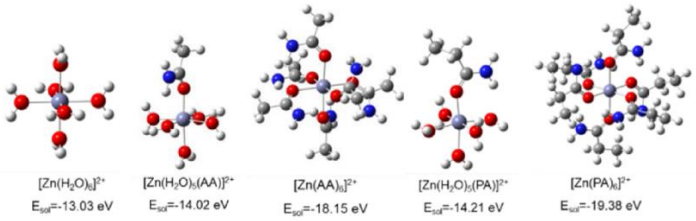

Figure 1 - Geometry optimization of $[Zn(H_2O)_x(AA/PA)_{6-x}]^{2+}$ complexes and the corresponding solvation energies based on DFT method

Figure 1 shows a portion of the geometries and solvation energies of different Zn^{2+} solvated sheaths by the DFT method. In an aqueous solution, Zn^{2+} forms a six-coordinated $[Zn(H_2O)_6]^{2+}$ solvated structure with water molecules, whereas AA and PA can replace the water molecules in the solvated sheaths to form $[Zn(H_2O)_x(AA/PA)_{6-x}]^{2+}$ (x=0~5). Calculations show that the solvation energies of all $[Zn(H_2O)_x(AA/PA)_{6-x}]^{2+}$ are less than that of $[Zn(H_2O)_6]^{2+}$. This suggests that both AA and PA bind Zn^{2+} more strongly than H_2O. In addition, PA has a more negative solvation energy and forms a more stable coordination structure than AA complexes with the same number of substitutions. The more stable coordination structure leads to an increase in the nucleation overpotential (NOP) for zinc deposition on the anode. The calculations also show that due to the electron-donating nature of the amide molecule, the Zn^{2+} solvated clusters formed with increasing AA and PA coordination numbers have lower molecular surface electrostatic potentials and lower LUMO energy level orbitals. This reduces the bound water activity in the Zn^{2+} solvated clusters and effectively inhibits the hydrogen evolution reaction (HER).

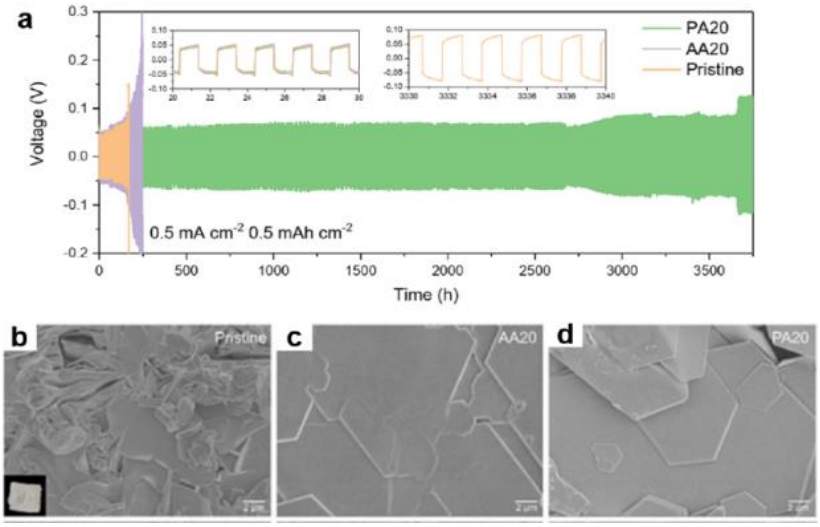

Figure 2 - Cycling stability of Zn/Zn symmetrical cells in Pristine, AA20 and PA20 electrolytes (a) and the SEM images of Zn anodes in Zn/Zn symmetrical cells after 85 cycles in the Pristine (b), AA20 (c), and PA20(d) electrolytes at 0.5 mA cm^{-2}-0.5 mA h cm^{-2}

We prepared three sets of 1M $ZnSO_4$-PAM hydrogel electrolytes. One set without amide additives and the other two sets with 20 wt% of AA and PA respectively. These three sets were noted as Pristine, AA20 and PA20 respectively and were assembled into a Zn/Zn symmetric cell to evaluate the long-cycle performance of Zn metal. Figure 2a shows the electrochemical performance of the Zn/Zn symmetric cell. At a current density of 0.5 mA cm^{-2} and a capacity of 0.5 mA h cm^{-2}. The cycle life of the symmetric cell with PA20 was substantially increased to 3800 h. Figure 2b-d shows the SEM images of Zn anodes with different electrolyte systems after 85 cycles at 0.5 mA cm^{-2} - 0.5 mA h cm^{-2}. After the introduction of the amide additive, the deposition of zinc on the anode surface is parallel to the substrate and is uniform and dense, with no obvious zinc dendrite generation.

In this paper, the main conclusions are as follows: (1) Calculations based on the DFT show that amide molecules replacing water molecules involved in the solvation structure of Zn^{2+} can improve the solvation energy of the clusters. Its electron-donating effect helps to reduce the electrostatic potential distribution on the surface of clusters and increase the LUMO energy level of the clusters, thus

suppressing the HER at the interface of the zinc anode. (2) The long-term cycling reversibility and stability of the Zn metal anode were evaluated in a Zn/Zn symmetric cell. Under the same conditions, the half-cell with PA20 electrolyte could be cycled 200 times with an average coulombic efficiency of 97.1%, and the symmetric cell could be stably cycled for 3800 h at a current density of 0.5 mA cm^2 without a significant increase in the polarisation, achieving a uniform and flat zinc deposition profile.

