irresistible

Geoengineering: Climate Control?

Students manual

Responsible Research and Innovation www.irresistible-project.eu

Colophon

IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTOVITY 5.2.2. Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

www.irresistitle-project.eu
Coordinator: j.h.apotheker@rug.nl

Consequências
Animais prejudicados
Associa o aumento do
dióxido de carbono
Antes
Escala de pH
Soluções Ácidas
Soluções Neutras
Soluções Básicas
Vinaróm

Welcome to the Climate Geoengineering module!

Geoengineering can be described as the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change, especially global warming caused by greenhouse gases emissions. Several methods have been considered for this purpose, with results, objectives, technologies and costs quite distinct from one another. They can be grouped into two categories: those relating to the removal of CO_2 from the atmosphere and the ones that change Earth's capacity to absorb solar radiation. So far, the disadvantages of Geoengineering approaches have tended to outweigh the advantages in most minds that have turned to the issue. However, in recent years such proposals have received more support from a number of prominent scientists and economists, with calls for more research into their feasibility, costs, side effects and frameworks for implementation.

With this module you will research about Climate Geoengineering and its strategies in mitigation of Global Warming. It is intended that you understand the Biological/Physical/Chemical principles behind each strategy and, also, its advantages and disadvantages.

In a second phase, you'll need to reflect about the 6 dimensions of Responsible Research and Innovation (RRI), and conceive situations that relate each dimension with Climate Geoengineering with the purpose of conceiving a final interactive exhibition, intended to be developed and presented by you and your classmates as a way to educate the community about this important topic.

1. Engage 8

2. Explore 21

3. Explain 34

4. Elaborate 39

5. Elaborate, Exchange & Empower 50

6. Evaluate 57

1

Engage

Task 0

Climate Change: what do I remember?

Perhaps you are already familiar with the topic of Climate Change. Perhaps you're not. And even if you are, there might be the case that you have forgotten some important aspects of it. Whatever the case, it is important that you are aware of what Climate Change is in order to fully understand and benefit from this module.

On the next pages you'll find some important questions that need to be answered. Perform an information search in order to be able to answer them. You'll find some suggested resources at the end of the assignment.

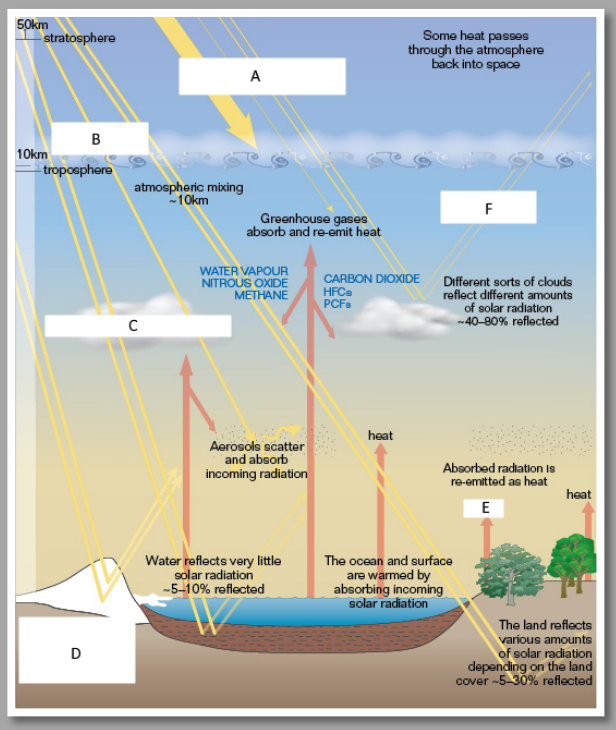
Task 0 | What do I remember?

1. How can you define **climate change**? Compare your definition with the IPCC definition. Was it different?

2. In a narrow sense, **climate** can be defined as the 'average weather' and described in terms of the *mean and range of variability of natural factors such as temperature, rainfall and wind speed*. More broadly, the climate is a system involving highly complex interactions between several components. Can you **name them** and try to identify some of the possible **interactions** between them?

3. The atmospheric component is the most unstable and rapidly changing part of the climate system. The atmosphere is divided into five layers with different temperature characteristics. The **lower two** have the most influence on the climate system. Which layers are these? **Characterize** them.

4. The next image represents a model of the natural greenhouse effect and other influences on the energy balance of the climate system.



