To the Question of Disposal and Recycling Carbon Dioxide

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Abstract. In the modern world, the issue of reducing carbon dioxide emissions has become relevant, this is confirmed by the conditions of climate change, macroeconomic instability and depletion of resources. The article discusses methods for solving this problem: The first method is associated with its transformation in the form of solid minerals and industrial use in the form of carbonates. The second way to reduce CO2 emissions is to create a power plant with a capacity of 20 MW, but this method increases the cost of electricity. The third method is based on the principle of air filtration. The essence of this method is to generate heat energy and collect carbon dioxide from the air. In addition to such processing methods, a number of others are being implemented by industry. So far, two main approaches have been used, where CO2 is reduced in gaseous form, or reduced in a liquid medium. From all of the above, the following conclusions can be drawn that the utilization of carbon dioxide is a complex project, both financially and technically, but technical progress does not stand still, but develops in full swing, there are solutions that are partially implemented and only await mass production.

1. Introduction
The issue of reducing carbon dioxide (CO2) emissions became relevant after the adoption in 2016 of the Paris Climate Agreement, approved in 174 countries and aimed at preventing a global increase in atmospheric temperature by 2 °C above pre-industrial levels. In the current context of climate change, macroeconomic instability and decreasing of resources decarbonization strategy is becoming more common around the world. Extensive efforts to decarbonization characterized by a transition to a clean energy, which leads to a permanent reduction of harmful emissions. [1,2]

2. Methods of solving this problem, with varying complexity of their implementation

2.1. The analysis of the carbon dioxide in the form of solid minerals with the absence of its negative impact on the atmosphere
Carbon dioxide assumes the form of a solid carbonate conserved in nature as the mineral by chemical reaction of calcium, magnesium and iron contained in the basaltic rock with a supercritical fluid CO. In this form, carbon dioxide can be stored underground without being released for quite a long time.

Options for addressing this problem is to transport it through existing oil wells or special lines. However, in Russia there is quite a lot of oil fields and, consequently, oil wells, which means that the first method can be used for our country. According to research, the optimal depth, excluding CO emissions into the atmosphere during the transportation of carbon dioxide, is about 1000 - 1500 meters. Consequently, the lengths of the pipelines are calculated to this depth.
In addition to this method of using CO2 in the form of carbonates, consideration should be given to its use in various technological processes. One of the options is to increase the pressure by injecting CO into oil wells, which increases the efficiency of oil production.

The same technology for reducing CO2, NOx and SOx emissions at coal-fired power plants was developed by Rodney Allam. However, it follows that this method has increased the cost of electricity by more than 60%, which makes the operation of TPP economically unprofitable. [4]

The next method of disposal was implemented in La Porte (Texas) companies NET Power, Exelon Generation, CB & I and 8 Rivers Capital. They launched the world's first power plant with a capacity of 50 MW. The “Allam Cycle”, named after its main inventor, Rodney Allam, was used in power generation.

This technique works as follows: a high pressure natural gas with pure oxygen are burned in the combustion chamber, and CO2 which is obtained by the reaction, in a closed circuit passes through a special turbine and is returned back into the process. The system has an efficiency of 58.9% and a high degree of carbon capture - almost 100%

Such a power plant does not pollute the atmosphere with practically anything from the standard "set": no mercury, no nitrogen oxides, no sulfur oxides. At the same time, the "Cycle of Allama" allows you to produce electricity at a low cost, like conventional gas turbines. [3]

This is not the only solution that has been adopted and implemented. The world's first plant that generates thermal energy and collects carbon dioxide from the air for resale, was opened in Zurich 2017 year.

The Climeworks startup, which organized the work of the company, believes that hundreds of thousands of such enterprises will be necessary to solve the environmental problems of the planet.

Special devices, processing and filtering the air from CO2, transmit the heat generated in the greenhouse for an underground pipeline. CO2 is also used in the production of carbonated drinks and fuels.