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MOF-MEMBRANES MODIFIED BY IONIC LIQUID FOR EFFICIENT CARBON CAPTURE

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Compared to oil and coal, natural gas is regarded as a primary fuel source. Although the main component of natural gas is methane (CH_4), it also includes significant amounts of acid gases, including carbon dioxide (CO_2) that must be eliminated before it can enter the pipeline. In this study, researchers have devised a straight forward post-modification approach utilizing ionic liquids (IL) to fill the gaps in MOF-based membranes. The objective of this technique is to enhance the separation efficiency of CO_2/CH_4 in membranes. Existing membranes, constructed through interfacial polymerization of MOF (UiO-66-NH_2) and trimesoyl chloride (TMC), possess nanoscale gaps that restrict their precise CO_2/CH_4 sieving capabilities. The modified membranes achieved a CO_2/CH_4 selectivity of 35, significantly higher than the non-selectivity observed in the original membrane. Additionally, the hydrogen-bond interaction between ILs and the membrane enhanced separation stability and prevented IL loss during gas permeation. Hence, the utilization of ILs in post-modification of MOF based membranes is considered highly advantageous in augmenting the gas separation capabilities for applications in natural gas purification.

PIM-1 membrane prepareD by in-situ plasma treatment for carbon capture

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Keywords: *global warming; carbon capture; plasma modification*

Global warming caused by excessive CO_2 emission threatens the survival and development of human beings. By plasma modification of the surface of PIM-1 membrane and the introduction of CO_2-affinity groups on the surface of the membrane, the permeability of the carbon capture membrane can reach 1005.5 Barrer and the selectivity is 36.5. The 2008 gas separation limit was exceeded. This method is simple to operate and provides a new idea for membrane carbon capture.

Excessive emissions of CO_2 and other greenhouse gases will cause extreme climate problems such as global warming and sea level rise, seriously threatening the survival and development of human beings[1]. In order to deal with the increasingly serious situation of global warming, China has proposed a "dual carbon target". Carbon capture technology, as one of the most direct means of carbon neutrality, is the underpinning technology to achieve the goal of "dual carbon"[2]. At present, relatively mature carbon capture methods include chemical absorption method, physical adsorption method, cryogenic separation method, and membrane separation method. [3]As a new separation technology, membrane separation has the advantages of high efficiency and low energy consumption.[4,5]

In order to prepare carbon capture membranes with high separation performance, as shown in figure 1, a surface modifying strategy of PIM-1 membrane by plasma was proposed. PIM-1 powder was prepared by the synthesis route shown in figure 2, PIM-1 gas separation membrane was prepared by solvent evaporation method, and the membrane surface was modified by O_2 plasma, and the prepared membrane was used to separate simulated flue gas.

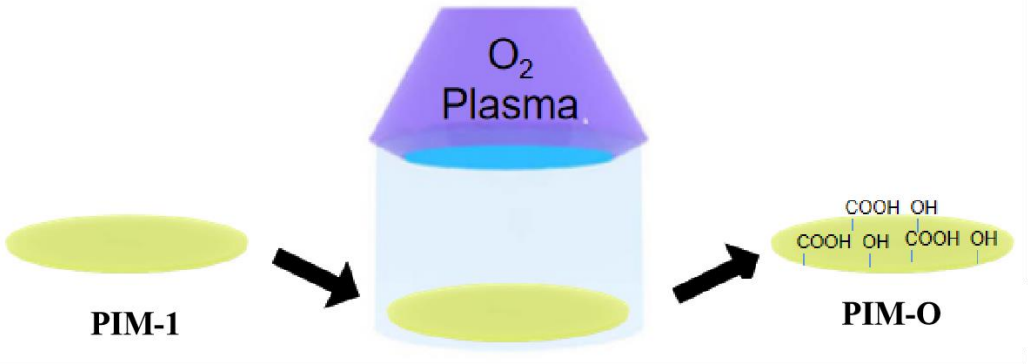

Figure 1 - Plasma-treated PIM-1 membrane process

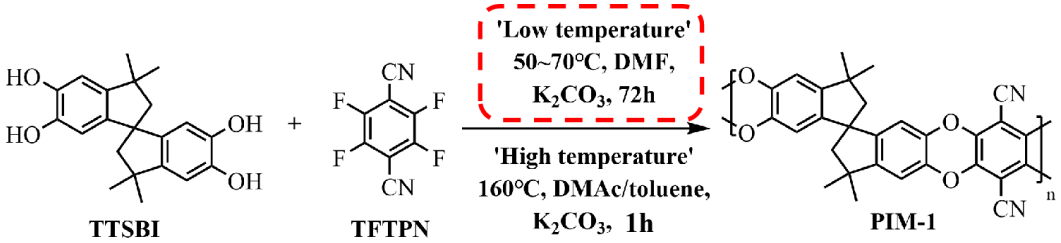

Figure 2 - synthesis route of PIM-1

In order to explore the optimal membrane-making conditions, PIM-1 membranes with different O_2 plasma treatment times were prepared, and the modified membranes with treatment time of 10s, 30s and 60s were named PIM-O10, PIM-O30 and PIM-O60, respectively. Figure 3 is the SEM image of the modified membrane. It can be seen that with the increase of modification time, the surface of the membrane is still very smooth and there is no obvious change. Figure 4 shows the AFM diagram of the modified membranes. The surface of each modified membrane is very smooth, and the characterization results are consistent with the SEM. Figure 5 shows the contact Angle test of the modified membrane. With the increase of modification time, the hydrophilicity of the membrane surface increases, and the contact Angle decreases from 88° to 35°. This is because the plasma modification introduces oxygen elements on the membrane surface, making the membrane surface more hydrophilic. Figure 6a shows the separation performance of each modified membrane. With the increase of modification time, the CO_2 permeation decreased from 3075.3 Barrer to 1005.5 Barrer, and the selectivity increased from 21.8 to 36.5, due to the introduction of CO_2-friendly -OH, -COOH,

-O-, etc., after the membrane surface was treated by O_2 plasma. As shown in figure 6b, membrane performance exceeded the 2008 upper bound[6].