Source: Garnaut R. (2008) **The Garnaut climate change review**. (Cambridge University Press, Cambridge, UK)

4.1. Complete its caption (letters A to F) according to the items provided next (numbers 1 to 6).

1. Heat
2. Reflected solar radiation
3. Incoming solar radiation
4. Clouds absorb and re-emit heat
5. 99% of ultraviolet radiation absorbed by ozone
6. Ice and snow reflect the majority of solar radiation

4.2. Try to translate the information given by the image to a text, in which you tell the **story that this image is trying to tell**.

5. Energy enters the climate system as visible, infrared and ultraviolet radiation from the sun, and is absorbed, scattered or reflected, re-emitted as heat, transferred between different elements of the system, used by organisms and emitted back into space. The balance between the energy entering and leaving the system is what determines whether the earth gets warmer or cooler, or stays the same. **What factors can influence the amount of heat that is retained in the climate system?**

6. The warming of the climate system evident in the last half century is a result of the cumulative effect of all the natural and human drivers that influence the amount of warming or cooling in the system. There was a contribution of different factors leading to an overall warming of the atmosphere since 1750, but the dominant influence has been an increase in concentrations of carbon dioxide. In the long term, the major influence of humans on the climate will be through activities that lead to increased concentrations of greenhouse gases in the atmosphere.

6.1. Which are the **predominant greenhouse gases** emitted by human activities and **which activities** are the most responsible for their emissions?

7. One of the greenhouse gases with the greatest influence on warming of the atmosphere is carbon dioxide (CO2). The 'carbon cycle' refers to the transfer of carbon, in various forms, through the atmosphere, oceans, plants, animals, soils and sediments. **Explain the carbon cycle and draw a scheme of it.**

8. Natural variability in the weather is reflected in the occurrence of 'severe weather events', defined as an *event of an intensity that is rare at a particular place and time of year*. **Name** some of the severe weather events and do a research in which you find some examples of real events occurred in your country or in other countries around the world.

Web resources

http://climatekids.nasa.gov/
http://scijinks.jpl.nasa.gov/
http://www.arm.gov/education/studyhall/globalwarming/
http://oceanservice.noaa.gov/education/discoverclimate/
https://downloads.globalchange.gov/Literacy/climate_literacy_highres_english.pdf
http://www.ncdc.noaa.gov/monitoring-references/faq/global-warming.php
https://www.climate.gov/climate-and-energy-topics/climate-system
http://ncse.com/climate

Task 1

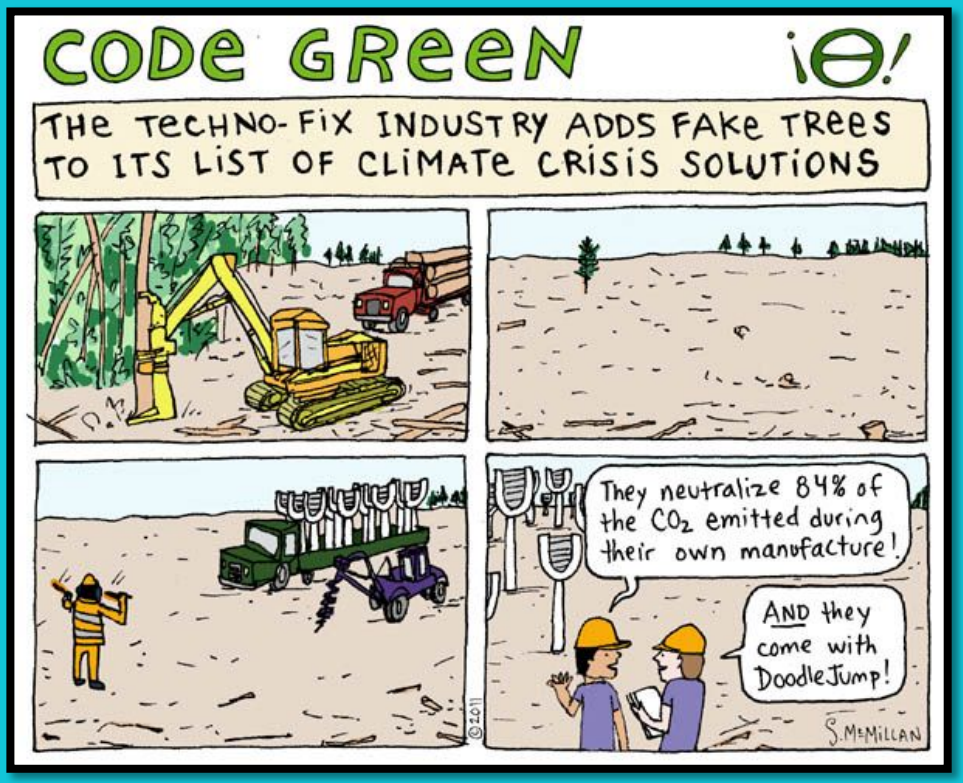
Climate Geoengineering: what is the message?

