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Geoengineering vs climate change

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PREFACE

The following educational package consists of two parts. The first contains basic information about the topic of the debate.

In the second part you will receive tips on how to directly prepare for the debate, in particular how to prepare arguments supporting or contradicting the following resolution:

Governments should invest in geoengineering techniques to counteract climate change

INTRODUCTION

Definitions

GEOENGINEERING - deliberate, large-scale, planned manipulation of the physical, chemical or biological aspects of the Earth system in order to counteract climate change. Geoengineering can relate to a wide range of techniques. Most of them belong to two basic categories: removal of carbon dioxide (CO_2) from the atmosphere and limitation of the amount of solar radiation reaching the Earth's surface.

CLIMATE CHANGE - the term refers to the increase in the average surface temperature on Earth. The vast majority (99%) of scientists believe that the current climate change is primarily due to the use of fossil fuels by humans, which release carbon dioxide and other greenhouse gases into the air. Researchers are afraid that the natural variability of conditions is now less important than the rapid, man-made warming, which has serious consequences for the planet's climate stability. The effects of climate change are global and diverse: from changing weather patterns that threaten food production to rising sea levels that increase the risk of catastrophic floods.

GREENHOUSE EFFECT - is a natural phenomenon that allows our planet to maintain conditions necessary for life to develop and last. The atmosphere captures some of the sun's rays that reach the Earth's crust, keeping them inside to get an average surface temperature of 15°C.
Gases occurring naturally in the atmosphere, including water vapor, carbon dioxide, methane and nitrous oxide, do not absorb the energy of short waves from the Sun, but absorb energy radiated back from Earth, keeping the planet warmer. If the atmosphere didn’t catch any of these rays reflecting off the surface, the average temperature of the Earth would be -18 ° C. The problem arises when levels of greenhouse gases become too high due to human activity, stopping too much solar energy, disrupting the natural systems regulating our climate. As a result, we observe, among others, more and more

extreme weather events and other influences. Even small changes in the global average temperature can cause serious and dangerous changes in climate and weather. It is enough to take into account the difference between 0 and 1 degrees Celsius - this one degree only means the difference between water in a constant and liquid state of aggregation.

Global Warming Potential (GWP) - an indicator used to quantify the impact of a given substance on the greenhouse effect. Compares the amount of heat captured by a specific mass of gas to the amount of heat retained by a similar mass of carbon dioxide. GWP is converted for a specific time interval, usually 20, 100 or 500 years. GWP for carbon dioxide is by definition 1 (one).

CARBON DIOXIDE EQUIVALENT CO_2 equivalent, abbreviated as CO2-eq is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same **global warming potential**. Carbon dioxide equivalents are commonly expressed as million metric tonnes of carbon dioxide equivalents, abbreviated as MMTCDE. The carbon dioxide equivalent for a gas is derived by multiplying the tonnes of the gas by the associated GWP.
MMTCDE = (million metric tonnes of a gas) * (GWP of the gas).
For example, the GWP for methane is 25 and for nitrous oxide 298. This means that emissions of 1 million metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 25 and 298 million metric tonnes of carbon dioxide.

CLOUD SEEDING - cloud seeding is the process of combining different kinds of chemical agents — including silver iodide, dry ice and even common table salt — with existing clouds in an effort to thicken the clouds and increase the chance of rain or snowfall. Cloud seeding can be done from ground-based generators or aircraft. Rainmaking or precipitation enhancement began in 1946 when the American scientists Vincent Schaefer and Bernard Vonnegu at General Electric successfully seeded a cloud with dry ice and then watched snow fall from its base

INCREASING THE OCEAN pH - crushing, scattering and dissolving alkaline rocks, such as limestone (calcium carbonate), silicates in the ocean, in order to increase its ability absorb carbon dioxide to store coal. Ocean acidification is one of the changes in changes and changes taking place in the environment.

Geoengineering is a deliberate manipulation in a **large-scale** environment. Modification of the environment (and more often - restoration of the original state) must be the **main goal, not a side effect of the action**. Geoengineering is therefore not, for example, ornamental gardening: evidently intentional manipulation of the environment, however, neither the intended nor the implemented effect is on a large scale. In turn, climate changes due to greenhouse gas emissions have a global effect, but they are not geoengineering, but only a side effect of burning fossil fuels for energy purposes.

The dream of controlling atmospheric conditions - rather weather than climate - accompanies mankind from its beginnings. One of the first attempts of this type was the practice of **suppressing hailstorms** using church bells in the Middle Ages, which was used, among others, in France to protect vineyards. Although the people of that time could associate it with the interference of the heavenly forces, the bells were an early version of the so-called an anti-hail cannons, used in agriculture today.

The breakthrough and the transition from the dreams of bringing rain to real actions and effects was introduced by technological development of the twentieth century, and as it often happens with technology - the WWII and the competition of the superpowers (Cold War). In the USSR, already in 1932, the Institute of Rain was created, where work was carried out on the modification of clouds, experimentation with cloud seeind using calcium chloride, dry ice and silver iodide. The US did not stay behind - the experiments on cloud seeding in 1946 by Schaefer and Langmuir in the General Electric research laboratory triggered a commercial boom in weather modification, so much so that it required control: in 1953, the Advisory Commission on Control was established at the US Congress.

Think and answer the following questions:

Should anthropogenic climate change be called geoengineering? And littering the ocean? [Ref. INFO CARD No. 1]

Which action is NOT an example of geoengineering? [Ref. INFO CARD No. 1]

a) Fertilizing with iron
b) Reduction of carbon dioxide
c) Management of solar radiation
d) Ocean acidification

CLIMATE CHANGE IN A NUTSHELL

What is the greenhouse effect? This is a natural process, resulting from the ability of the atmosphere to pass a large part of solar radiation (mainly light) and to stop the radiation of the Earth (including thermal radiation). Thanks to this, the surface of the Earth and the lower layers of its atmosphere is warmer than it would be if the atmosphere did not exist - due to the greenhouse effect, the average temperature of the Earth's surface is -17 ° C, only + 15 ° C. Without the greenhouse effect on Earth, life could not arise and develop.

So where did so much confusion come from, regarding this phenomenon?

The problem is not the greenhouse effect itself, but changes in its severity. Since the end of the 18th century, we've been adding to the natural greenhouse effect, by producing large amounts of gases released from industry and agriculture (known as emissions), as a result: keeping more energy at the surface and increasing the temperature. This is commonly referred to as global warming or climate change. The most important of these greenhouse gases in terms of their contribution to warming is **water vapor**, but concentrations show slight changes of this gas as it can persist in the atmosphere only for a few days. On the other hand, **carbon dioxide (CO_2)** lasts much longer (it would take hundreds of years to return to pre-industrial levels). In addition, there is limited amount of CO_2 that can be absorbed by natural reservoirs, such as the oceans. Most man-made CO_2 emissions involve **burning fossil fuels** as well as cutting down coal-absorbing forests. Other greenhouse gases, such as methane and nitrous oxide, are also released as a result of human activity, but their overall abundance is low compared to carbon dioxide.

The predicted effects of climate change include, among others

- extinction of fauna/flora,
- soil depletion, problems with crops
- water shortage
- anomalies and extreme weather phenomena
- decrease of land and habitats

Since the Industrial Revolution in 1750s, CO_2 has increased by more than 30%, and methane levels have increased by more than 140%. The CO_2 concentration in the atmosphere is now higher than ever in at least 800,000 years. Has it been warmer in the past? Of course. But firstly, rapid climate change has always been associated with the so-called MASS EXTINCTIONS, secondly - the world as we know it, the landscape, fauna, flora, way of life, our civilization is built to the climatic conditions to which we are accustomed.

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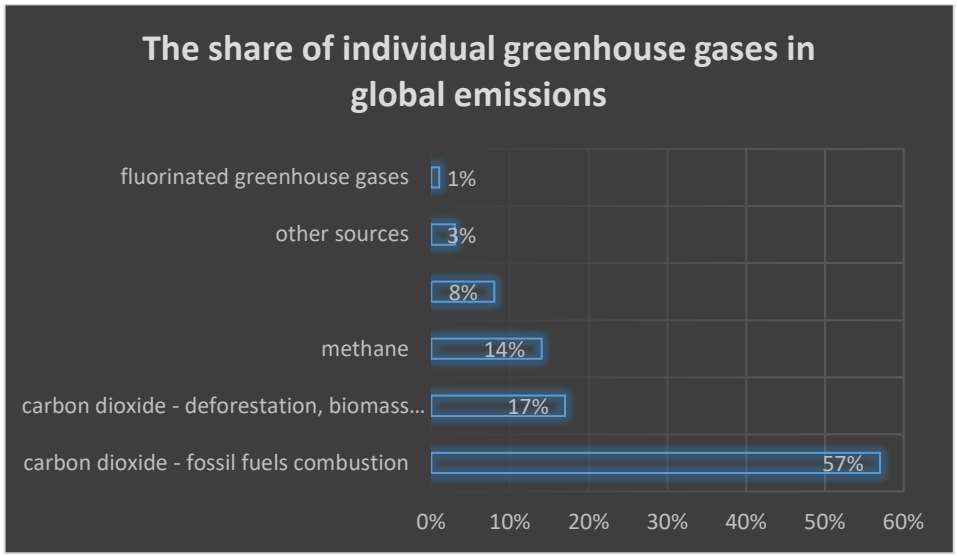

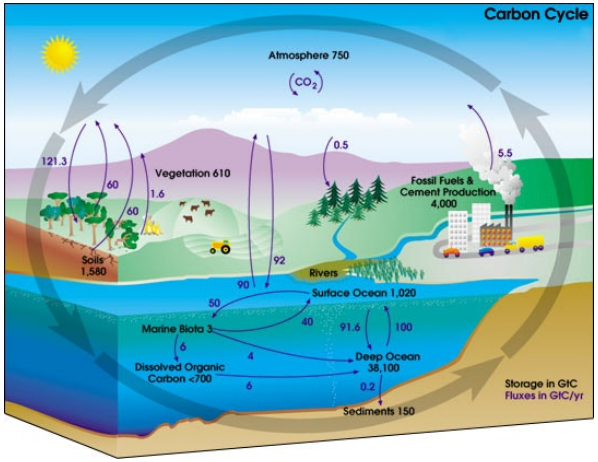

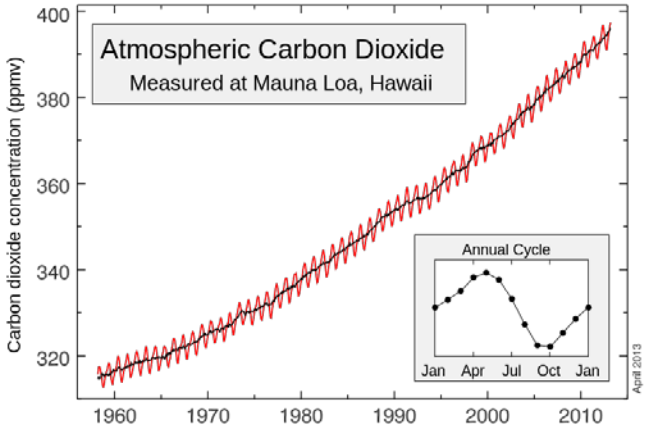

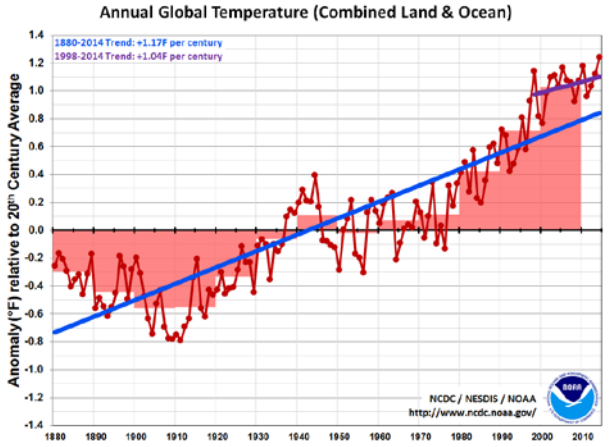

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Think and answer the following questions:

Does Earth cope with additional carbon dioxide in the atmosphere? [Ref. INFO CARD No. 2]
Which moment in history can be considered a breakthrough when it comes to climate change? [Ref. INFO CARD No. 3]

Extra material: Climate change in a nutshell - Climate Change 101 with Bill Nye | National Geographic
VIDEO, 4:09 : https://youtu.be/EtW2rrLHs08

SELECTED GEOEINGINEERING TECHNIQUES:

What is the answer of geoengineering to climate change? It is focused on 2 aspects:

Limiting the amount of carbon dioxide in the atmosphere

Limiting the amount of radiation

SRM – SOLAR RADIATION MANAGEMENT

SRM techniques try to reflect sunlight back into space and include a range of ideas, from orbiting mirrors, tons of sulphates sprayed into the stratosphere and modifying clouds, plants and ice to make them more reflective of more sunlight

CDM – CARBON DIOXIDE MANAGEMENT

These proposals assume that it is possible to suck carbon out of the atmosphere on a massive scale, using a combination of biological and mechanical methods, from sowing the ocean with iron pellets to create planktonic blooms, creating forests of mechanical "artificial trees"

ERM – EARTH RADIATION MANAGEMENT

These techniques are focused on the assumption that the negative effects of climate change can be offset by allowing the escape of heat into space - for example by thinning Cirrus clouds.

CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) is understood as the separation and removal of CO2 in fossil fuel combustion processes, its transport and injection into a selected geological structure/post-mining excavation or on the seabed. There are several technologies to obtain a concentrated CO_2 stream:

- pre-combustion
- post-combustion
- oxy-combustion

Carbon dioxide should be separated from other exhaust and industrial gases before being injected underground. CO_2 separation is one of the most expensive elements of CCS technology. This process is associated with energy consumption, resulting in increased fuel consumption and reduced efficiency of electricity generation, compared to a power plant without separation of carbon dioxide. These factors, together with the need to install additional devices, increase unit investment expenditures on electricity production, and thus increase the costs of energy production.
Modifications of this technology include Direct Air Capture (DAC) - capturing carbon dioxide directly from the atmosphere (currently there are 7 companies operating in the world with such installations, as for July 2019).

CCS usually refers to mechanical catchment of CO2 emissions from power plants or other industrial sources; usually, CO2 is captured, absorbed chemically before combustion gases leave the chimney. CAccording to UN Conventon on biodiversity CCS is not considered as geoengineering.

Data presented in the 2008 IPCC Report entitled "Energy Technology Perspectives" indicate CCS technology as one of the key to reduce CO2 emissions. The analyzes presented in the report show that CCS technology may contribute to approx. 20% reduction of CO2 emissions planned for 2050 [5]. Carbon capture and storage in deep geological formations is to be only a transitional technology, used until the technology is developed, allowing energy production from fossil fuels with simultaneous reduction or elimination of CO2 emissions or technologies that allow obtaining energy from fuels other **than fossil fuels.**

CARBON CAPTURE AND STORAGE

- **CO2 leak, esp. catastrophic, can disrupt the initial environmental benefits associated with the capture and storage of CO2 emissions, and can pose a threat to humans**
- **failure of Kemper County, a $ 7.5 billion CCS project in Mississippi, as proof that technology is essentially unachievable. In June 2017, after several years of controversy, Kemper finally abandoned coal and decided to burn gas. In the UK, the government has repeatedly tried and failed to liquidate CCS projects with the** help of private power plant operators
- **CCS is cost and energy-intensive - around 30% of the electricity generated in the capture facility after combustion (technology used to generate energy through CCS) would be required to supply the CCS components**

Mimicking the mechanism of the natural process - photosynthesis: powered by sunlight, take carbon dioxide from the air and use it to build roots, shoots and leaves.
- use of captured CO2 "feeding" algae producing biofuels; production of building materials (reaction with limestone rocks)
- If we continue to produce most of our electricity from fossil fuel combustion, we can at least reduce the carbon dioxide emissions by as much as 85%
- many geological reservoirs have the potential to store 100 - 1000 gigatonnes of CO2. The most promising reservoirs are porous and permeable rock bodies, generally at depths of approximately 1 km

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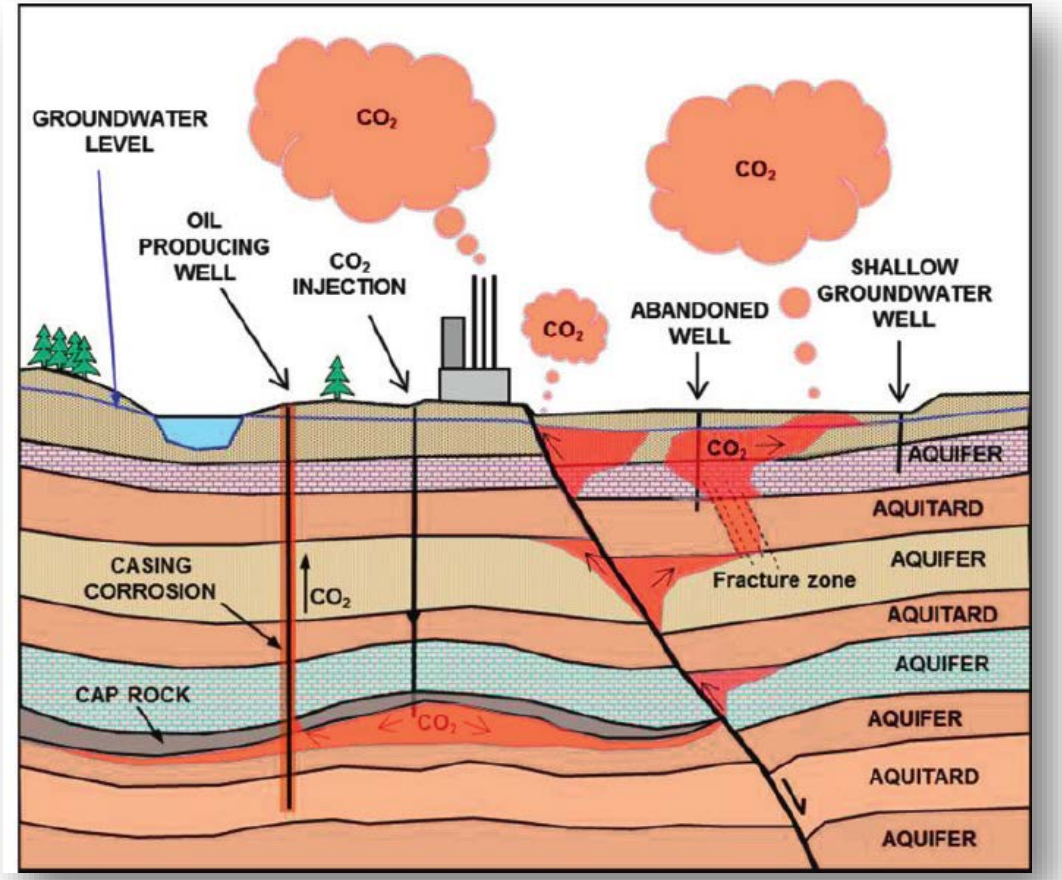

Threat of catastrophic leaks - a source of illustrations: Brydie, James & Perkins, Ernie & Fisher, D & Girard, M & Valencia, M & Olson, M & Rattray, T. (2014). The Development of a Leak Remediation Technology for Potential Non- Wellbore Related Leaks from CO2 Storage Sites.. Energy Procedia. 63. 4601-4611. 10.1016/j.egypro. 2014.11.493.

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CASE STUDY

In-situ R&D Laboratory for Geological Storage of CO2 (CO2SINK)

Source: CORDIS, EUROPE

Although geological sequestration of carbon dioxide (CO_2) offers a promising way to significantly reduce CO_2 emissions in Europe, there are public concerns about the safety and impact of environmental technologies for carbon capture and storage (CSS). Efforts to address these concerns are associated with a better understanding of the CO_2 sequestration process.

The project called "Local Geological Storage and Research Laboratory for Geological Storage of CO_2" (CO2SINK) has contributed to such efforts by monitoring its own activities related to CO_2 injection under the city of Ketzin near Berlin. The main goal of the project was to develop and test monitoring techniques with the support of a public external cooperation program.

The gas storage facility in Ketzin offered existing surface infrastructure, thus limiting the need to develop new solutions. In addition, it has well-known geological properties, which to a large extent are also characteristic of many areas in Europe. This advantage means that project results will be easier to transfer to other areas. What's more, the test site is located in close proximity to the urban area, which offers a unique opportunity to present land-based CO_2 storage. This was considered particularly important in increasing the general awareness of the benefits of geological storage of CO_2 as an opportunity to reduce greenhouse gas emissions.

During the 21-month period, a total of 33 thousand injections were made at the Ketzin facility. Tons of CO_2! The effects of this measure were observed and measured as part of long-term field monitoring using commercially available geochemical sensors that were used throughout the project's lifetime. Geophysical and geochemical techniques were used as well as sensor systems for monitoring shafts, propagation of CO_2 streak, temperature changes, gas composition and seismic effects.
One of the successes of the CO2SINK monitoring process was the indication that after five months of CO2 storage, microorganisms adapted to changes in environmental conditions. This and other successes were the inspiration for many national and international activities that significantly contributed to the implementation of the various objectives of the project.

Project partners undertook a series of activities to inform the wider community about the project, as well as about CSS in general.

The plant in which the project was implemented was the host of a small visiting center, which also offered the opportunity to visit, while several open events aroused wide interest of the local, national, European and international press.

HIGH ALBEDO CROPS

The Earth's Albedo varies all the time depending on what the surface is covered with (snow, green plants in spring, withered autumn, etc.), on cloud cover etc., The second parameter important for the surface temperature of the Earth is emissivity for infrared. While albedo talks about a part of the reflected radiation, emissivity talks about radiated energy. Again, it should be remembered that the energy radiated by the ground can be captured by the atmosphere and remain in the atmosphere.

If sea ice in the Arctic melts, the albedo will be like the ocean (depending, for example, on plankton). Of course, albedo and emissivity are important for the greenhouse effect. Plants reflect energy (short wave radiation), just like snow and other light surfaces. Plants have a higher or lower reflectivity of radiation, depending on factors such as the shape and size of the leaves and coverage - e.g. a layer of wax. Even different varieties of the same species can have higher or lower albedo: different varieties of maize have different morphologies - their leaves are arranged in different ways; different varieties of barley and millet, have more or less waxy leaves.
Researchers used a computer model to see what would happen if all crops around the world were turned into higher albedo strains. It turned out that the global temperature averaged over 150 years would drop by 0.1 ° C. This is not much, however, a significant part of the land area in North America and Eurasia is occupied by agriculture, temperatures in the summer may in such a case fall even by 1 ° C. It would be a welcome relief for regions that will be exposed to dangerous heatwaves in the coming century.

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Plants with wax coating have higher albedo than others. Scientists propose genetically modified varieties

More than a decade ago, the entrepreneur Alvia Gaskill has developed a program that covers a large part of deserts with a white polyethylene film reflecting sunlight and reducing surface temperature. Deserts have plants, animals and people living in them, and it is difficult to imagine life in a ecosystem covered with plastic. Desert dust, which will be hindered by plastic coatings, is essential for the global climate because it affects solar radiation, cloud formation and even ocean cooling.

High albedo crops

changes in species composition

limitation of food production

so called "monocultures" - risk of spreading diseases, soil degradation

forests/trees have a lower albedo -possible deforestation

local/regional

uneven, globally insignificant effect - 0,1 ° C in 150 years

relatively low costs

using natural processes

better quality of life on local level- albedo can increase by 0,04 with use of special species/forms on current agriculture areas;

this lowers temperature by 1^0 C in summer months, mostly in Western Europe

CASE STUDY

What is the potential of high albedo crops in the fight against global warming?

Source: Dominique Carrer et al 2018 Environ. Res. Lett. 13 044030

The management of land cover in agricultural areas is a powerful tool that can play a role in mitigating climate change. As part of a case study, using satellite data, we showed this introduction of cover crops for crop rotation during the set-aside period would increase albedo in the area of over 4.17% of Europe's area. According to these studies, the effect of this increase would be equivalent to a reduction of 3.16 MtCO2. This corresponds to the mitigation potential per unit area (m2) of 15.91 g CO2. This effect can be increased by 27% if the ground cover is maintained for more than 3 months. The countries with the greatest mitigation potentials are France, Bulgaria, Romania and Germany.

CRM

OCEAN FERTILIZATION

The second largest natural absorber of carbon dioxide - occupying over 70% of the Earth's surface - are the oceans. They store more than 50 times more carbon dioxide (CO_2) than the Earth's atmosphere and 20 times more than the terrestrial biosphere, and it is estimated that they have absorbed even 30% of CO_2 since the industrial revolution. In connection with this, theories and technologies appeared that aimed at (increased) use of oceans as CO_2 absorbers. The method of reducing atmospheric greenhouse gases is iron fertilization. It involves the introduction of iron compounds (but also nitrogen or phosphorus) to ocean waters, which is supposed to stimulate the rapid growth of phytoplankton. This, in turn, is supposed to absorb carbon dioxide and - falling to the seabed - lead to its (long-term) storage in the oceans. Fertilizers of fertilization argue that increased photosynthesis, caused by the development of phytoplankton, will lower the level of carbon dioxide in the atmosphere and thus weaken global warming, dead phytoplankton will fall into deep water, taking absorbed carbon that will be stored for a long time on the ocean floor, more phytoplankton means greater the amount of food for other species, and thus more fish and food for the growing population of the Earth.