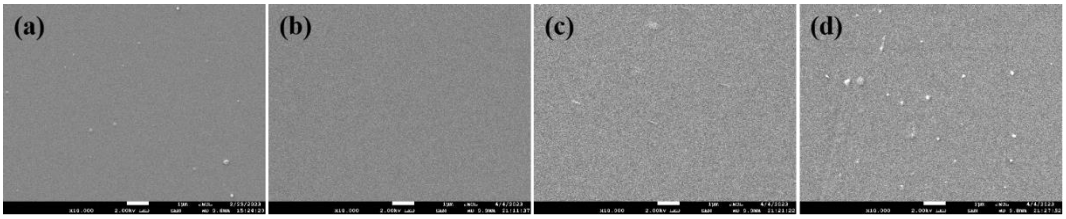

Figure 3 - SEM images of PIM-1(a), PIM-O10(b), PIM-O30(c), PIM-O60(d)

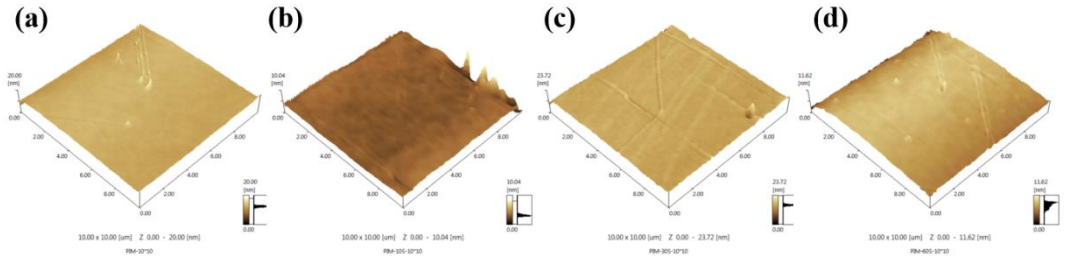

Figure 4 - AFM images of PIM-1(a), PIM-O10(b), PIM-O30(c), PIM-O60(d)

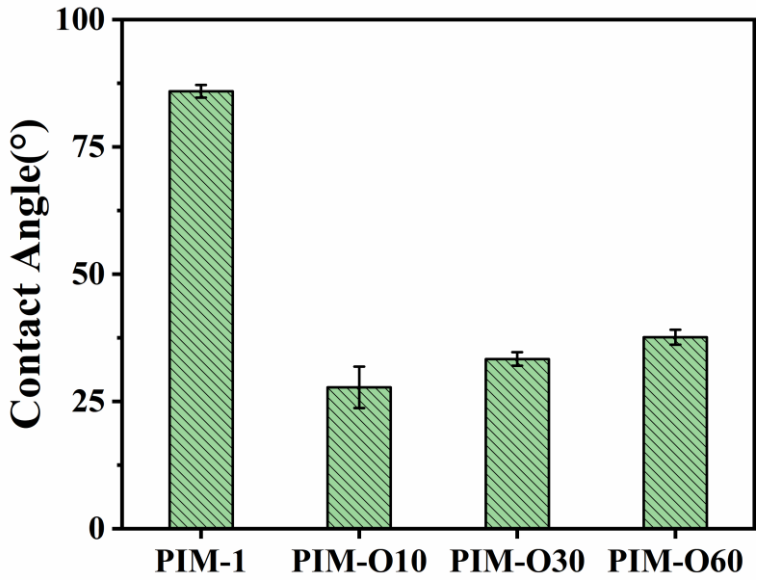

Figure 5 - contact angle of PIM-1(a), PIM-O10(b), PIM-O30(c), PIM-O60(d)

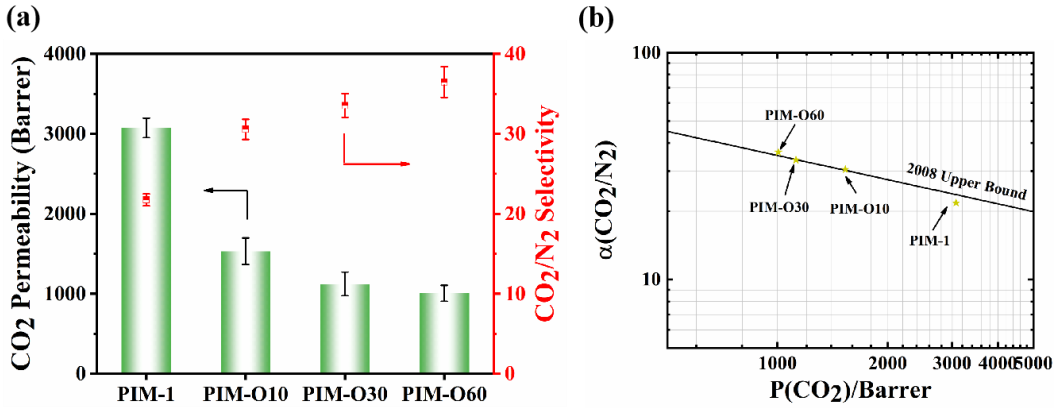

Figure 6 - (a) gas separation performance for 50/50 CO2/N2, (b) 2008 Upper Bound

In this work, an O_2 plasma modification strategy was applied to introduce CO_2-friendly -OH, -COOH and -O- on the surface of PIM-1 membrane. When the modification time was 60s, the CO_2 permeation was 1005.5 Barrer and the selectivity was 36.5. The performance of the prepared membrane exceeds the 2008 upper bound. The modified method has the advantages of simple operation, high selectivity and broad application prospect.