This task has the purpose of promoting a first glimpse on Climate Geoengineering, more precisely on some of its strategies. As you might start to understand thorough the module, this Climate Change mitigation approach has received critics – some are present on the 3 cartoons you're about to analyze.

Task 1 | What is the message?

Analyze the next set of 3 cartoons, which are related to the topic you're about to study: Climate Geoengineering. After a couple of minutes watching each cartoon, please write down what you see in each one: what's **your interpretation** of each cartoon? What **message** do you think each one is trying to pass? Share your opinions with your classmates.

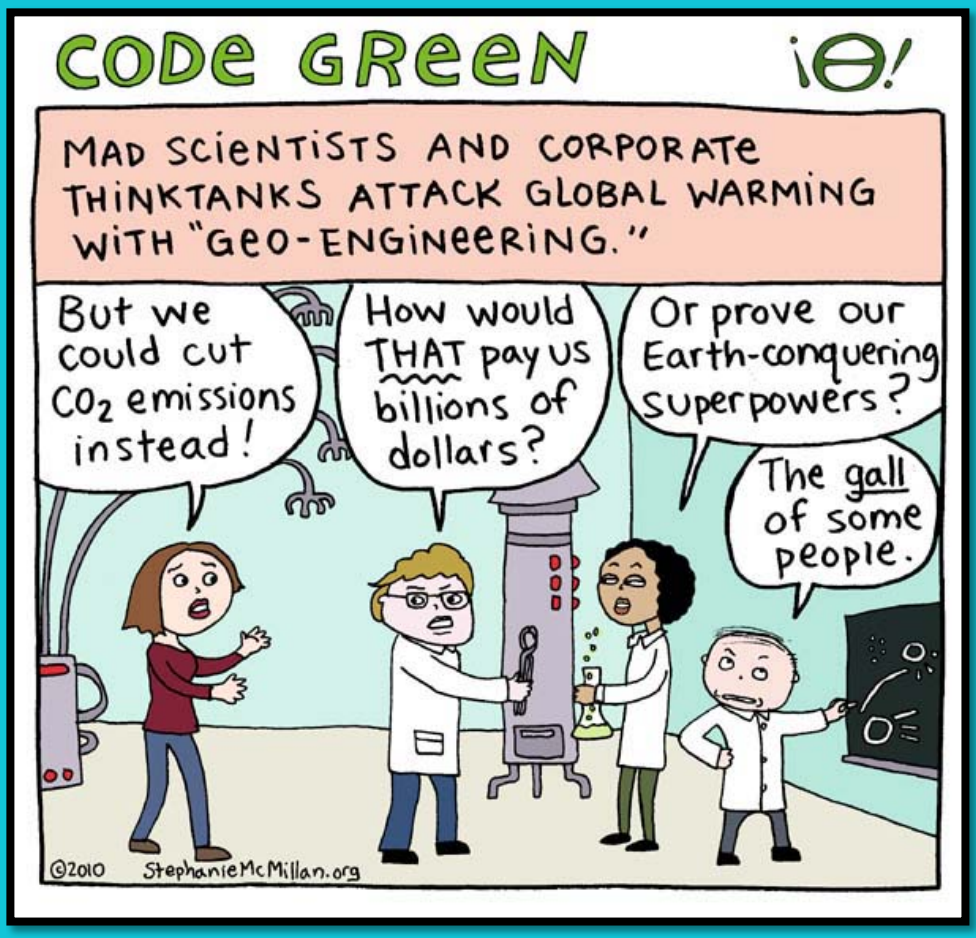
Cartoon 1



Source: http://www.stephaniemcmillan.org/codegreen/comics/2011-08-01-fake-trees.jpg

Note: Doodle Jump is a platforming video game.