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Artificial supply of iron to large areas of oceanic waters will result in increased development of phytoplankton and thus an increase in the number of organisms in which photosynthesis occurs

The marine food chain is based on photosynthesis by marine phytoplankton, which combines carbon with inorganic nutrients to produce organic matter. Production is limited by the availability of nutrients, most commonly nitrogen or iron. Numerous experiments have shown how iron fertilization can increase the yield of phytoplankton. Nitrogen is a limiting nutrient in most of the ocean and can be supplied from various sources, including cyanobacterial fixation. The ratio of carbon to iron in phytoplankton is much higher than the ratio of carbon to nitrogen or carbon to phosphorus, so iron has the highest potential of sequestration per unit of added weigh

Ocean fertilization

- Adding the iron completely changes the marine ecosystems,
- death of large phytoplankton blooms reduces the amount of oxygen dissolved in water,
- •life processes of microorganisms developing under conditions of low oxygen content in water may cause the formation of strong greenhouse gases such as methane (greenhouse gas 62-fold stronger than carbon dioxide) and nitrous oxide (greenhouse gas with a force of 275-fold higher than carbon dioxide) .
- in order to achieve the benefit of ocean fertilization in the form of coal storage, it would have to be carried out in large areas of the ocean in the southern hemisphere, as it is the only HNLC region where surface water sinks into the ocean, taking coal with it.

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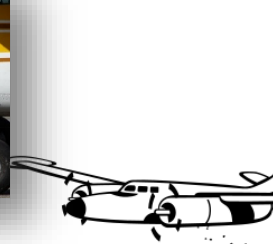
CASE STUDY

"*Give me half a tanker of iron, and I will give you a glacial era*." These words, humorous, were spoken by the oceanographer John Martin, who in the 90s formulated a thesis that approximately 430,000 tons of iron would be enough to bring the Antarctic Ocean to achieve the result of removing 3 x 10^9 tons of carbon dioxide from the atmosphere every year. J. Martin's works have been treated quite seriously - both by scientists and industry. Iron fertilization is regarded as a potential way to reduce carbon dioxide emissions for commercial purposes, namely for the purposes of trading in carbon dioxide emissions. The most advanced project in this area was approved by the American company Planktos Corp., which announced in May 2007 that its ship "Weathebird II" will deploy 90 tons of hematite (iron oxide) in the area of approximately 10,000 km^2, only 560 km from Galapagos Archipelago. It was supposed to be the first of six planned by Planktos Corp. projects for the years 2007-2009 in the Pacific and Atlantic area. Due to the very negative reaction of public opinion (including the government of Ecuador, but also non-governmental organizations - NGOs), the project did not get adequate funds and did not come to fruition. However, also other companies such as Climos, GreenSea Ventures Inc. (USA) and Ocean Nourishment Corp. (Australia) have prepared plans for fertilizing the oceans with iron15. Scientific interest in fertilizing the oceans with iron proved to be significant. In the years 1993-2009 14 experiments in this range were carried out. As can be seen from the above data, the experiments were carried out predominantly in the Antarctic Ocean waters, and to a lesser extent in the Pacific and Atlantic Ocean. This is due to the fact that iron fertilization - in order to be an effective method of carbon sequestration - must take place in waters with a high nutrient content .

SRM



CLOUD SEEDING

Cloud seeding applies to some types of clouds (cumulus, stratocumulus), because these clouds reflect radiation back into space. Cirrus clouds have opposite properties, they "stop" radiation at the Earth's surface, preventing it from escaping back to space; in this case, geoengineering techniques focus on "puncturing" rather than "strengthening" such clouds.

NOTE: another, but related method is injection of aerosols in the atmosphere - e.g. sulfate aerosols into the stratosphere, which do not absorb solar radiation, but reflect them and play a similar role to dust particles and aerosols suspended in the stratosphere after the eruption of volcanoes and cause cooling of the Earth by reflection of solar radiation. Sulfur compounds should be introduced in the upstream part of the stratospheric circulation in a tropical atmosphere; about 1-2 million tons of sulfur per year is needed to reduce the warming by 1.4 W/m^2. This type of change will cause visible effects, such as change in the color of sunrise and sunset and a decrease in the amount of stratospheric ozone.

Another technique is to introduce soot particles into the stratosphere that would absorb solar radiation, but that would heat the stratosphere and reduce the stratospheric ozone concentration. This method would require burning fossil fuels.

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Cloud seeding s a process of combining different types of chemicals - including silver iodide, dry ice and even ordinary rock salt - with existing clouds to thicken the clouds and increase the chances of rain or snowfall. Chemicals are either ejected from the earth's surface or released during the flight. plane

And as a result, the cloud cover increases, it is brighter - it has a higher albedo, it reflects more solar radiation back into space

The method of Stratospheric Aerosol Injection includes supplying sulfates to the atmosphere at high altitude, about 20 km (possibly also silver or potassium iodide) One of the methods proposed is the use of special balloons to inject sulfur aerosol in the stratosphere, i.e. the atmosphere layer above the troposphere. The stratosphere is separated from the troposphere by tropopause, and within it the temperature rises with altitude. Such conditions hinder the mixing of air between the layers, which means that the aerosol blown into the stratosphere stays in it not for several days, but for several years.

Stratospheric Aerosol Injection

Change in global precipitation patterns - drought in sub-Saharan areas of Africa, problems with food production
Harmful chemicals injected into the atmosphere and falling to the ground, polluting e.g. aquatic ecosystems (silver iodide solution)
Potential violation of the ozone layer as a result of chemical reactions
Efective only for certain types of clouds (already generating rain) - difficulties in assessing effectiveness - even despite technological progress, it is difficult to distinguish weather that occurred naturally from weather conditions caused by sowing clouds
No control over the effect - the possibility of causing a catastrophic flood when countering drought in a given area

Relatively cheap and feasible method - low cost of chemicals; the possibility of using existing aircraft or building relatively inexpensive guns

Counteracting catastrophic droughts, saving crops, counteracting famine

Imitation of natural, well-proven processes and their intensification

CASE STUDY

Military personnel from the United Arab Emirates officially admit that since 2006 they have been conducting cloud seeding operations so that the largest drought plaguing the Arabian Peninsula in 900 years has come to an end. Each year, the military perform about 160 missions during which silver iodide loads are dropped from the aircraft onto the clouds. In the Emirates, seeding operations are carried out mainly over mountainous areas, i.e. near the border with Oman, to raise rainwater levels in aquifers and water bodies. The chance of successful cloud seeding over the mountains is greater than over the deserts. Scientists who cooperate with the authorities of the United Arab Emirates to cause rain, talk about the first effects of their mission. However, there are also spectacular failures. One of them is the disaster that affected the northernmost emirate of Ras Al Khaimah.
Residents were looking forward to life-giving rain. When the clouds came, in just a few dozen hours it fell as much rain as it usually falls for 2.5 years!

The emergency services received 3,000 calls from terrified residents who had to face the long-unseen element, which was the last thing they expected during a long-term devastating drought.
Rescuers helped over 700 people who got stuck in cars on flooded roads. In some places, the water reached a height of several meters. Drivers and passengers were almost drowned. 170 tourists were rescued in the area of Jebel Jais, the highest mountain in the Emirates, who got stuck due to floods and landslides.

ENVIRONMENTAL AND GEOPOLYTICAL EFFECTS

Think and answer the following questions

What conditions should be met by methods of combating climate change?
Choose the 5 most important according to you

safe	cheap	Long term effects	predictable	reversible
feasible	efficient	controllable	Well tested	fast results
No pollution	Regulated on international level	Large scale results in large areas	Minimized modification of environment	positive side effects

WHAT DO SCIENTISTS SAY?

PLAN B or LAST CHANCE plan?

What is **PLAN A** and **PLAN B** in the context of climate change?

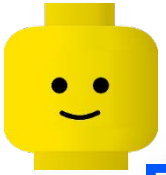
Plan A aims to significantly reduce greenhouse gas emissions for a long-term solution, but global progress has been slow and at current emission levels global temperatures may increase by 5.5 degrees Celsius to 2,100. (This is currently considered the worst case scenario, although some scientists believe that we are already in this course).

Plan B is **geoengineering**. Many environmental scientists consider geoengineering techniques to be a real complement to reducing greenhouse gas emissions, but not a substitute solution. Some believe that geoengineering is "bandage for the planet", helping only solve the problem once it has occurred. They argue that technologies will be used as an excuse for countries to continue to emit large amounts of greenhouse gases (GHG) instead of investing in a real reduction of greenhouse gas emissions.

The world may increasingly seek geoengineering following the latest UN climate report, which says it can be accepted as a temporary "countermeasure" if the world is moving towards a dangerous level of warming.

The authors of the new study, carried out by the Intergovernmental Panel on Climate Change, argue that there is a strong consensus that injecting millions of tons of sulfur dioxide into the stratosphere can help limit the temperature rise to the most ambitious goal of the Paris Agreement.

But the authors warn that there are serious doubts about social, environmental and environmental impacts, which means that the world would be much better if policymakers strengthened natural cooling systems such as afforestation and accelerated efforts to reduce carbon emissions.



DAVID KEITH: professor of physics at Harvard's School of Engineering and Applied Sciences (SEAS) and professor of public policy at Harvard's Kennedy School of Government, he is the founder of Carbon Engineering, implementing carbon dioxide sequestration

VIDEO: Watch TED talk with David Keith (16:27)

EXTRA MATERIAL - ARTICLE: **Halving warming with idealized solar geoengineering moderates key climate hazards <-read**

In the half insulation reduction scenario used in this study, it is suggested that solar geoengineering should not cause deterioration of rainfall / access to water or extreme weather events. It's a case of "this dose decides what is poison," says David Keith, a Harvard engineer and geoengineering expert.

The study is based on a high resolution model that is particularly useful in simulating hurricanes and extreme rainfall. The authors examined several different potential climatic parameters, including average and maximum temperatures, maximum annual rainfall and total water availability for a given region, defined as the amount of rainfall that falls in relation to the amount of water that evaporates from this area. They evaluated the region's results by regions around the world, dividing the globe into the same segments that used the Intergovernmental Panel on Climate Change in their analyzes of regional climate impacts. In each case, they assessed whether the climate effect was exacerbated by solar geoengineering - that is, it deteriorated in comparison with climate change and geoengineering. They found that no region has seen any of these variables deteriorated by solar geoengineering.

Some scientists, however, are skeptical about the results of this study. First, the study simulates the effects of solar geoengineering, according to Alan Robock, an expert on climate and aerosols, rather than accurately reflecting the effects of aerosols in the air, which may have additional side effects, such as warming of certain parts of the atmosphere, change of atmospheric circulation or impact on the ozone layer .

The statement that no region on Earth would experience any climatic effects worsening by geoengineering, even in the half-warming scenario, would be premature, the researchers conclude. But this questions the belief that such results are inevitable, or that they always outweigh the benefits.

A 2010 study published in Nature Geoscience found that, under a solar geoengineering regime, there would be different responses across large regions, making consensus about how much to reduce incoming solar radiation difficult, if not impossible.

Some atmospheric scientists, like Dr Alan Robock at Rutgers University, argue that the complexity of the climate system means that it's difficult to draw firm conclusions about the consequences of such a radical intervention. They point out that the chemistry of the upper atmosphere – including the ozone layer – is complicated and poorly understood. Reducing the amount of sunlight reaching the Earth in a computer model may give little clue as to what would happen in the actual climate system if a layer of sulphate aerosols were injected into it.

Critics say even researching such technologies creates a moral hazard, because by suggesting an easy fix for global warming, it encourages delay in ending our addiction to fossil fuels. The stratospheric sulphate plan "may well encourage weaker action on emissions reduction," says Joanna Haigh, an atmospheric physicist at Imperial College London.