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RESEARCH ON CHINA'S ENERGY-CONSUMING RIGHT TRADING SYSTEM UNDER THE PERSPECTIVE OF COLLABORATIVE GOVERNANCE OF POLLUTION REDUCTION AND CARBON REDUCTION

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Keywords: *pollution and carbon reduction; synergistic governance; environmental equity trading; energy-consuming right trading system; legal regulation*

Energy-Consuming Right Trading System is the key to solve the problem of high energy consumption, high pollution and high carbon emission from the source. Based on the legal perspective, this paper utilizes literature research, normative analysis and empirical analysis methods. From the theoretical level, it explains the operation logic and basic structure of the Energy-Consuming Right Trading System. At the same time, it improves the legal system framework to ensure the normal operation of the Energy-Consuming Right Trading System, and provides a new pattern for the international energy-saving trading practice.

Collaborative management of pollution reduction and carbon reduction is an inevitable choice for integrating the construction of ecological civilization and green economic and social development. In June 2022, China's Ministry of Ecology and Environment and other departments jointly issued the *Implementation Plan for Synergizing Pollution Reduction and Carbon Reduction*, which provides a feasible solution for pollution reduction and carbon reduction. It points out that "accelerating the improvement of market mechanisms, synergizing the promotion of pollution reduction and carbon reduction, and forming effective incentives and constraints" is the key to closely linking market-based environmental policy instruments with the "carbon peak and carbon neutral goal", and promoting the synergistic development of pollution reduction and carbon reduction. At present, China is vigorously promoting the construction of the environmental equity trading market, and has

formed an environmental equity trading system covering emissions trading, carbon emissions trading, energy-consuming right trading system, water use rights trading and green electricity certificate trading (Table 1).

Table 1 - List of environmental equity trading systems in China (non-exhaustive list)

Areas coverage	System Name	System Purpose	Running Mode	Efficacy
Pollutant control emissions	Emission trading	Control of major pollutant emissions	Aggregate control + quota trading	Promoting synergistic governance for reducing pollution and carbon emissions
Greenhouse gas emission reduction	Carbon emissions trading	Control of greenhouse gas emissions	Aggregate control + quota trading	
Resource utilisation	Energy-Consuming Right Trading	Control of energy consumption	Aggregate control + quota trading	
	Water rights trading	Control of water consumption	Aggregate control + interest trading	
	Green Electricity Certificate Trading	Enhancing green electricity consumption	Certificates + Quota	

Among the environmental rights and interests trading, the energy-consuming right trading system is an innovative energy consumption trading model in China. It is a powerful environmental and economic policy that employs market mechanisms to save energy and reduce consumption, and promotes the control of the total volume and intensity of energy consumption as well as the realization of the "dual-carbon" goal. As an important part of the synergistic governance of pollution reduction and carbon reduction, energy-consuming right trading system based on the control of total energy consumption is more focused on frontal governance than terminal governance methods such as emissions rights and carbon emissions trading. The system mainly consists of two links: the initial allocation of energy use rights by the government among energy-using subjects and the market transactions by various

types of trading subjects, and the various legal rules regarding the two constitute the basic framework of the legal system of energy-consuming right trading.

Based on the important role of the energy-consuming right trading system in the collaborative governance of pollution reduction and carbon reduction, this paper centers on this research theme and standardizes the use of literature research method, normative analysis method and empirical analysis method. Through searching and organizing all kinds of literature, to analyze the role of the system on the synergistic governance of pollution reduction and carbon reduction at the theoretical level, to comprehensively review the implementation of the system and the formulation of legal rules, to improve the legal structure of the system, and to provide practical legal protection for the synergistic efficiency of pollution reduction and carbon reduction at the front-end of the governance.

Energy conservation has become an important initiative for countries around the world to address environmental issues. The dual role of the energy conservation system in alleviating the energy crisis and improving the ecological environment not only makes the energy-consuming right trading system have an important implementation value, but also puts forward new requirements for the legal guarantee of the system's operation. At the same time, the improvement and popularization of the energy-consuming right trading system also provides a new form for the practice of international energy-saving system, which greatly enriches the practice and exploration of energy-saving trading.

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THE DARK SIDE OF LOW-CARBON HYDROGEN

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Keywords: *hydrogen, decarbonization, ecology, low carbon hydrogen*

One of the main challenges facing modern energy is achieving carbon neutrality in order to fulfill the commitments made under the Paris Climate Agreement. One of the ways to achieve these goals is to switch to the use of low-carbon energy sources. In this context, special attention is paid to low-carbon hydrogen, which is considered one of such sources. It is assumed that hydrogen is environmentally neutral, since it does not emit harmful substances into the atmosphere and can contribute to the decarbonization of global energy. However, despite this, some experts express the opposite opinion, arguing that hydrogen can have a more negative impact on the environment and the composition and state of the atmosphere than traditional fuels.

The purpose of this study is to analyze and evaluate the negative aspects of the impact of low-carbon hydrogen on the environment and the state of the atmosphere. The environmental effects of using low-carbon hydrogen and traditional fuels are also compared.

To achieve this goal, a comprehensive analysis of literature data, scientific publications, and the results of previous studies on the impact of low-carbon hydrogen on the environment was carried out. Mathematical models were also used to quantify potential negative effects. The comparative analysis was carried out taking into account data on emissions of various substances during the production and use of low-carbon hydrogen and traditional energy sources.