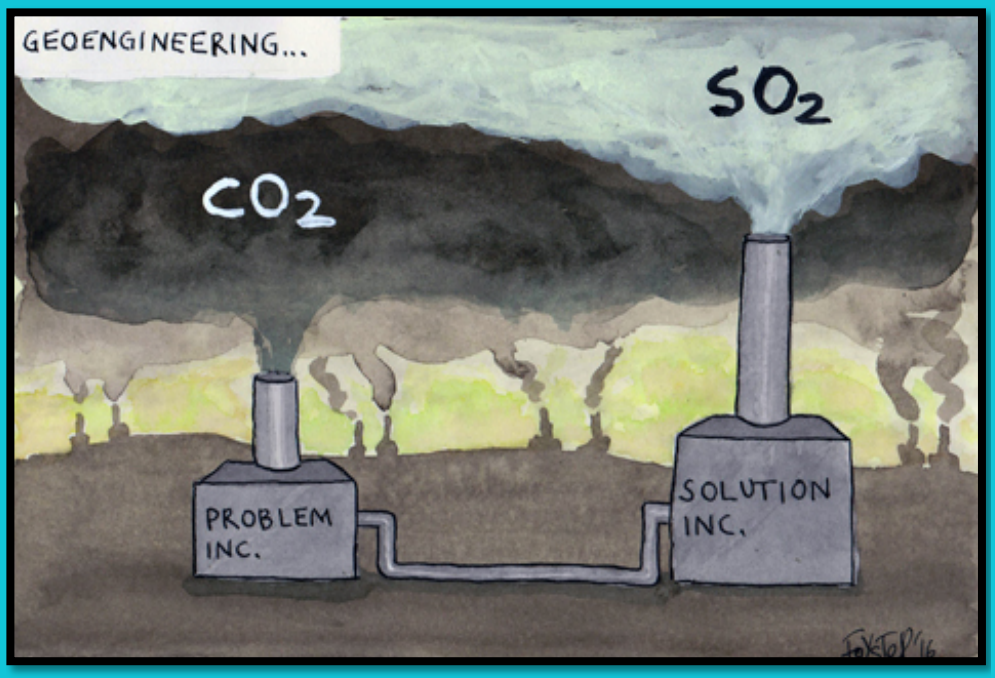
Cartoon 2



Source: http://www.minimumsecurity.net/stephaniemcmillan/codegreen/comics/2010-09-27-mad-scientists.jpg

Note: A think tank or policy institute, research institute, etc. is an organization that performs research and advocacy concerning several topics, like, for example, climate change.

Cartoon 3



Source: http://www.eurekastreet.com.au/uploads/image/16/47204.jpg

Note: Injections of sulfur dioxide (SO_2) in the stratosphere have been proposed in Climate Geoengineering because of its cooling effect.

Task 2

Climate Geoengineering: is it real or just another conspiracy theory?

Have you ever heard of Climate Geoengineering? Have you ever heard of Climate manipulation? For some it is something real, for others is just another conspiracy theory. For the majority, it's something never heard. In this task you're invited to analyze some resources (news headlines, videos and news articles) with the purpose of building a concept-map or a draw that reveals your understanding of this topic and how it might be connected with other topics, as Climate Change, Global Warming, Pollution, and others.

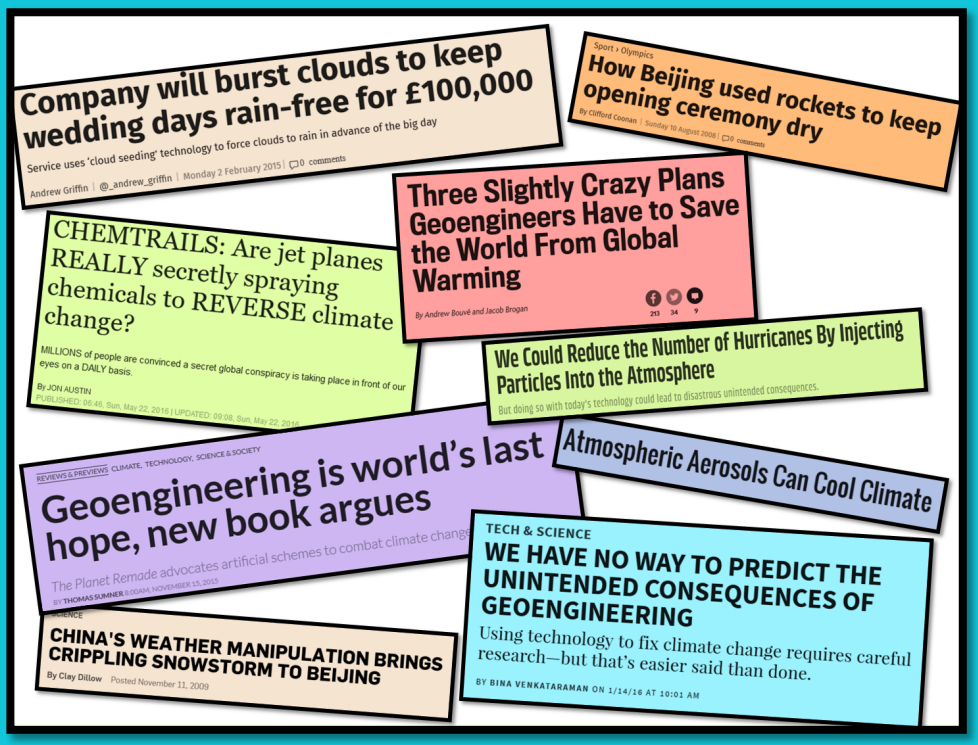
Task 2 | What do I (think I) know about Climate Geoengineering?