VIDEO: watch TEDtalk We can control climate, but should we? The ethics of geoengineering (14:14)

PREPARATION OF ARGUMENTS: USEFUL INFORMATION

Info card 1	Info card 2	Info card 3	Info card 4
Additional carbon dioxide emissions vs equilibrium on Earth About 40% of the additional emission is "absorbed into the normal cycle of carbon circulation in nature, but 60% remains in the atmosphere. The climate system reacts in its own way. First, the acidity of the oceans absorbing excess carbon dioxide increases. If only the oceans were the source of the emission, this phenomenon would not have taken place. Second, the atmospheric oxygen concentration decreases. Oxygen combines with coal in the combustion of fossil fuels. If the oceans were the source of emissions, oxygen should not be lost. Thirdly, the content of the 12C isotope in the atmosphere increases (which translates into a decrease in the relative content of the 13C carbon isotope). This indicates that the source of additional CO_2 is fossil fuels, containing proportionally more carbon	**When did we start to influence the climate on Earth so much?** Our influence grew significantly at the beginning of the 19th century - so-called "Industrial revolution" is the large-scale combustion of energy resources, then the emissions, concentration of carbon dioxide in the atmosphere and average surface temperature increase. On the other hand, exceeding 400 ppm (2016) is also a line from which - according to many - there is no coming back.	**Serious institutions invest in research** The CIA collaborates with the US National Academy of Sciences (NAS) to fund a 21-month "technical evaluation" of various geoengineering techniques, including proposed solar management systems and carbon dioxide removal. This is the first NAS geoengineering survey funded by the intelligence agency. The budget is $ 630,000.	**Aerosols and 'ozone hole'** The release of reflective sulfate aerosols into the stratosphere to cool the planet results in the formation of sulfuric acid, which reacts with ozone to damage the protective ozone layer, which in turn may lead to increased skin cancer, eye damage and other adverse health consequences.

isotope 12C to 13C than inanimate matter. Does this excess really make a difference? Over hundreds of thousands of years, the concentration of carbon dioxide in the atmosphere oscillated around 180-300 ppm - it was enough for the Earth to transform thoroughly, going from glaciations to warm interglacials. Today, this concentration is over 400 ppm and is growing unprecedentedly.			
Info card 5	**Info card 6**	**Info card 7**	**Info card 8**
Solar engineering and carbon dioxide Theoretically, methods based on limiting the amount of solar energy have no effect on the content of greenhouse gases in the atmosphere, but the use of solar geoengineering could indirectly reduce the amount of CO2 in the atmosphere by inhibiting the melting of permafrost, reducing emissions in the energy sector and causing changes in the carbon cycle feedback.	**Guano makes Arctic COOLer** Researchers have found that ammonia released from huge amounts of guano of seabirds helps create low lying clouds, producing condensation nuclei. Clouds can partially block sunlight and thus lower the temperature. This applies above all to birds that form colonies in the Arctic (auks, puffins, terns, etc.). Birds leave even 33 000 tons of guano (manure) in the Arctic yearly. As they note, this is a significant regional effect in the entire Arctic, but insufficient to counteract its constant rapid warming.	**Geoengineering vs photosynthesis and energy** The release of sulphate aerosols should theoretically lower global temperatures, reflecting a small percentage of incoming sunlight away from the Earth. However, additional particles would also dissipate more residual light in the atmosphere. This would reduce by 20% the amount of sunlight that has a direct path to the ground, and would increase the level of softer, scattered light. Reducing direct sunlight would affect the solar industry, which is based on direct sunlight to generate a significant portion of its power. But increased indirect sunlight would increase photosynthesis under tree crowns.	**Thermal trap** he increase in air temperature is delayed, because the atmosphere, in a way, with a delay, is catching up with all the heat that the Earth has accumulated. After about 40 years from the potential immediate stop of combustion of fossil fuels, the climate is likely to stabilize at a temperature higher than normal for previous generations. Even if carbon dioxide emissions suddenly stop, carbon dioxide already in the Earth's atmosphere can continue to heat our planet for hundreds of years, according to research by Princeton University in the journal Nature Climate Change. Researchers have simulated the Earth on which, after the emission of 1,800 billion tons

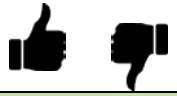
		However, the most visible effect would be above us.	of carbon into the atmosphere, all carbon dioxide emissions have suddenly stopped. Over the millennia after this simulated shutdown, the coal itself gradually disappeared; 80 percent disappeared after 1000 years. Lowering atmospheric carbon dioxide alone should lead to cooling. For the first 100 years, the planet cooled down significantly, but over the next 400 years, the temperature increased by 0.37C.
Info card 9	**Info card 10**	**Info card 11**	**Info card 12**
White sky The blue color of the clear sky comes from the light scattered by the particles in the air. The scattering is much stronger for short blue wavelengths than for longer red wavelengths - that's why we perceive the sky as blue. Aerosol particles, however, are much larger than particles of air components and more strongly disperse red light, which washes away the blue light scattered by smaller particles and makes the look sky brighter and whiter. Increasing the number of particles with a diameter from 0.1 to 0.9 micrometers will affect the spectrum of scattered light and, as a result, the color of the sky. Blocking just two percent of the sun's light toward the Earth can make the sky three to five times brighter and whiter than it is now. The psychological effects of this phenomenon are not studied.	**Expensive or not** A global technology for delivering sulfates into the atmosphere could cost $ 2 to 2.5 billion a year. About $ 500 billion a year is invested in green technologies.	**No switch off, no safety button** The so-called "termination shock" is the predicted rapid and significant increase in global temperatures after the sudden and complete / significant discontinuation of the implementation of geoengineering techniques - at such a rate that adaptation of fauna, flora and humanity would not be possible. Such unexpected termination could occur due to global armed conflict, energy shortages, technological failure, etc. The effects of geoengineering techniques, once initiated, are difficult to control. For most geoengineering methods, in particular those related to solar radiation management (e.g. seeding of clouds) but also e.g. fertilization of oceans, it is not possible to immediately stop the interference and reverse its effects	**Geoengineering vs rainfall** Global warming increases the average rainfall due to increased evaporation. A study in the Journal of Geophysical Research suggests that geoengineering can significantly reduce rainfall, to the extent that it may threaten crops and the availability of drinking water, because the "shading" of the Earth associated with techniques slows evaporation, so there is a net fall in precipitation.

Story card 1	Story card 2
OPERATION POPEYE – WEATHER AS WARFARE During the Vietnam War, the US Air Force carried out over 2,600 flights aimed at the CLOUD CLOUD on North and South Vietnam, Laos and Cambodia as part of a secret operation aimed at extending the monsoon season and stopping North-Vietnam troop movements due to muddy roads and flooded lines communication. Silver iodide and lead iodide were released into the atmosphere, which led to the extension of the monsoon season on average from 30 to 45 days. The purpose of these activities was: • Softening of road surfaces • Development of landslides along roads • Maintaining high soil saturation with water Weather was already perceived as a potential weapon much earlier. In 1872, the US Congress authorized secretaries of war and navy to investigate the relationship between artillery fire and rain propagation proposed by Edward Powers in the book "War and Weather" (1871). After declassifying the Popeye operation in 1974, the UN banned the militarization of weather phenomena - the ENMOD treaty (1977) was introduced, which banned offensive, large-scale weather modification. Operation Popeye was quite successful and achieved its goals. Here is a quote from the 274th Memorandum from the Deputy Undersecretary of State for Political Affairs (Kohler) to the Secretary of State (Rusk) regarding its conduct (Washington, 13 January 1967). "In our opinion, the experiments ended with an undeniable success, indicating that at least in weather conditions and terrain, such as those on which the actions were taken, the US government realized the possibility of a significant modification of the weather. The tests were simply "too successful" - you cannot accurately predict the volume of induced rainfall and the range of the affected area. The only available control is therefore to stop the sowing mission of the clouds. "	**Time travel** Let's assume it's 2054 and you're a member of the Global Technology Council. World governments have not halved greenhouse gas emissions by 2030 - the deadline set in the UN report from 2018, thus triggering the rapid warming chain. The Council reviews applications for the use of geoengineering technologies and must give its consent. 3 requests were received. Consider how you would vote at a Council meeting. **REQUEST No 1** Mega storms and fires regularly kill hundreds and displace tens of thousands of people in the United States, in coastal cities, people are abandoning massively low-rise neighbourhoods, regularly flooded and flooded. Fresh water and food are missing because the drought is drying up the source and pushing the rice basket of the Mekong Delta delta. In order to provide relief and contain chaos, global superpowers want to block 40% of sunlight from 100,000 huge mirrors.  **REQUEST No 2** The weather forecast says that during the opening ceremony of the Olympic Games in Warsaw there will be a pouring rain that will destroy all plans that cost millions of dollars. The organizers are considering spraying sulfur dioxide into the atmosphere to create clouds and make the rain fall faster to make sure that the sky is blue on an important day. 

Reporter Jack Anderson published in March 1971 a report about Operation Popeye. Public opinion was furious, the operation caused indignation and was called the "Watergate weather war".

REQUEST No 3

The Tibetan plateau has suffered from drought for 5 years. The Chinese plan to implement a plan to send thousands of rain-generating machines to the Tibetan plateau to increase rainfall in the region



Story card 3

Mimicking nature

The Pinatubo volcano (1485 meters high) became famous for the second largest volcanic eruption in the 20th century. In July 1990, a 7.8 m earthquake occurred 100 km northeast of the Pinatubo region due to the re-awakening of the volcano. The outbreak of the Pinatubo volcano in the Philippines in 1991 led to the emission of 10 million tons of sulfur into the atmosphere. It acted like a mirror reducing the amount of solar radiation reaching the surface of the Earth. As a result, it cooled down many months by 0.3-0.5 degrees Celsius.

Paul Crutzen inspired by the Pinatubo effect published in 2005 an article in the scientific journal Climate Change, in which he calculated that it would be enough to release 5.3 million tons of sulfur into the atmosphere to temporarily cool the Earth.

In 2011, the Particle Injection for Climate Engineering (SPICE) project was initiated, part of which is a $ 30,000 test. The experiment was discontinued because it caused great controversy.

Story card 4

Nyos: the KILLER LAKE

Nyos lake in northwestern Cameroon has had one of the strangest and most mysterious natural disasters in history.

Evening on August 21, 1986. Farmers living near the lake heard rumbling, a huge foamy stream shot out of the lake, and a white cloud gathered over the water. The cloud grew to about 100 meters high and flowed through the area. It fell in a valley where people lived. Suddenly, they began to fall en masse, losing consciousness or dying in a few breaths. In Nyos and Kam, the first villages affected by the cloud, only 4 people survived.

Lake Nyos is a volcanic lake, formed on the top of the crate; about 5,000 tons of carbon dioxide per year gets to the base of the lake through a volcano cloak. The unlucky day more than 1,700 people died after about 1.6 million tons of carbon dioxide were suddenly released from the lake as a result of the so-called Limnic eruption. This amount of carbon dioxide is an order of magnitude greater than the largest possible amount of carbon dioxide stored in CCS.

Preparation for the debate

After reading the materials presented, you can proceed to directly prepare the arguments for the debate. Below are a number of questions. Answers to them can be good arguments for discussion. Some of them strongly support the thesis, others will help in refuting it. Some arguments are debatable and can be used by both sides.

Task. Answer the following questions. Write answers that are also arguments for discussion in the appropriate place in the table (Worksheet No. 1).

Question card 1	Question card 2	Question card 3	Question card 4
How fast are the effects of reducing greenhouse gas emissions?	*How fast can the effects of geoengineering methods be stopped or reversed?*	*What are the consequences of limiting the inflow of solar radiation for RES (Renewable Energy Resources)?*	*How does investing in geoengineering affect the search for emission reduction methods?*
Question card 5	**Question card 6**	**Question card 7**	**Question card 8**
Does geoengineering limit all identified negative effects of climate change?	*What are the possible side effects of the geoengineering methods prom the perspective of environment and public health?*	*Is it possible to stop all greenhouse gas emissions immediately?*	*What happens if all anthropogenic emissions of greenhouse gases into the atmosphere are suddenly stopped? Will this stop global warming?*
Question card 9	**Question card 10**	**Question card 11**	**Question card 12**
Do all methods of geoengineering require the use of chemicals?	*How do geoengineering methods potentially affect rainfall?*	*Are geoengineering techniques expensive or cheap?*	*Is it possible to use some methods at very low costs?*
Question card 13	**Question card 14**	**Question card 15**	**Question card 16**

Is the decision process regarding the use of geoengineering techniques globally fair?	*Is it possible to use geoengineering techniques for purposes other than related to climate change?*	*Is there a natural process / processes that partially are imitated by the geoengineering methods?*	*Are the technologies that we commonly use today always accepted and greeted enthusiastically?*

Division into PROPOSITION and OPPOSITION teams

Task.

You already have arguments that you can use during the discussion. At this stage, you will prepare yourself directly to formulate the argument in accordance with the assigned role and to justify and defend them. Try to predict which counterarguments the opponents will use and prepare your answer. In order to do this, use worksheet No. 2.

Odyssey
Oxford Debates for Youths in Science Education

Erasmus+

Geoengineering vs climate change

Material for the debate:

„Governments should invest in geoengineering techniques to counteract climate change”

Institute of Geophysics
Polish Academy of Sciences

CENTER FOR THE PROMOTION OF SCIENCE

IRESE

ENERGIA
AVASTUSKESKUS
ENERGY DISCOVERY CENTRE

Geoengineering: what it is, what it is not

Large-scale, sudden, deliberate manipulation of the natural environment using various engineering techniques.