The plant requires much less space to operate than plants that can process the same amount of carbon dioxide. Such facilities can be operated in areas where there is no agricultural activity. The first plant in Switzerland processes around 900 tons of CO2 per year. This amount of carbon dioxide is emitted into the atmosphere by about 200 cars. To dispose of 1% of the world's carbon dioxide emissions by 2025, Climeworks require about 750,000 units, which will extract the carbon dioxide from the air. The company plans to expand production and collect 10 gigatons of CO2 annually by 2040-2050. [6]

In addition to these processing methods, there are others, such as the US company Novomer together with Albemarle Corporation successfully produced polypropylene carbonate (PPC), using carbon dioxide waste. They produce high quality adhesives for industrial use. The research on the project was carried out with financial support from the US Department of Energy for Fossil Energy. A German chemical company has successfully used CO2 to create polyurethane. The company Bayer considers that it may be used to create a soft foam used in mattresses.

Scientists at the Australian Royal Institute of Technology have learned how to convert carbon dioxide into coal. This method should help to combat the greenhouse effect and global warming. Scientists boldly argue that the electrocatalytic process using liquid metal at room temperature will create industrial CO2 conversion technology.

2.2. They started their research for a reason
It is believed that the technologies, which convert emitted anthropogenic CO2 into solid products suitable for storage for an indefinite period, will play a crucial role in stabilizing the global climate after the current transition of the world economy on a carbon-neutral energy sources.

- Annually emitted 40 Gt / year (40 * 109 tonnes);
- Accumulated weight anthropogenic CO2 emissions - 1000 Gt CO2.
CO2 is a remarkably stable molecule, and therefore the development of CO2 reduction electrocatalysts that operate at low overvoltage and at room temperature is challenging.

So far, 2 dominant approaches have been used, where CO2 is either recovered in gaseous form at high temperatures, or dissolved CO2 is electrocatalytically recovered in a liquid medium.

One of the researchers, Tom Daenecke, reported:
- The process of converting carbon dioxide into coal at room temperature is possible with the use of liquid metals if they are used as a catalyst.
- The process is possible in an industrial scale.

Previously it was thought that the CO2 may be converted only at extremely high temperatures.

The scientists created a liquid metal electrocatalyst contains cerium (Ce) nanoparticles, which promotes the electrochemical reduction of CO2 to layered solid carbonaceous particles. The process of formation of a catalyst based on cerium oxide (CeO2) at the liquid metal / electrolyte interface was used, which, together with cerium nanoparticles, facilitated the conversion of CO2 at room temperature.

Reducing CO2 to solids is challenging because any product can coat the catalyst surface through van der Waals adhesion, blocking access to catalytically active sites and causing catalyst damage in a process known as coking (the formation of carbonaceous materials that adhere to the catalyst surface and reduce catalytic activity).

In simple terms of chemists, due to the process of inhibition of van der Waals adhesion (between dissimilar molecules of various substances) at the interface between liquids, scientists have managed to make the electrode extremely resistant to deactivation by coking caused by solid carbonaceous compounds.

The obtained solid carbonaceous materials may be used for the manufacture of high-performance capacitor electrodes.

The maximum capacity of experimental 2-electrode capacitor -250 Fg-1 was registered at 10 mV s-1, which is comparable with some of the most effective carbon based supercapacitors in liquid electrolytes.

Research director Dorn Esrafil Zadeh confirmed that the substance becomes a supercapacitor, which in the future will allow to use it as one of the components of the engines of the future cars.

The process also allows to produce as a by-product synthetic fuel, which can also have commercial application.

2.2.1. The conversion process. The conversion process is as follows: CO2 is dissolved in an electrically charged container filled with liquid metal and electrolytes.

Gradually, carbon dioxide turns into a solid state and coal is formed. Performing such a procedure in a laboratory allowed scientists to develop the technology.

The practical implementation of this method will be taken up by engineers if it is confirmed that the technical process will be profitable. [5]

From all of the above, the following conclusions that decarbonisation is a complex project, both financially and technically, but technological progress does not stand still, and developing in full swing, there are solutions that are partially implemented and only expect mass production.

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