After exploring the next document (news headlines), videos and the article, **in pairs** build a concept map or a draw that represents your own understanding of Climate Geoengineering and present it to your classmates, justifying your choices. You can use Popplet to build your concept map.

POPPLET http://popplet.com/

News headlines

Note: These are real news headlines, retrieved from real online newspapers.



Videos and news article

VIDEO: James Fleming with A Brief History of Weather and Climate Control (12:33): https://www.youtube.com/watch?v=v7TBqqII6y4

VIDEO/DOCUMENTARY: Weather Warfare (44:19; HISTORY CHANNEL): https://www.youtube.com/watch?v=ACaXYxCQhvY

ARTICLE (Liz Burlingame, 2013, weather.com): Can We Control the Weather?: http://www.weather.com/news/science/can-we-control-weather-20130616

2

Explore

Task 3

Climate Geoengineering: what technologies?

It is intended you now dig deeper into the theme, understanding that there are various strategies of Climate Geoengineering that are currently being researched and/or officially being mentioned in important reports. You have to identify the main aspects that distinguish them, and also to understand the main Biological, Geological, Physical and Chemical principles behind each strategy.

Task 3 | What technologies? Version 1

1. Read **Text A - A brief introduction to Climate Geoengineering**. What are the two main groups of Climate Geoengineering approaches? What are the main aspects that distinguish them?

2. Class should be divided into two large groups (SRM, Solar Radiation Management group; and CDR, Carbon Dioxide Removal group) and these, into subgroups. Each subgroup has to perform a research related to one or more technologies/strategies of SRM or CDR regarding A2 and B2. You can use the suggested resources given. Then each of the two large groups must prepare a collaborative document (one about SRM and one about CDR) - and turn it into a poster (using GLOGSTER), presentation (using PREZI) or a virtual wall (using PADLET).

Research scheme:

A. SOLAR RADIATION MANAGEMENT (SRM)

- A1. What is it?
- A2. Strategies and technologies?
  - Physical / Chemical / Biological principles related?
  - Advantages and Disadvantages?

B. CARBON DIOXIDE REMOVAL (CDR)

- B1. What is it?
- B2. Strategies and technologies?
  - Physical / Chemical / Biological principles related?
  - Advantages and Disadvantages?

GLOGSTER http://edu.glogster.com/?ref=com

PREZI http://prezi.com/

PADLET https://padlet.com/

Text A – A brief introduction to Climate Geoengineering

Geoengineering can be described as the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change, especially global warming caused by greenhouse gases emissions. Such term is used to describe 'technological efforts to stabilize the climate system by direct intervention in the energy balance of the earth'. Several methods have been considered for this purpose, with results, objectives, technologies and costs quite distinct from one another. They can be grouped into two categories: those relating to the removal of CO_2 from the atmosphere and the ones that change Earth's capacity to absorb solar radiation. The removal of carbon dioxide from the atmosphere allows the heat in the form of infrared radiation to escape more easily into space. Methods that alter the capacity of absorption of solar radiation are more controversial; they aim at reducing the capacity of the atmosphere to absorb solar radiation by increasing their ability to reflect this radiation (albedo), changing Earth's temperature almost immediately.

A range of geo-engineering proposals have been put forward, including:

- The release of aerosols into the stratosphere to scatter incoming sunlight (Crutzen 2006)
- Cloud seeding through the artificial generation of micro-meter sized seawater droplets (Bower et al. 2006)
- Fertilization of the ocean with iron and nitrogen to increase carbon sequestration (Buesseler & Boyd 2003)
- Changes in land use to increase the albedo (reflectivity) of the earth's surface (Hamwey 2005).

Geoengineering proposals appear to have several advantages. First, they may be cheap in comparison to reductions in greenhouse gas emissions. They can be implemented by one or a small number of countries and thus do not require the widespread global action that stabilization of greenhouse gases will require (Barrett 2008). They may act quickly, with a lag from implementation to impact of months rather than decades. Geo-engineering techniques could potentially be deployed to avoid reaching a tipping point related to temperature increase. However, such proposals also have disadvantages.