MOSTLY: fight against climate change

Example1: 1 day all people in China plant a tree

Example 2: people on

Earth Begin to use exclusively recycled paper

Example 3: 2000 new wind power plants are launched in one week

Brief history of ruling the weather (…climate?)

- **Bringing rain– tribal dancing, „rain whisperer” in Wild West**
- **1841 – „Philosophy of storms” – American meteorologist,James Pollard Espy – idea to bring rain during draught by setting fires**
- **1932 – USSR – Leningrad Rain Institute funded**
- **1946 – USA – General Electric Research Institute funded**
- **1967-1972 – military use of geoengineering – OPERATION POPEYE during Vietnam war**

Brief history of ruling the weather (…climate?)

- **2006** – ‚stratospheric war" – and what if we launched milion tonnes os aulfate aerosols above the Arctic? Idea: Lowell Wood; aim: to increase of sea ice
- **2008** – Olympics in Bejing– a storm was delayed to make sure there was beautiful weather during opening ceremony
- **2011** – IPCC – report on geoengineering
- **2013** – CIA+NAS (National Academy of Sciences) – budget: 630 000 $ - feasibility study; first NAS programme financed by intelligence

What does law say?

Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques w skrócie *Environmental Modification Convention (**ENMOD**)*) – international agreement, 10 December 1976 –Resolution of General Assembly of UN 31/72,

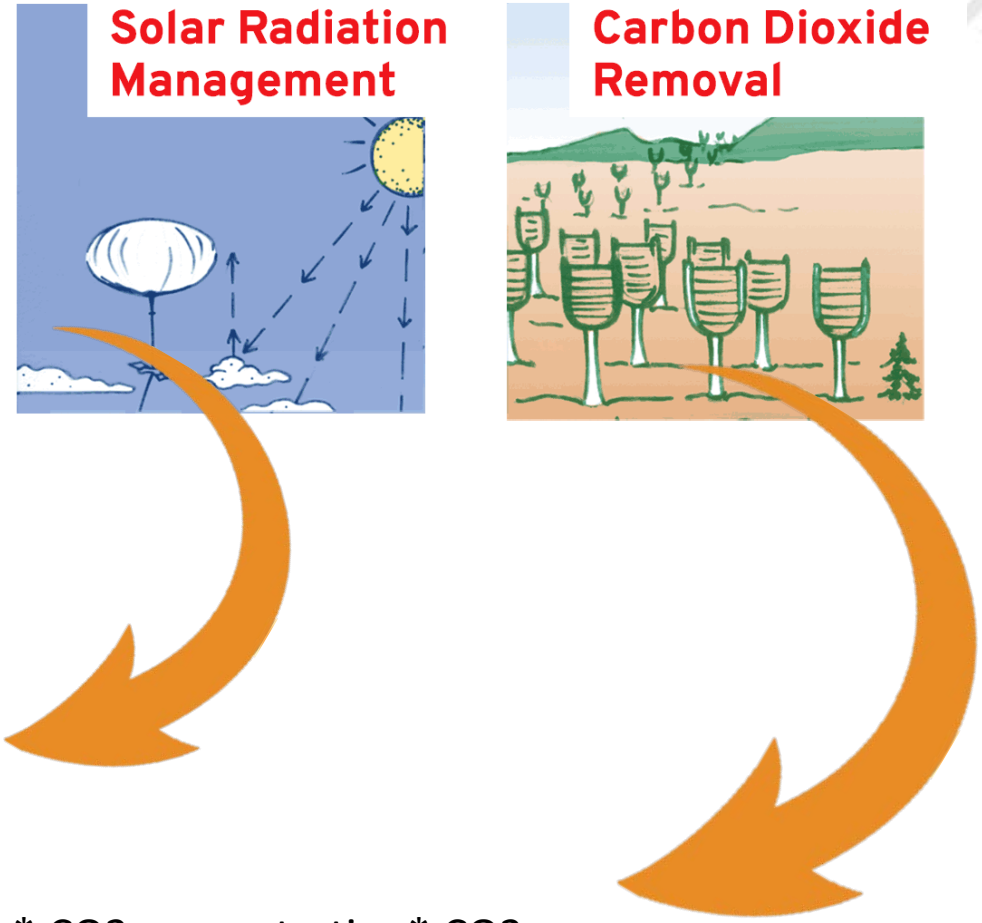
- Ratified by Poland 4 May 1978 r.
- **77 countries are now parties (NOT USA)**

- Convention was violated from the very beginning

GEOENGINEERING - how does it work?

2 main approaches

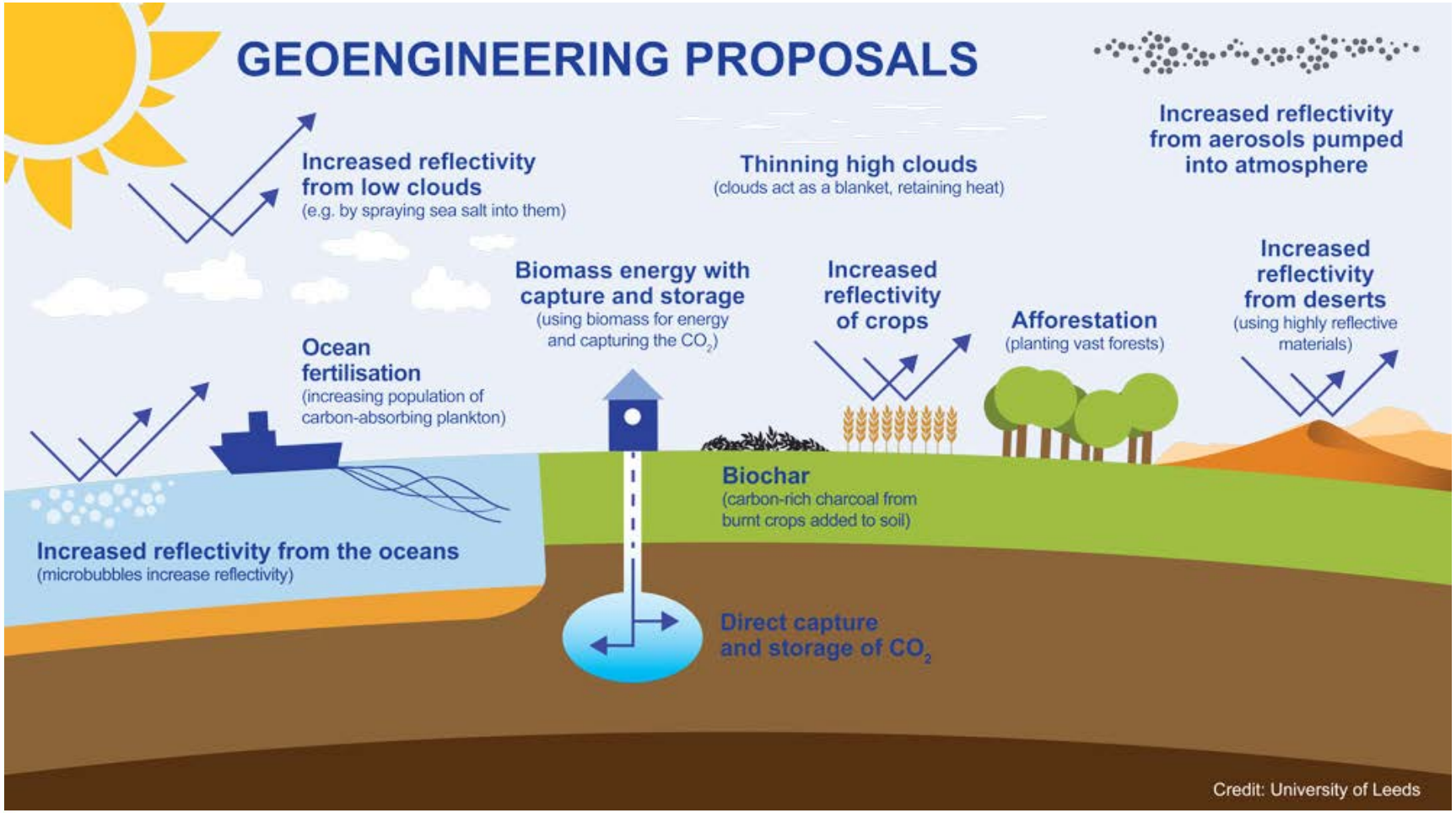
- Carbon dioxide removal (CDR)
- Solar radiation management (SRM).



giant mirrors * blankets* cloud seeding* painting buildings white* high albedo crops

Ocean fertilization* CO2 sequestration* CO2-hungry crops*rock weathering

(some) Geoenginenering techniques



FACT:
Works much faster than limiting emissions

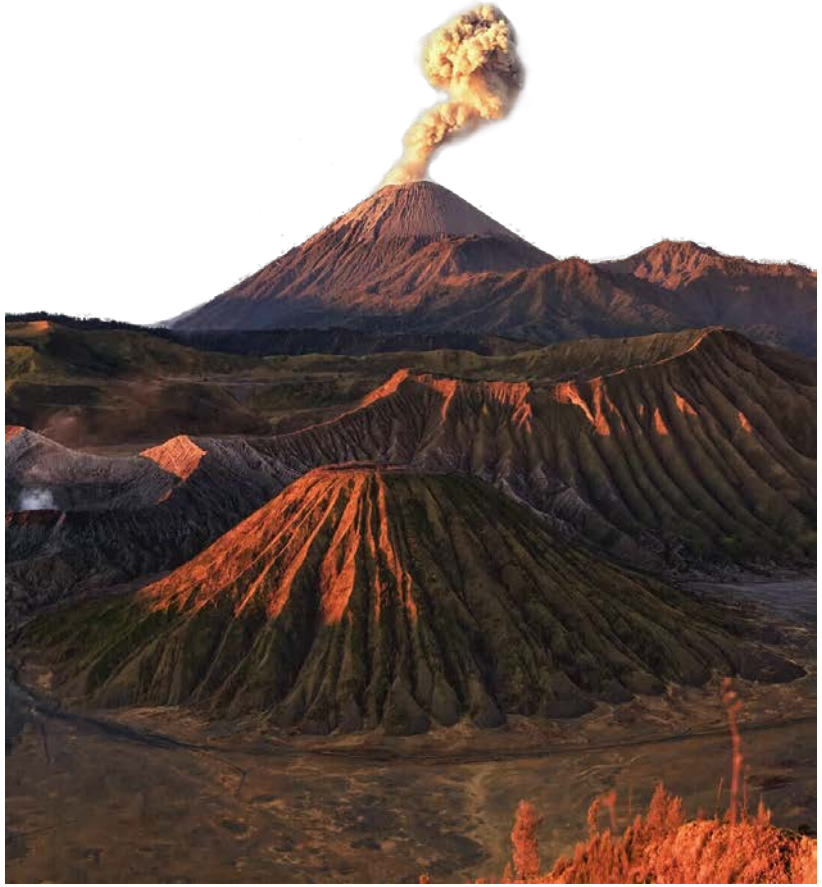
FACT:
No „switch-off”, no control once launched in many cases

Imitating nature vs TURBOnature

- Mt Pinatubo - The outbreak of the Pinatubo volcano in the Philippines in 1991 led to the emission of 10 million tons of sulfur into the atmosphere. It acted like a mirror reducing the amount of solar radiation reaching the surface of the Earth. As a result, it cooled down many months by 0.3-0.5 degrees Celsius

- Birds guano - in the Arctic, ammonia from bird guano contributes to a process analogous to the sowing of clouds. Volcanic eruptions are a source of dust that increases the amount of solar radiation reflected back into space.