The analysis revealed a number of potential negative aspects of the impact of low-carbon hydrogen on the environment. These aspects include emissions from hydrogen production, energy consumption for its creation, as well as possible consequences when using it. As a result of a comparative analysis with traditional

fuels, it was found that hydrogen, despite its low combustion emissions, can cause significant environmental problems at the production stage.

Thus, the use of low-carbon hydrogen requires additional attention to its life cycle and production processes in order to minimize the negative impact on the environment.

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BRICS IN THE GLOBAL CLIMATE AGENDA

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Keywords: *BRICS, SDGs, climate crisis, challenges, climate change*

The close connection between climate issues and the economic and energy sectors of each BRICS country has made climate cooperation an important factor in deepening cooperation among the countries of the organization. Actively addressing climate change is also an important opportunity for the BRICS countries to successfully transform their development models to make their economic and social development more sustainable. On the other hand, proactively addressing climate change is also an important opportunity for the BRICS countries to successfully change their development approach to make their economic and social development more sustainable. That is why strengthening cooperation in the field of climate and energy is an important element of all BRICS summits. Strengthening cooperation on climate and energy has been an important element of all BRICS leaders' summits. Based on this, in this article the author examines the role of BRICS in solving the problem of climate change.

The purpose of this work is to study the role of BRICS in resolving the climate crisis, to consider BRICS mechanisms on the way to resolving the crisis.

Achieving the research goal is carried out through the integrated use of such general scientific and special methods as:

– historical and logical;

– descriptive;

– methods of analysis and synthesis;

– abstract-logical.

Research results. In the future, energy and climate issues will undoubtedly remain an important factor for the BRICS, determining their domestic policies and international relations. The desire to obtain oil and gas (China, India, South Africa)

to support economic development and the search for stable oil markets (Brazil and Russia) determined BRICS relations with other countries and regions. Conversely, along with increasingly scarce oil resources, the incentives and rhetoric of international climate negotiations and its impacts are pushing the BRICS to consider alternative energy sources.

Decarbonization and the green transformation offer enormous opportunities for the global economy, trade and finance, and green innovation and development represent a new round of global competition for development models. Guided by a carbon neutrality agenda, the world's largest economies are accelerating the transformation of economic quality, efficiency and power to build an economic system based on green, low-carbon and circular development. To this end, the BRICS countries exchange information and cooperate at the national, local, sectoral and corporate levels in areas such as clean energy, low-carbon technologies, building sustainable and resilient infrastructure, carbon markets and climate change adaptation. The broad and deep cooperation among BRICS countries in the field of green innovation and green economy, as well as the large green market they cultivate, will encourage more developing countries to achieve green recovery, green transformation and upgrading.

TRANSNATIONAL CARBON CAPTURE AND STORAGE PROJECT IN THE ASIA-PACIFIC REGION

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Keywords: *carbon capture and storage, CCUS, geological storage, Asian-Pacific region, CO_2 transportation*

Achieving the goals of limiting warming to 2°C or 1.5°C would result in stranded oil and gas assets. The economic impact of stranded assets could be in the trillions of dollars. Carbon capture and storage (CCS) can allow fossil fuels to be used for longer periods of time, reducing the potential risk of stranded assets. [1]. The vast majority of greenhouse gas (GHG) emissions occur in the Asia-Pacific region, represented by countries such as the Russian Federation, the People's Republic of China, Japan and others (see Figure 1). Based on the above, the study is timely due to the growing economic and energy cooperation between the Russian Federation and the People's Republic of China, which could be key participants in an ambitious transnational CCS project.

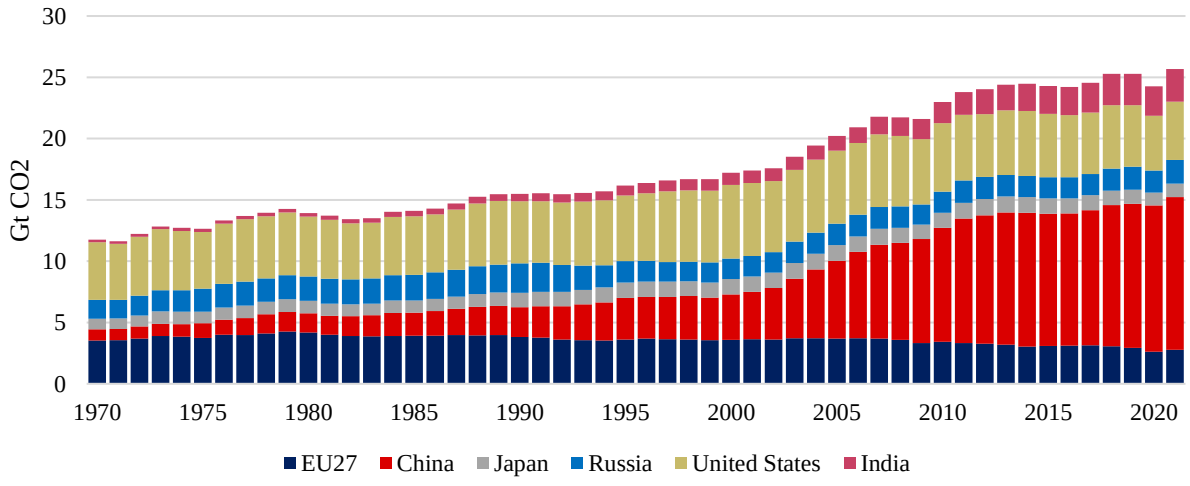

Figure 1 - Total CO_2 emissions of leading countries [2]

CCS is an emerging technology with significant potential to mitigate climate change. However, the main barriers to widespread deployment are financial. Some of the limiting factors are High capital costs, operating costs, infrastructure costs, uncertain financial returns, regulatory and political constraints, public perception and acceptance. An effective way of overcoming these constraints could be to implement a CCS project along the lines of a production sharing agreement.