- Those that focus on reducing solar radiation will do nothing to prevent the acidification of the ocean as a result of increased atmospheric concentrations of carbon dioxide, and therefore leave untouched part of the wider environmental problem.

- Geo-engineering techniques are generally untried. Some studies have been undertaken including through small-scale experiments on ocean fertilization (Buesseler & Boyd 2003), investigation of similar natural phenomenon such as the release of aerosols from mount Pinatubo in 1991, and computer simulations (Wigley 2006; Govindasamy & Caldeira 2000). However, there will always be the risk of unanticipated consequences, which need to be considered analytically.

- The fact that these solutions can be implemented unilaterally may also give rise to risks of conflict.

So far, the disadvantages of geo-engineering approaches have tended to outweigh the advantages in most minds that have turned to the issue. However, in recent years such proposals have received more support from a number of prominent scientists and economists, with calls for more research into their feasibility, costs, side effects and frameworks for implementation.

Sources

Martins, A. (2009). Respostas à mudança climática: cooperação internacional e os esforços de mitigação, adaptação e Geoengenharia. Tese de Licenciatura. Universidade Federal do Rio Grande do Sul.
Garnaut R. (2008). *The Garnaut climate change review*. (Cambridge University Press, Cambridge, UK)

Resources

OXFORD GEOENGINEERING PROGRAMME (OGP)
http://www.geoengineering.ox.ac.uk/what-is-geoengineering/what-is-geoengineering/
http://www.geoengineering.ox.ac.uk/what-is-geoengineering/why-consider-geoengineering/

IPCC REPORT (2007) - Mitigation of Climate Change (Chapter 11, Section 11.2. *Technological options for cross-sectoral mitigation: description and characterization*)
http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch11s11-2-2.html

ROYAL SOCIETY REPORT (2009): Geoengineering the climate: science, governance and uncertainty (pp. 9-36)
https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2009/8693.pdf

ARTICLE (2009): Why capture CO2 from the Atmosphere?
https://static.squarespace.com/static/51957744e4b088893b86e2f3/t/51b2261ce4b0252f42fc4f25/1370629660125/Keith-WhyCaptureCO2FromtheAtmosphere.pdf

IPCC REPORT (2013): CLIMATE CHANGE 2013 - The Physical Science Basis (Box TS.7 | Climate Geoengineering Methods, p. 98)
http://www.ipcc.ch/report/ar5/wg1/docs/WGIAR5_SPM_brochure_en.pdf

REPORT IPCC (2011): Expert Meeting on Geoengineering (pp. 2-3)
https://www.ipcc-wg2.gov/meetings/EMs/EM_GeoE_Meeting_Report_final.pdf

ARTICLE (2008): 20 reasons why Geoengineering may be a bad idea
http://climate.envsci.rutgers.edu/pdf/20Reasons.pdf

ARTICLE FROM SCIENTIFIC AMERICAN (2010): What Is Geoengineering and Why Is It Considered a Climate Change Solution?
http://www.scientificamerican.com/article/geoengineering-and-climate-change/

BRITANNICA ENCYCLOPEDIA: Geoengineering
http://www.britannica.com/science/geoengineering

ARTICLE: Geoengineering as Collective Experimentation
http://link.springer.com/article/10.1007%2Fs11948-015-9646-0#page-1

WEBSITE ARTICLE: Geoengineering
http://www.explainthatstuff.com/geoengineering.html

Task 3 | What technologies? Version 2

1. Read **Text A - A brief introduction to Climate Geoengineering**. What are the two main groups of Climate Geoengineering approaches? What are the main aspects that distinguish them?

2. Perform a research in order to answer the following questions. With the information gathered, you must build a poster/presentation and present it to your classmates. You can use GLOGSTER for the poster and PREZI for the presentation.

1. What kind of techniques can be used to remove carbon dioxide from the atmosphere?
2. What kind of techniques can be used to manage the solar radiation that arrives Earth surface?
3. Are these techniques useful? What do you think, how much can they help to prevent climate change?
4. Suggest which carbon dioxide removal/solar radiation management technique you think is best. Who makes the decision on which technique is used?
5. Draw a picture of one technique of carbon dioxide removal technique/solar radiation management technique. This helps you remember later how it works.
6. Explain what kind of problems might arise if Geoengineering is put to practice.