- GMO-high albedo crops – wax/special varieties: extra reflection – local effect



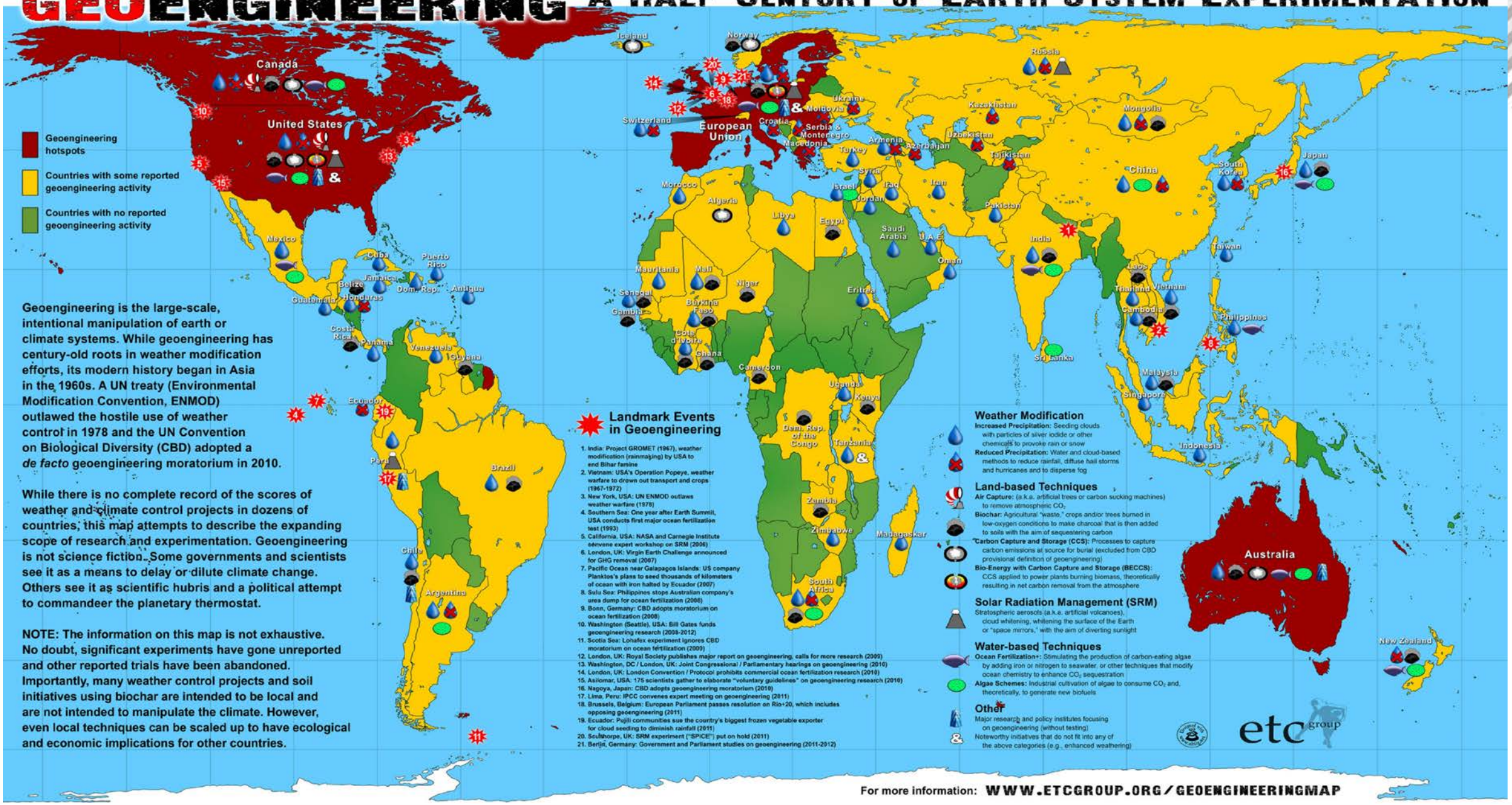
How much does it cost?

FOR EXAMPLE:
SRM: Total pre-start costs to launch a hypothetical SAI effort 15 years from now are ~$3.5 billion in 2018 US dollars. A program that would deploy 0.2 Mt of SO2 in year 1 and ramp up linearly thereafter at 0.2 Mt SO2/yr would require average annual operating costs of ~$2.25 billion/yr over 15 years.

CCS: The Carbon Capture & Storage Association (CCSA) estimated that the earlier CCS projects in the power sector would cost between €60–€90 per tonne of carbon dioxide abated, the equivalent of around $69-$103 per tonne.
The association also predicted that these costs will decline to €35–€50 ($40-$57) in the early 2020s, thanks to technological advancements.

About $ 500 billion a year is invested in **green technologies (renewable Energy)**

GEOENGINEERING A HALF-CENTURY OF EARTH SYSTEM EXPERIMENTATION



Geoengineering is the large-scale, intentional manipulation of earth or climate systems. While geoengineering has century-old roots in weather modification efforts, its modern history began in Asia in the 1960s. A UN treaty (Environmental Modification Convention, ENMOD) outlawed the hostile use of weather control in 1978 and the UN Convention on Biological Diversity (CBD) adopted a *de facto* geoengineering moratorium in 2010.

While there is no complete record of the scores of weather and climate control projects in dozens of countries, this map attempts to describe the expanding scope of research and experimentation. Geoengineering is not science fiction. Some governments and scientists see it as a means to delay or dilute climate change. Others see it as scientific hubris and a political attempt to commandeer the planetary thermostat.

NOTE: The information on this map is not exhaustive. No doubt, significant experiments have gone unreported and other reported trials have been abandoned. Importantly, many weather control projects and soil initiatives using biochar are intended to be local and are not intended to manipulate the climate. However, even local techniques can be scaled up to have ecological and economic implications for other countries.

Landmark Events in Geoengineering

1. India: Project GROMET (1967), weather modification (rainmaking) by USA to end Bihar famine
2. Vietnam: USA's Operation Popeye, weather warfare to drown out transport and crops (1967-1972)
3. New York, USA: UN ENMOD outlaws weather warfare (1978)
4. Southern Sea: One year after Earth Summit, USA conducts first major ocean fertilization test (1993)
5. California, USA: NASA and Carnegie Institute convene expert workshop on SRM (2006)
6. London, UK: Virgin Earth Challenge announced for GHG removal (2007)
7. Pacific Ocean near Galapagos Islands: US company Planktos's plans to seed thousands of kilometers of ocean with iron halted by Ecuador (2007)
8. Sulu Sea: Philippines stops Australian company's urea dump for ocean fertilization (2008)
9. Bonn, Germany: CBD adopts moratorium on ocean fertilization (2008)
10. Washington (Seattle), USA: Bill Gates funds geoengineering research (2008-2012)
11. Scotia Sea: Lohafex experiment ignores CBD moratorium on ocean fertilization (2009)
12. London, UK: Royal Society publishes major report on geoengineering, calls for more research (2009)
13. Washington, DC / London, UK: Joint Congressional / Parliamentary hearings on geoengineering (2010)
14. London, UK: London Convention / Protocol prohibits commercial ocean fertilization research (2010)
15. Asilomar, USA: 175 scientists gather to elaborate "voluntary guidelines" on geoengineering research (2010)
16. Nagoya, Japan: CBD adopts geoengineering moratorium (2010)
17. Lima, Peru: IPCC convenes expert meeting on geoengineering (2011)
18. Brussels, Belgium: European Parliament passes resolution on Rio+20, which includes opposing geoengineering (2011)
19. Ecuador: Pujili communities sue the country's biggest frozen vegetable exporter for cloud seeding to diminish rainfall (2011)
20. Southorpe, UK: SRM experiment ("SPICE") put on hold (2011)
21. Berlin, Germany: Government and Parliament studies on geoengineering (2011-2012)

Weather Modification

Increased Precipitation: Seeding clouds with particles of silver iodide or other chemicals to provoke rain or snow

Reduced Precipitation: Water and cloud-based methods to reduce rainfall, diffuse hail storms and hurricanes and to disperse fog

Land-based Techniques

Air Capture: (a.k.a. artificial trees or carbon sucking machines) to remove atmospheric CO_2

Biochar: Agricultural "waste," crops and/or trees burned in low-oxygen conditions to make charcoal that is then added to soils with the aim of sequestering carbon

Carbon Capture and Storage (CCS): Processes to capture carbon emissions at source for burial (excluded from CBD provisional definition of geoengineering)

Bio-Energy with Carbon Capture and Storage (BECCS): CCS applied to power plants burning biomass, theoretically resulting in net carbon removal from the atmosphere

Solar Radiation Management (SRM)

Stratospheric aerosols (a.k.a. artificial volcanoes), cloud whitening, whitening the surface of the Earth or "space mirrors," with the aim of diverting sunlight

Water-based Techniques

Ocean Fertilization+: Stimulating the production of carbon-eating algae by adding iron or nitrogen to seawater, or other techniques that modify ocean chemistry to enhance CO_2 sequestration

Algae Schemes: Industrial cultivation of algae to consume CO_2 and, theoretically, to generate new biofuels

Other

Major research and policy institutes focusing on geoengineering (without testing)

Noteworthy initiatives that do not fit into any of the above categories (e.g., enhanced weathering)

etc group

For more information: WWW.ETCGROUP.ORG/GEOENGINEERINGMAP

Environmental issues

- Catastrophic events (leaks of CCS – like during Nyos Lake event), no „swith off”, no control over triggered effects
- Modification of land use, ocean ecosystems, ozone layer
- Pollution (atmosphere)
- Disruption of sea food webs
- Extra use of energy – extra production of greenhouse gases
- Disruption of water cycles – extreme events, droughts in some regions
- … unpredictable consequences

Ethical questions

- Who’ s in control of these measures?
- Who decides which techniques to use where
- Can you destroy one area to save another?
- Can it be used inappropriately – as a weapon?
- Is it better to invest in technofix or focus on limiting emissions?

Who's for, who's against?

- David Keith of the University of Calgary in Canada, his initiative is supported financially by Bill Gates
- IPCC – Report 2018 - **there is high agreement that injection of chemicals into stratosphere could help limit rises**
- **Irresponsible' to rely on techniques to strip carbon or reflect sunlight to slow global warming, EU analysis concludes**
- consortium of 14 institutes, EuTRACE, warned against such targeted interventions due to issues developing the nascent technologies and high costs,
- "It is not yet clear whether it is possible to develop and scale-up any proposed climate engineering technique to the extent that it could be implemented to significantly reduce climate change," said Naomi Vaughan at the Tyndall Centre for Climate Change Research at the University of East Anglia.

Additional, external resources

- OWNING THE WEATHER –Discovery Channel, youtube (45 minutes):

https://youtu.be/4S-yVYNPiFU

- „PRO” – FUTURISM
- https://futurism.com/climate-change-geoengineering

YES/NO **Carnegie Climate Geoengineering Governance Initiative**

https://www.c2g2.net/

- „CON” – **Geoengineering Monitor**

http://www.geoengineeringmonitor.org

Odyssey
Oxford Debates for Youths in Science Education

Erasmus+

Thank you for attention!

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The projest has been funded with the support of European Commission within ERASMUS+ program

„Geoengineering vs climate change”

Material for teachers

With methodological guidelines, a lesson plan and an answer key to worksheets

The educational package "Geoengineering and climate change" was developed within "Oxford debates for the education of young people in the field of mathematics and science" project.
It is a key material, facilitating the achievement of primary project goals, including increasing reasoning skills and interest in STEM, which in the future may result in taking up a scientific career.
When preparing students for the debate, one should not neglect the development of such skills as: communication excellence, argumentation or public speaking. Students should improve their ability to persuade effectively, argue properly, reason accordingly and speak out correctly. Composition of texts, using rhetorical means in oral statements, speaking in accordance with the rules of language culture, text interpretation, public speaking and presentation of texts, discussions and negotiations are of equally high importance.
In order to achieve the abovementioned goals, the implementation of thematic educational packages should be preceded by classes dedicated to preparation for debating as such. This can be accomplished in consultation with teachers of other subjects and the class teacher. The development of basic communication skills can be included in the class teacher's work plan, and the prepared lesson plans can be used during regular classes. Auxiliary materials can be found in the following documents:

1. **Warm up practice** – Annex No 2 to National frameworks for implementation of Oxford debates in STEM in school practice (pages 37-39);
   This document includes the following exercises: active listening, public speaking and debating skills.

2. **Lesson plans aimed at general development of debating skills** – Annex No 2 do National frameworks for implementation of Oxford debates in STEM in school practice (pages 40-55);

   This material consists of 7 lesson plans prepared by Dr. Foteini Englezou, president of the Hellenic Institute for Rhetorical and Communication Research. Scenarios are a guide to work. It is not necessary to follow all the lessons. The teacher can decide which scenarios (or their selected fragments) are most useful for working with a specific group of students. The document offers the following lesson plans:

   1. Communication skills
   2. Express your scientific argument, not your opinion
   3. Build a valid scientific argument
   4. Searching for evidence
   5. Enhancing students’ linguistic skills
   6. Rebuttal and refutation
   7. Fallacies

3. Methodological Guide for Teachers. ODYSSEY: Oxford Debates for Youths in Science Education

The final stage of preparation for debates based on specific packages is to familiarize students with the principles of debating, described in detail in the abovementioned document.

Geoengineering vs climate change

The "Geoengineering vs climate change" educational package consists of the following elements:
• Multimedia presentation;
• Introductory video: https://youtu.be/qt2ZFHy4giU;
• Educational package "Geoengineering and climate change" - material for students;
• Worksheets (the same for all packages);
• "Geoengineering vs. climate change" - material for the teacher (with answer key).
It is recommended to implement the package during a minimum of three lesson units.

Currently observed climate changes, manifested primarily by global warming, but also by the increase in the extremity of atmospheric phenomena, resulted in focus on nature protection and sustainable development paradigm. However, some scientists go one step further, implying that we're or could be able to influence earth system to counteract climate change or to modify it.