As a result of this work, we have proposed a conceptual transnational CCS project in which the implementation and exploitation of the main phases (capture, transport, and geological disposal) would be shared between the participating countries (see Figure 2).

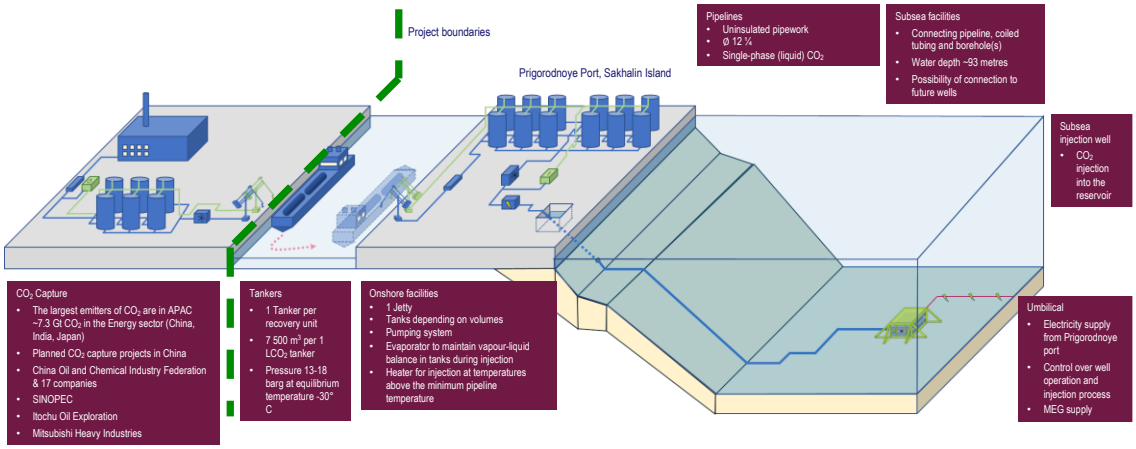

Figure 2 - Conceptual design of the transnational CCS project [3]

The proposed approach will not only reduce GHG emissions in the study region, but also diversify the revenue streams of the Russian Federation's oil and gas companies in the context of the global decarbonisation of the industry.

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RIVER OTTER (*LUTRA LUTRA* L., 1758) IN THE NORTH OF ITS RANGE (NORTH-EAST ASIA) AND RISKS ASSOCIATED WITH THE DEVELOPMENT OF THE MINING INDUSTRY

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***Keywords**: Yakutia, river otter, hydrobionts, mining industry*

Northeast Asia is a northern periphery of the Eurasian otter range. Its extent of occurrence extends to the Arctic Circle. This region is the coldest in the Northern Hemisphere where the otter meets the most adverse conditions of extremely low winter temperatures. The largest and only native semi-aquatic predator here is the river otter. Basic limiting factors are short frost-free season and deep-freezing wetlands. The main factor limiting its spread in northeast Asia is continuous, stable ice formation on watercourses and reservoirs in winter. The real habitat of the species here corresponds only to those rivers where there are always ice-free, open water areas that do not freeze in winter and a sufficient supply of food resources for life.

The current state of the population and the ecological features of this predator in Yakutia remain completely unstudied, the distribution is uncertain, and the number is unknown.

Historically, the population density of the species at the northern limit of its range is low [1, 2, 3; etc.]. According to some estimates, the river otter population here in suitable habitats does not exceed an average of 0.3-0.4 individuals/10 km of floodplain [4]. In some cases, this figure can reach 1.6 specimens/10 km of floodplain [5]. The limited number of places suitable for wintering increases the elimination of young animals and creates increased competition between individuals. The search for areas to live forces young otters to make large land crossings, where they become extremely vulnerable to predators and often die.

Therefore, even at normal rates of reproduction, the number of the species remains at a consistently low level.

Otter skins have always been in high demand in the fur market. In the 19th century within the modern borders of Yakutia, about 136-137 river otters were caught annually, and in some years up to 500 otter skins were exported from the region [6]. Currently, due to its small numbers, the species is protected in three of the 4 administrative regions of northeast Russia and is included in the Red Books of the Republic of Sakha (Yakutia) [7], Chukotka Autonomous district [8], and Magadan Region [9].

Increasing resource consumption, depletion of exploited mineral deposits and technological developments are driving the expansion of the mining industry into new regions, with particularly great interest recently shown in the vast undeveloped northern territories. Ecosystems of the Arctic and Subarctic are characterized by a simplified structure, low rate of renewal and increased vulnerability, therefore, studying the characteristics of the functioning of ecosystems in the Arctic and subarctic territories of Yakutia under the active influence of technogenesis is of undoubted relevance.

The active development of the mining industry in the region significantly expands the range of negative factors of anthropogenic origin. Geological exploration and direct mining inevitably entail emergency situations (oil spills, releases of toxic substances, etc.), disposal of production waste, damage to water bodies, etc. All this leads to a reduction in natural habitats and negatively affects the abundance and diversity of living organisms. Particularly great damage is caused to species living in pessimal living conditions on the periphery of their range, as well as stenotopic animals. The greatest harm from the mining industry for animals such as the river otter is caused indirectly, as a result of the destruction of habitats and places where they survive the winter period, increasing the accessibility of habitats for visiting by people through the created road and transport infrastructure and increasing disturbance, in which animals leave their habitats, reducing the abundance food objects as a result of pollution of reservoirs and watercourses, etc.

A reduction in population density and the number of animals leads to a deterioration in the rate of reproduction and fragmentation of the habitat. The development of road transport and pipeline infrastructure is exacerbating the growing problem.