GLOGSTER http://edu.glogster.com/?ref=com

PREZI http://prezi.com/

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Garnaut R. (2008). *The Garnaut climate change review*. (Cambridge University Press, Cambridge, UK)

Task 4

Solar Radiation Management: what's the influence of color on albedo?

This task is an experimental activity through which you can investigate the effect of surface color in albedo, since painting rooftops white is one of the Climate Geoengineering strategies of Solar Radiation Management. It is also an opportunity for you and your classmates to develop experimental/research skills.

The data retrieved from the experimental activity can be used by you to revise the knowledge you have built so far.

Task 4 | Increasing the albedo of the urban areas

Many technological strategies have been proposed to manipulate Earth's environment as a way of rapidly responding to and potentially offsetting some of the warming resulting from anthropogenic climate change. This portfolio of Geoengineering ideas includes a wide range of approaches and technologies, ranging from sequestration of atmospheric CO_2 to solar radiation management via increasing planetary albedo. For each technology, often novel and unproven, there are almost equal numbers of studies discussing positive and potential negative effects (including cost) of technologies. However, among the proposed approaches, increasing the albedo of the urban areas and human settlements (hence increasing the albedo of Earth as a whole) by increasing the reflectivity of artificial urban surfaces (rooftops, pavements), is based on proven technologies that have been used for centuries with no known negative effect. Human-made high-albedo surfaces absorb less incoming solar radiation, and all else being equal, will have a lower temperature than surfaces with low solar reflectance. If used in the context of houses and buildings in warm climates, a roof with high solar reflectance can also decrease cooling energy use in air conditioned buildings and increase comfort in unconditioned buildings. Roofs and pavements with high solar reflectance can also mitigate summer urban heat islands, improving outdoor air quality and comfort.

Extracted from

Akbari H, Matthews H D and Seto D 2012 The long-term effect of increasing the albedo of urban areas *Environ. Res. Lett.* **7** 024004

Experiment | Solar Radiation Management: what's the influence of color on albedo?*

Next you'll find a possible experimental plan in which you and your classmates use thermometers, white and dark paper, and lamps to measure differences in albedo between the light and dark materials.

Background information

Albedo is the measurement of how much solar energy is reflected off a surface. It is common knowledge dark-colored clothing is warmer than light-colored clothing. The quantitative measure of this difference is called albedo. Albedo is defined as the ratio of reflected radiation from the surface to incident radiation upon it. As a dimensionless quantity (meaning it has no units) it can be expressed as percents or as a number between 0 and 1. One property that affects albedo is the color of a surface. When the sun shines on a surface, solar radiation, or solar energy, is either absorbed into or reflected off that surface. Materials that are lighter in color have a higher albedo than the same materials with a darker color. Black jeans have a low albedo; they reflect very little solar energy. White jeans have a high albedo; they reflect a large amount of solar energy.

Albedo affects Earth's environment. Soil, water, and snow also have albedo measurements. Fresh snow reflects 90 percent of the solar energy striking its surface, so its albedo measurement is 0.90. This means that only 10 percent (100-90) of the solar energy that reaches the snow is absorbed. The albedo of a water surface depends on the angle at which the sunlight strikes it and whether the surface is smooth or rough.

* This experimental activity is adapted from the classroom activity "Amazing Albedo" from the American Museum of Natural History, which can be accessed here http://www.amnh.org/content/download/1709/24545/file/aa_a04_albedo.pdf

Research questions

1. How does the color of a surface influence its ability to reflect or absorb heat?
2. How does the color of a surface impact on how it responds to incoming solar radiation?
3. How might this factor have an impact on global warming?

Materials and Procedure

- 1 sheet of black construction paper
- 1 sheet of white construction paper
- Heat lamp (or natural sunlight)
- 2 thermometers
- Scissors
- Stopwatch
- Stapler
- Graph paper
- Ruler

1. Cut two rectangles, one from the black paper and one from the white paper. The rectangles should measure 8 cm x 4 cm.

2. Fold the rectangles in half to form squares. Staple the squares to make pockets that can fit around the bulbs of the two thermometers. Slip the paper pockets over the bulbs (Fig.1). Using the **worksheet** below, record the initial temperature reading for each thermometer. Note: the envelopes must be placed over the bulb end of the thermometers. And the thermometers must be equidistant from your heat source. Why?