The presented educational package "Geoengineering vs. climate change" includes an overview of activities and opportunities in the field of geoengineering's impact on the climate. It also allows students to formulate arguments supporting these actions as well as demonstrating the dangers of human intervention.

The debate on the resolution: "Governments should invest in geoengineering techniques to counteract climate change" may take place both during extracurricular activities in the field of natural sciences, in particular related to environmental protection, and in geography lessons. The level of the materials is adjusted mainly to secondary schools

Lesson 1. What are geoengineering techniques and what is their impact on the climate?

For most students, geoengineering techniques and their impact on climate may be a new topics. Geography classes are focused mainly on natural climate-creating factors, while the impact of human activity on the climate is generally limited to the increase in the greenhouse effect and pollution of the atmosphere. Meanwhile, there are a number of geoengineering techniques that can influence the climate to counteract adverse climate change.

It is recommended that students receive the materials a few days prior to the lesson. This will allow them to get acquainted with the topic of the lesson initially and facilitate active participation in the classroom. A multimedia presentation or a video recorded by the author of the package can be used during the lesson. An open discussion of selected (previously assigned to students) geoengineering techniques is also beneficial.

Lesson 2. „ Governments should invest in geoengineering techniques to counteract climate change" – constructing arguments for and against the resolution

The aim of the second lesson is to formulate as many arguments as possible (both for and against the resolution) that will be used by students during the debate, summarizing the work with the package.

Lesson plan

1. Organizational issues, checking the attendance list, familiarizing with the topic and objectives of the lesson [5 minutes].

2. Preparation of arguments [25 minutes]
3. The teacher divides the class into teams of two. Each team receives 16 **question cards** available in the educational package (materials for the student) and 2 copies of worksheet No. 1 (one for each student infividually). Based on the questions, students formulate arguments for the presented thesis, against the thesis and those that are debatable and can be used in the discussion by both parties. Students work together, but each student individually completes his/her worksheet. There are examples of selected arguments for worksheet 1 are in the answer key.
4. Teams: proposition and opposition are formed [10 minutes].

Team selection may be executed in 2 forms, each of them having both advantages and disadvantages.

Students declare which arguments are closer to their beliefs. The teacher divides the class into teams (each with a similar number of students) in the manner reflecting their convictions. The second method assumes a division similar to the one above, with the difference that ultimately the team consisting of the supporters of a given resolution becomes the "opposition" team, while the opponents of the thesis become “proposition” team. The supporters of such a division assume that it teaches the participants of the debate to a greater extent to use arguments supported by facts, and is less based on emotions. Alternatively, division into teams can also be done randomly.

Finally, team selection can also be made by the teacher in a subjective way, ensuring that each team has both leaders and students who require more help, so that both teams have similar “winning potential”. In order to save time for division, the teacher can do it at the beginning of the lesson, for example by distributing worksheets number 1 to the students, printed on sheets of different colour or marked in some other manner.

5. The teacher distributes worksheets number 2 to the students (one for each student) and explains the homework. An example of a filled out worksheet is available in the answer key.
6. Students in each team read prepared arguments in accordance with the assignment to a given group. Each student receives 1 argument, which he/she will develop (as homework) according to the guidelines in worksheet No.2.
7. Each team also appoints 3 people who will present the arguments prepared by the entire group. Students decide the order of their speeches. During the debate, other team members who are not directly involved in the debate, fill out worksheet
8. Summary of the lesson, evaluation of students' work [5 minutes].

Lesson 3. Debate

During the final lesson, the teams conduct a debate according to the guidelines contained in the "Methodological Guide ..." It takes 45 minutes in total to conduct a full debate. During the debate, the teacher does not comment on the arguments or indicate the fallacies made by the students on an ongoing basis.

An exercise-based debate should be structured as follows:

1. Opening of the debate by the moderator/chairperson [3 minutes].
2. Initial vote by the audience [2 minutes].
3. 1st Researcher-Debater of the A research-team: Constructive Speech [4 minutes].
4. 1st Researcher-Debater of the B research-team: Constructive Speech [4 minutes].
5. Cross-fire between the researchers-debaters (1) of both research teams [3 minutes].
6. 2nd Researcher-Debater of the A research-team: Rebuttal Speech [4 minutes].
7. 2nd Researcher-Debater of the B research-team: Rebuttal Speech [4 minutes]
8. Cross-fire between the researchers-debaters (2) of both research teams [3 minutes].

9. Preparation time for the Summary and Final Rebuttal by both research teams [2 minutes].
10. 3rd Researcher-Debater of the A research-team: Summary Rebuttal [2 minutes].
11. 3rd Researcher-Debater of the B research-team: Summary Rebuttal [2 minutes].
12. Grand Cross-fire between the researchers-debaters (1 & 2) of both research-teams [3 minutes].
13. 3rd Researcher-Debater of the A research-team: Final Focus Rebuttal [2 minutes].
14. 3rd Researcher-Debater of the B research-team: Final Focus Rebuttal [2 minutes].
15. Final vote by the audience / Short written feedback [3 minutes].
16. Presentation of the results by the moderator [2 minutes].

If the debate takes place during extra-curricular activities, then it is recommended to devote, for example, 90 minutes for this part. This will allow you to prepare the room for the debate, recall the rules, conduct the debate and discuss its course and finally evaluate the work of students.

In terms of classroom conditions, it would be ideal to allocate two adjoining lesson units to the debate. Taking into account the school circumstances, organizational difficulties and the inability to devote too many lessons to content extending the core curriculum, the debate can be conducted in one lesson, while maintaining high discipline in time. In this case, it is recommended that during the next lesson with the class additional 10 minutes are spent discussing the debate, pointing to strengths and mistakes made by the participants of the debate.

In this format, 6 students (3 from each team) actively participate in the debate. The teacher may also appoint a moderator from among the students and a time keeper. The rest of the students will receive worksheet number 3. Their task will be to listen carefully to the debate and to note the opposing team's strengths and areas for improvement, and to justify their choice. Completed worksheet no. 3 may be the basis for issuing a grade for activity in the lesson for students who did not take part in the debate directly, but participated in its preparation and were active observers of its course.

The project has been funded with the support of European Commission within ERASMUS+ program

Worksheet No 1 – answers

FOR	„GREY AREA"	AGAINST
How fast are the effects of reducing greenhouse gas emissions? This is definitely not an immediate effect. If we accept a global warming reduction to 1.5 degrees as our goal, global greenhouse gas emissions must fall by 55% by 2030, according to the UN. Currently, total global emissions fluctuate around 53.5 gigatonnes of carbon dioxide equivalent (CDE). The difference between where we are now and where we should be by 2030 is therefore about 29 gigatonness of carbon dioxide equivalent (CDE). And the effect is still growth - only slower, limited to 1.5 degrees Celsius, not inhibiting the rise in temperature or reversing the process. The effort is therefore huge, and how quickly can we count on the effects? According to one experiment, after completely "turning off" emissions, after a hundred years of cooling, the planet warmed up by 0.37 degrees Celsius, over the next 400 years, when the ocean absorbed less and less heat. While the resulting temperature spike seems to be small, it should be remembered that the Earth has warmed until today by 0.85 degrees Celsius compared to pre-industrial times. *Is it possible to stop all greenhouse gas emissions immediately?* Such global arrangements are very difficult to enforce. In 2015, in the so-called Paris Agreement states agreed on the goal of "limiting the rise in average Earth's surface temperature well below 2 degrees Celsius above pre-industrial levels and continuing efforts to limit the temperature rise to 1.5 degrees." Countries have also presented their voluntary emission reduction plans, referred to as INDC (Intended Nationally Determined Contributions). Meanwhile, after three years of maintaining constant global greenhouse gas emissions, it increased by 1.1% in 2018. The lack of any emissions in practice means an immediate stop to industrial production or a 100% switch to renewable energy sources and zero-emission transport.	*Does geoengineering limit all identified negative effects of climate change?* It depends on the technique, and there isn't any perfect solution that would cover it all. SRM techniques do not limit, for example, ocean acidification, which is a consequence of climate change and seriously endangers food chains. On the other hand, CRM techniques can be helpful in that matter. Continued burning of fossil fuels, somehow "legitimized" by geoengineering techniques, also includes air and water pollution, water consumption, violation of indigenous rights, political instability, violence and others. Geoengineering gives no solutions here. *Is it possible to use geoengineering techniques for purposes other than related to climate change?* Yes, both for and against humanity. Tested and improved techniques within geoengineering can be used for so-called terraformation - potentially adapting other planets to recreate Earth-like living conditions. We do not know when such a "backup" planet will be very useful to us, e.g. in the event of a threat from space. On the other hand, geoengineering interventions may have regional winners and losers; to such an extent that geoengineering successfully changes climate patterns in a predictable manner, it will probably be used as a war tool, very dangerous and	*How fast can the effects of geoengineering methods be stopped or reversed?* In the case of initiation of e.g. cloud seeding or ocean fertilization- it is not possible to abruptly stop the process in case of unforeseen circumstances. There is no "switch off" button- we lose control of the process. *What are the consequences of limiting the inflow of solar radiation for RES (Renewable Energy Resources)?* SRM methods are designed to reduce the amount of solar radiation reaching the Earth's surface, the widespread use of such techniques would limit the potential of one of the largest alternatives for generating electricity from fossil fuels: solar energy (photovoltaics). *How does investing in geoengineering affect the search for emission reduction methods?* The transition to geoengineering, which promises quick results, threatens to delay the implementation of the transition from fossil fuels and may limit funding and investment in other climate solutions. Some geoengineering methods require huge amounts of energy, which means less climate-friendly energy for other needs. *What are the possible side effects of the geoengineering methods prom the perspective of environment and public health?*

What happens if all anthropogenic emissions of greenhouse gases into the atmosphere are suddenly stopped? Will this stop global warming?

The simple answer is: no, it won't stop the global warming. The released carbon dioxide will remain in the atmosphere for thousands of years. Only after many millennia it will return to circulation, e.g. to rocks, for example by forming calcium carbonate (limestone) - when shells of marine organisms settle on the ocean floor. But in the perspective of our civilization, once released carbon dioxide is essentially forever in our environment. It doesn't disappear unless we delete it ourselves. If we stop emitting greenhouse gases from tomorrow, this does not mean the end of global warming. The temperature will continue to rise, and probably after about 40 years the climate will stabilize at a temperature higher than "normal" for previous generations.

Do all methods of geoengineering require the use of chemicals?

Some CRM and SRM methods do not require the use of potentially harmful substances. With some techniques, even cloud seeding can be done by simply spraying seawater, not sulfates. On the other hand, the use of limestones instead of sulphates may even have additional positive effects - e.g. preventing the destruction of the ozone layer.

Is it possible to use some methods at very low costs?

Yes, according to some scientists, in some cases existing technical solutions can be used, for example: modification of cirrus clouds, which, unlike other clouds, do not reflect most of solar radiation back into space, but form at high altitudes and low temperatures stop long-wave radiation and have a similar effect to greenhouse gases. Sparse clouds can be obtained by injecting condensation nuclei (such as dust). Dust at such altitudes can be sprayed from passenger planes during regular flights.

Is there a natural process / processes that partially are imitated by the geoengineering methods?

YES, on a local / regional scale - e.g .: destructive, as it has already been in the past (see STORY CARD Operation Popeye).

How do geoengineering methods potentially affect rainfall?

The impact of engineering methods on precipitation is various:

1) ☹ Reduction of rainfall, especially in tropical regions

Sulphate particles "injected" into the atmosphere not only reflect sunlight, reduce temperature, but also absorb heat arising from the Earth's surface. This reduces the temperature difference between the layers of the atmosphere, which is the mechanism that drives cloud formation and rainfall.

2**) ☹ Extending the monsoon periods and increasing the number of extreme phenomena**

In turn, reducing rainfall in the Arctic can have positive effects on glaciers (rain simplifies the surface covered with ice). ☺

Are geoengineering techniques expensive or cheap?

A global technology for delivering sulfate into the atmosphere could cost $ 2 to 2.5 billion a year. " About $ 500 billion a year is invested in green technologies. On the other hand, adaptation to the effects of climate change, such as raising the level of oceans, is a cost many times higher, practically impossible to determine accurately.

The consequences of using geoengineering techniques are difficult to predict, because the climate system is complicated and sensitive to changes.

Examples of anticipated consequences:

- Injecting sulphates into the atmosphere can destroy the ozone layer, which in turn leads to an increase in the amount of UV radiation reaching the Earth; it is a serious threat to human health (skin cancer, eye damage)
- Ocean fertilization causes algal blooms, potentially anaerobic zones, destructive to life
- Many geoengineering proposals require the intensive exploitation of huge amounts of land (e.g. plantations with high albedo). These projects would inevitably displace millions of people and potentially destroy entire ecosystems.