The problem of declining biodiversity requires the combined efforts of the widest possible range of people to successfully solve it. The development of interaction between the scientific community and subsoil users in the conservation and restoration of the natural environment is the most effective tool that needs to be developed for the well-being of future generations.

Carried out within the framework of the Russian-Asian Consortium for Arctic Research RACAR.

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STUDY OF MORPHOLOGIES AND PROPERTIES BASED ON CRYSTALLINE SELF-ASSEMBLY OF AMINO ACIDS

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Keywords: *crystal structure,amino acid,self-assembly,properties,mechanism*

In this study, amino acids were studied for crystallization. Crystallographic comparisons were made as to whether or not they contained benzene rings, and as to the number and position of the hydroxyl groups on the benzene rings, etc. Small differences in the chemical structures led to the different crystal morphologies of the amino acids, and the crystal structure and molecular arrangement of the amino acid crystals were determined by means of single-crystal X-ray diffractometry and other means. Further studies were conducted to evaluate the properties of the crystals, such as thermal stability, mechanical properties and piezoelectricity, etc.

The Tao follows the course of nature. Bottom-up organization-mediated self-assembly of organic molecules takes advantage of non-covalent interactions between small molecules to spontaneously form well-defined formerly relatively stable organizations under thermodynamic equilibrium conditions [1]. This self-assembly process has the potential to fabricate advanced smart materials and therefore has received high attention in the scientific community. Small molecules such as short peptides or nucleic acids can be formed into nanoscale materials with certain structures and functions through this self-assembly process, thus realizing some specific applications. Recent studies have shown that some very simple molecules, such as single amino acids [2,3], have been widely studied for self-assembly and considered as potential functional biological or bio-inspired materials, which have the advantages of low cost, easy production and good biocompatibility. Self-assembly using them can lead to nanoscale materials with specific structures and functions and be used in a variety of fields, including drug delivery, tissue engineering and sustainable energy, providing new avenues for the development of

sustainable, efficient and environmentally friendly materials. Recent studies have begun to delve deeper into single amino acids with the discovery that single amino acid crystals have striking piezoelectric properties. However, more advanced and complex attributes of the intrinsic properties of amino acids are yet to be discovered, and it is important to understand the molecular basis and physical properties of amino acids and their supramolecular assemblies, among other discoveries in different fields.

Herein, we investigated the self-assembly of five amino acids with similar chemical structures, L-F, L-S, L-Y, L-T and L-DOPA, and their physicochemical properties. The amino acids can all form different crystal structures in aqueous solution, and their molecular structures were resolved by single-crystal X-ray diffractometry, including the crystal cell parameters, molecular stacking modes, arrangement patterns and intermolecular interactions. In addition, the morphological features of the crystals were observed by optical microscopy and scanning electron microscopy, and the thermal stability and mechanical properties of the crystals were comprehensively investigated by means of differential scanning calorimetry, thermogravimetric analysis and atomic force microscopy. This study provides a viable research strategy for analyzing the relationship between crystal structure and performance by exploring the physical properties of supramolecular self-assembly for various applications. This strategy utilizes simple natural building blocks to achieve the assembly of supramolecular structures with specific structures and functions by modulating the way molecules interact with each other, leading to the development of materials and devices with highly efficient properties and multifunctionality, for example in the fields of energy harvesting, piezoelectric devices, and soft robotics.

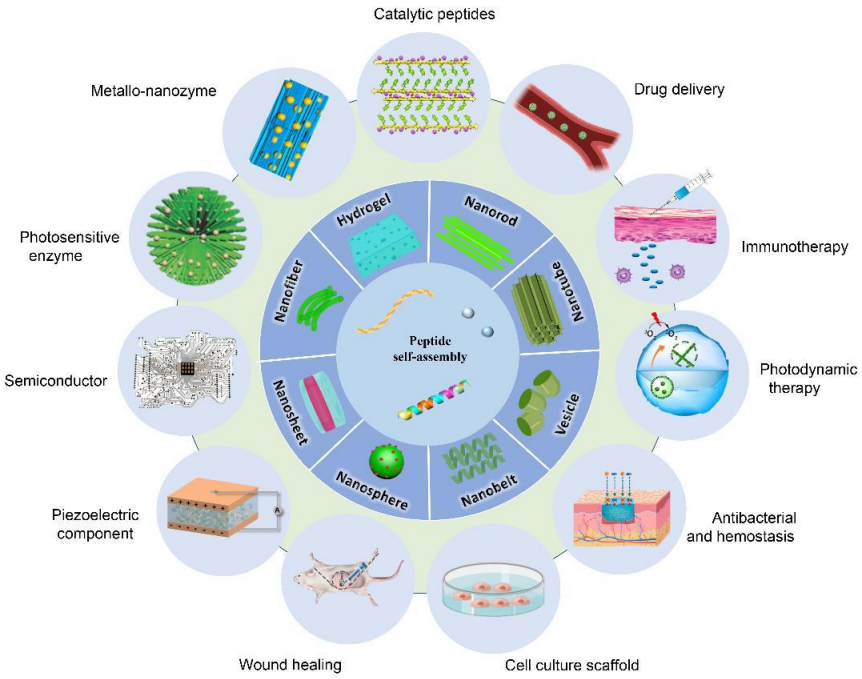

Figure 1 - Peptide-based self-assembly: From molecular design, formed nanostructures to various applications [4]

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RESEARCH ON LEGAL SYSTEM OF CCUS TECHNOLOGY IN CHINA

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Keywords: *carbon capture, utilization and storage, legal system, risk supervision, carbon sequestration risk*

Carbon capture, utilization and storage (CCUS) technology is gradually recognized as one of the most potential carbon reduction technologies in the world. This paper takes how to build the legal system of CCUS technology as the key issue to be solved, and combined with the application and development of CCUS technology, analyzes the existing problems in the policy, law and specific system formulation of CCUS technology under the background of carbon neutrality, and puts forward countermeasures and suggestions on the construction of China's CCUS technology legal system from the macro and micro levels.