Negative effects will not bypass agriculture. It's not just a question of possible drought, but also the effects of aerosol injection. Scientists have collected a number of data sets to understand the impact of volcanoes on farming in the past. In particular, they looked at how many aerosols - fine particles suspended in the atmosphere that have a cooling effect on the climate - the eruption of Mount Pinatubo in 1991 and El Chichon in 1982 released into the atmosphere. Then they compared it with the level of sunlight reaching the ground and yields of wheat, rice, soybean and corn, crops that account for about half of the world's calorie intake - the impact was negative. This is a serious threat to the stability of providing food to humanity.

Is the decision process regarding the use of geoengineering techniques globally fair?

There is a high risk of conflict between nations that are undertaking their own unilateral attempts at

1) in the Arctic, ammonia from bird guano contributes to a process analogous to seeding clouds. 2) Volcanic eruptions are a source of dust that increases the amount of solar radiation reflected back into space (see the history sheet for the eruption of Mt. Pinatubo). *Are the technologies that we commonly use today always accepted and greeted enthusiastically?* No. TECHNOFOBIA is still a common phenomenon, new technologies are a source of concern and conspiracy theories. This is not a new phenomenon. Socrates, who never wrote, said that the invention of the letter would bring oblivion and only the appearance of wisdom, but not truth or true judgment. His student Plato, writing on the scroll, agreed, saying that writing was a step backwards for the truth. Thomas J. Watson, president and CEO of IBM, said in 1943: "There is a global market for about five computers." When the Stockton-Darlington Railway was opened in 1825, people feared the worst: the human body was certainly not created to travel at an incredible speed from 50 km per hour! People honestly believed their bodies would melt. Electricity, telegraph or, more recently, WI-FI raised similar concerns.		climate change. This is a field for the powers to compete at the expense of less developed countries. It is unclear who would make decisions with such global effects. On October 18-29, 2010, a United Nations (UN) meeting was held in Nagoya (Japan). A moratorium (temporary suspension) on climate-related geoengineering activities was announced at the Convention on Biological Diversity (www.cbd.int). It is worth remembering that the United States has not ratified the UN Convention. The poorest countries will most likely suffer from negative effects.

Worksheet No 2 – examples of argument

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals
Techniques tested and refined in geoengineering can have wide applications for the benefit of mankind. They can, for example, be used in the so-called terraformation, i.e. the potential adaptation of other planets to recreate terrestrial-like living conditions. We do not know when such a "backup" planet will be very useful, e.g. in the event of a sudden threat from space. If we are able to shape the climate and control its changes, we will be able to build a civilization even in theoretically unfavorable conditions.	Since geoengineering is successful in changing climatic patterns in predictable ways, it is likely to be used in the first instance not to build life on another planet, but as a weapon, a very dangerous and destructive one, as it has been done in the past - for example during the so-called Operation POPEYE, when the U.S. Air Force flew over 2,600 cloud-seeding flights during the Vietnam War. Silver iodide and lead iodide were released into the atmosphere, which led to the prolongation of the monsoon season, leading, for example, to landslides and the softening of roads.	Fears of the development of any new technology hold back progress. TECHNOPHOBIA is still a common phenomenon. When the Stockton-Darlington railroad opened in 1825, people feared the worst: the human body was certainly not designed to travel at the incredible speed of 50 km/h. People sincerely believed that their bodies would melt. Similar concerns were raised by electricity, telegraph or, more recently - WI-FI. We must not be held back by the fear that science might be misused.
		Geoengineering cannot be viewed as a man-made weapon - some geoengineering techniques, including the cloud seeding just mentioned, mimic natural processes. Examples? In the Arctic, ammonia from birds' guano naturally contributes to a process analogous to cloud seeding, cooling the climate locally. Volcanic eruptions are a source of dust that increases the amount of solar radiation reflected back into space, as was the case, for example, after the eruption of Mt. Pinatubo in 1992.

		People's potentially bad intentions should not discredit scientifically sound solutions.
	There are great doubts as to whether geoengineering techniques will actually be used for the benefit of mankind, given that the decision-making process regarding the use of geoengineering techniques is not globally fair and has the potential to cause international conflicts. This is a field for great powers to compete at the expense of less developed countries. It is unclear who would make decisions with such global impact. The poorest countries are most likely to suffer negative effects, e.g. due to problems in food production.	Fears of inequality in access to technology and exposure to its effects would inhibit any scientific progress. WI-FI. We must not be held back by the fear that science might be misused. Geoengineering may be the best solution for the poorest countries, and changing rainfall patterns can reduce drought and thus prevent problems with access to food or drinking water.
		The poorest countries are already bearing the costs of progressive climate change, which poses a real threat to them. For years, attempts have been made to find global solutions to limit emissions, and the efforts are not bringing the expected results quickly. In 2015, in the so-called Paris Agreement, countries agreed to the goal of "limiting the rise in mean surface temperature to well below 2 degrees Celsius above pre-industrial levels and continuing efforts to limit the temperature rise to 1.5 degrees." Countries also presented their voluntary emission reduction plans. Meanwhile, after three years of maintaining constant global greenhouse gas emissions, it increased by 1.1% in 2018.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals
When governments or international organizations make decisions about how to deal with climate change, they must take into account the fact that they have limited resources, primarily financial resources. Investments in very expensive geoengineering means limiting investments in other long-term and sustainable climate solutions, such as Renewable Energy Sources.	Not all geoengineering methods require huge financial outlays. After all, existing technical solutions can be used in some cases. An example is the modification of cirrus clouds, which, unlike other clouds, do not reflect most of the solar radiation back into space, but form at high altitudes and low temperatures, stop long-wave radiation and have an impact on a climate similar to greenhouse gases. Sparse clouds can be obtained by injecting the so-called condensation nuclei (such as dust). Dust at such altitudes can be sprayed by passenger planes on normal cruises.	The choice of "constraining ourselves" or "geoengineering" is not only a financial one. Continuing to burn fossil fuels is in a way "legitimized" by geoengineering techniques: if there is a technical solution, why reduce resource consumption, production, profits? This has implications that go beyond climate change itself, including air and water pollution, water consumption, violation of the rights of indigenous communities, political instability, violence and more. Here, geoengineering offers no solutions.
		Most of the methods currently being considered on a large scale, such as cloud seeding, come at high cost, not only in terms of financial resources. Some geoengineering methods require huge amounts of energy, which means less climate-friendly energy for other needs. They also have negative environmental effects, such as changing global rainfall patterns, droughts in sub-Saharan Africa, and food production problems.
	Investments in the so-called "sustainable" solutions, such as renewable energy, cannot be compared with geoengineering in terms of their effectiveness in combating climate change. Geoengineering methods work immediately. On the other hand, even if we stopped burning fossil fuels tomorrow, global warming would not be stopped. The carbon dioxide released so far will remain in the atmosphere for thousands of years. Only after many millennia will it return to circulation, e.g. to rocks, for example by the formation of calcium carbonate (limestone) - when the shells of marine organisms settle to the bottom of the ocean. But from the perspective of our civilization, once released carbon dioxide is in our environment. Temperature will continue to rise, and it is likely that the climate will stabilize in around 40 years.	The rapid nature of geoengineering methods is not their undisputed advantage, on the contrary. In the case of initiating, for example, cloud seeding or ocean fertilization - it is not possible to stop the process immediately in case of emergency. There is no "off-switch" - we lose control over the process, a whole chain of reactions begins on a global scale and has unpredictable effects, even environmental ones. An example is the situation that took place in the United Arab Emirates, where each year, fighting drought, the military performs about 160 missions, during which loads with silver iodide are dropped from planes onto the clouds, as a result of which one region suffered a catastrophic flood: during just a few dozen hours had as much rain as usually falls for 2.5 years, which led, among others about huge landslides.

Worksheet no. 1

The educational package contains a set of questions to help prepare arguments for discussion on the resolution. On their basis, prepare a set of arguments and group them into those that are clearly in favor of the resolution, against the thesis, and those arguments that can be used by both teams. Write them down in the appropriate parts of the table.

FOR	„GREY AREA”	AGAINST

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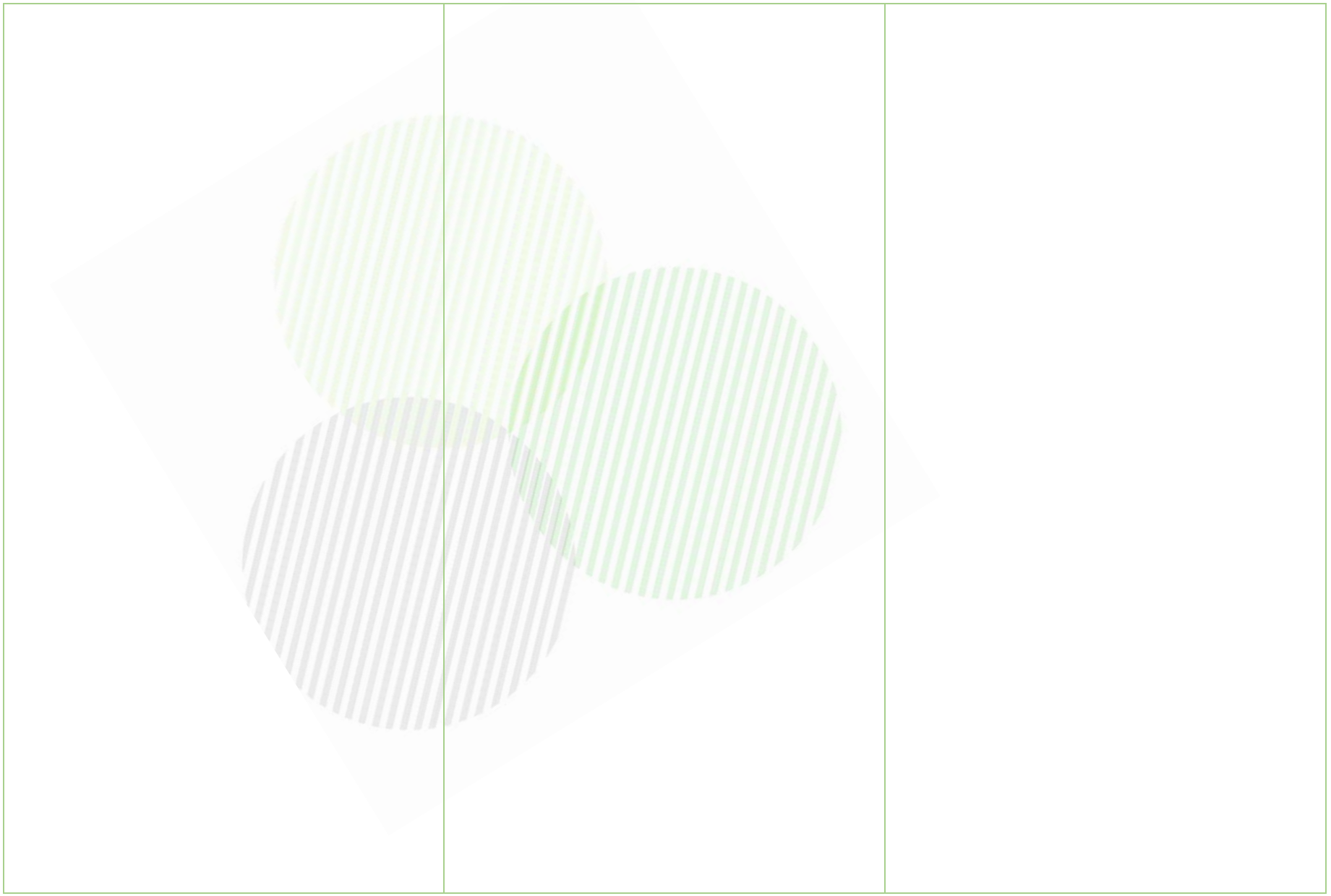

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Worksheet no. 2

Based on the materials provided by the teacher, prepare arguments for discussion. One group of students prepares arguments supporting the resolution, the other one - opposing arguments. Use the proposed template.

ARGUMENT 1.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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ARGUMENT 2.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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Worksheet no. 3

Name and surname:……. Class……. Team: proposition/opposition

During the debate, hear and observe carefully the speeches of the debates from the other team. Then, evaluate which speech convinced you the most and which areas of your opponents' speech should be improved.

1. In terms of **argumentation (**e.g. the quality of the arguments presented, credibility of the data and scientific evidence) in the rival team I was most convinced by the speaker No. .....

Reason:

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2. In terms of **the style of presentation and communication with the audience** (e.g. confident, persuasive, authentic and dynamic posture, moderate gestures, assertive voice variety, good eye contact with the audience, use of moderate humor, friendly and professional approach to all participants, effective use of body language) in the rival team I was most convinced by the speaker No. .....

Reason:

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Indicate the element of the rival team's performance that requires improvement. Justify your answer.

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Reason:

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