1.Explain the basic concept and origin of carbon capture, storage and utilization (CCUS). The necessity and feasibility of developing carbon capture, storage and utilization technologies were analyzed.

2.Based on the theory of sustainable development, risk prevention theory and social order rules, this paper analyzes the construction of the legal system of carbon capture, storage and utilization in China.

3.Clarify the accountability mechanism for carbon capture, storage and utilization in China, clarify the subject and method of responsibility, and clarify the principle of responsibility.

The research methods of this paper are literature analysis and comparative analysis.Due to the differences in economy, culture and geographical environment of different countries and regions, the legal norms, mechanisms and theories formed under the background of such differences are naturally different. By comparing the legal system of carbon capture, storage and utilization between China and foreign countries, the similarities and differences between them are analyzed, and their

advantages are absorbed and used for reference, so as to provide a good solution to the legal system of carbon capture, storage and utilization in China.

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ANALYSIS OF THE IMPACT OF EXOGENOUS HAZARDS ON MAIN OIL AND GAS PIPELINES USING MACHINE LEARNING METHODS

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Keywords: *environmental safety, oil and gas complex, pipeline system, dangerous exogenous processes, emergency situations, deep learning*

The Russian Federation has a widespread network of main pipelines in various landscape conditions. Due to the heterogeneity of natural areas, emergency leaks of the pumped product occur on the linear part every year. One of the main natural causes of accidents and various defects in main pipelines are exogenous geological processes, such as karst and erosion processes, landslides, mudslides, avalanches, flooding.

The work is devoted to the indication of dangerous exogenous processes in various sections of the main pipelines of Russia. In particular, we are talking about the application of machine learning methods. Machine learning is a branch of artificial intelligence in which structured data is processed using an algorithm to solve a problem.

The work uses the ArcGIS Pro software with the «deep learning module». Deep learning is a type of machine learning that uses multiple layers of algorithms in the form of neural networks. The input data is analyzed through different layers of the network, with each layer defining specific characteristics and patterns in this data.

The introduction of neural networks into the process of indicating exogenous processes makes it possible to optimize the operator's work and increase efficiency. To train a deep learning model, reference values and input rasters are required. At the output, we get a trained model that we can use when decrypting selected objects in different territories.

To identify dangerous exogenous processes, the following main pipelines were selected in this work:

- the East Siberia-Pacific Ocean main oil pipeline - the ESPO section passing through Yakutia (from Olekminsk to Aldan) is considered in detail;
- Sakhalin-2 main oil and gas pipeline – special attention is paid to the Makarovsky district;
- the Bovanenkovo-Ukhta main gas pipeline – the section of the Baydaratskaya CS to the nearest CS has been selected for evaluation.

The Yamal territory, namely the section of the Bovanenkovo-Ukhta main gas pipeline, was chosen as an example of the detection of exogenous processes using the deep learning method. Flooding was taken as a dangerous exogenous process.

Thus, with the help of a neural network, we get rendered areas with a dangerous exogenous process.

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DEEP REINFORCEMENT LEARNING FOR ENERGY MANAGEMENT SYSTEM AT SOLAR-BASED MICROGRID

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***Keywords**: microgrid, renewable energy, optimization, reinforcement learning, model predictive control*

Purpose of the study: search for an optimal algorithm for minimizing the costs of the energy system (microgrid).

Introduction

This work is devoted to a comparative analysis of reinforcement learning algorithms and classical optimization algorithms for solving the problem of minimizing the costs of the energy system within the framework of the Energy Management System (EMS).

The modern methods for solving the problem of minimizing the costs of the energy system include:

- Rule-Based Control (RBC) is a method based on previously established rules.
- Predictive Control Method (MPC) – a method based on the use of the theory of optimal and adaptive control for the constructed model of the object.
- Reinforcement Learning (RL) methods - are machine learning methods in which the algorithm learns from feedback from the environment.

The solution to microgrid optimization is relevant due to the increase in the number of distributed energy sources.

Research methodology

As part of this study, an analysis was made of recent publications in the field of energy management optimization (EMS) using rule-based control (RBC), model

predictive control (MPC) algorithms, and approaches based on reinforcement learning.

The best algorithms for managing microgrids were selected based on recent publications in the field of microgrid optimization [1-3]. The following algorithms were chosen for the simulation: RBC, MPC with mixed-integer linear programming, MPC with derivative free optimization and reinforcement learning algorithms.

For modeling, a microgrid was chosen consisting of 2 electrical energy storage devices, a solar power plant, and a load. The system operates in parallel with the grid, but without the ability to export electricity. The data was obtained from real energy facilities.

A digital model of the environment was created using the py-mgrid library. The system was divided into a training and test environment. The results of the experiments were logged to the MLflow server. The reinforcement learning algorithms were written in the Pytorch framework.

Conclusion

As a result of the simulation, the best result was obtained by the MPC-MILP algorithm with a cost in the test environment of 271,328 rubles, the second less effective was the DDQN algorithm with a cost of 275,219 rubles, the results of the study are presented in Table 1.

Table 1 - results of the algorithms

Algorithm	Costs during the test period
Rule-based approach	285 210
MPC with derivative free optimization	284 101
DQN	280 211
DDQN	275 219
PPO	273 120
MPC-MILP	**271 328**

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