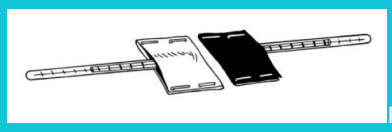

Fig. 1

3. Position the heat lamp about two feet above the surface of the table (Fig. 2).

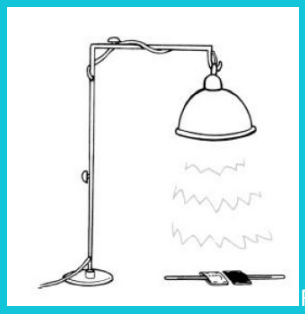

Fig. 2

4. Make predictions with your group about how the temperature will (or will not) change over time. Record your predictions on your worksheet.

5. Turn on the lamp. If you must touch the bulb or the shade, use oven mitts. The lamp parts get very hot during the experiment. Every two minutes, record the temperature of each thermometer on your worksheet. Continue taking readings for ten minutes.

6. Make a graph of the temperature you recorded on the two thermometers over time. Use scrap paper to lay out your graph intervals and draw a rough sketch before creating a final graph on a separate graph paper.

7. Analyze the data with your group. Use the questions on your worksheet to guide your analysis.

Worksheet

1. Record starting temperatures for each of the two thermometers in the first column of the chart below.

	t_0	t_2	t_4	t_6	t_8	t_{10}
White						
Black						

2. Make a prediction: what do your think will happen to the temperatures of the two thermometers over time? Which temperature will rise faster? Which will get hotter? Why do you think so?

3. Which thermometer registered the fastest rise in temperature? Which one registered the slowest rise? Why do you think this happened?

4. Considering what you have discovered about how surfaces interact with heat depending on color, try answering the initial questions. Illustrate your conclusions about how surfaces interact with solar radiation, including the Earth and the Sun in your drawing, and indicate how the color of a surface affects its ability to reflect/absorb heat, hence, the albedo.

5. Some scientists, however, consider that the option of having city surfaces painted white is not as good to reducing global warming as initial some have though. Perform a research and try to find studies (and their reasons) that express this idea. Summarize their conclusions and present them to your class. See, for example: http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-11-00032.1

Guiding questions to develop your own experimental plan

a) Formulate one research question that relates the color of a surface (rooftop) and global warming.

b) Taking into account that question, formulate one hypothesis (that is, what do you think it will happen, and why?)

c) What are you going to change (that is, what is the independent variable)?

d) What are you going to measure (that is, what is the dependent variable)?

e) Formulate a protocol in order to answer the initial question: think about the materials that you will need and also the procedure. Assemble your equipment and set up the experiment.

f) Take record of the data. Make notes about the reliability of data or possible difficulties you came across during the experiment.

g) Analyze and interpret the data (make a graphic from which you can extract the results): what happened and why?

h) Do the results confirm or refute the initial hypothesis?

i) Answer your research question and mention possible limitations your answer may have. For example, are there some situations or circumstances that your answer does not cover, or can you come up with error estimates that you can report?

3

Explain

Task 5

Climate Geoengineering: sharing knowledge!

It is time to share with the class the findings you and your classmates made on the previous tasks. Through a sharing-session, you will present the knowledge built so far. To assess the effectiveness of your presentation, you will need to build a questionnaire for your classmates to fill. You will also have to build another concept map/draw and compare with the first you've done in Task 2 – how different are they? And what does that tell you about what you've learned so far?

Task 5 | Sharing session: presenting and assessing its effectiveness

1. Now you have to **share with your classmates** the knowledge built in previous tasks (you can include the results from the experimental activity on the albedo!) through a sharing-session. In this session each of the two large groups must present the document (poster, presentation or wall) and answer your classmates' questions.

2. Also, each of the two groups has to **create an assessment instrument** (an online questionnaire using Google Forms) that allows for the assessment of the other classmates knowledge. Were the presentations effective and allowed for them to know more about the topics you and your group members researched and presented?

GOOGLE FORMS https://docs.google.com/forms

3. Lastly, you have to **create a concept-map/draw** that integrates the new knowledge you've learned about the topic of Climate Geoengineering. Compare this second map/draw with the one you've made in the beginning of the module, in task 2. Can you figure out what has changed and what have you learned so far? For building the concept map you can use Popplet.

POPPLET http://popplet.com/

Rubrics

You'll find the rubric for the concept map on page 60 and for the presentation on page 61. Don't forget to check them before you develop your presentation and concept map.

4

Elaborate

Task 6

RRI in Climate Geoengineering | Part I – Introduction to RRI

According to the European Commission, the process of scientific research and innovation (innovation being the result of scientific research) should be *Responsible*. To ensure that this responsibility is implemented, it is important that this process takes into account six aspects/dimensions. In this task you'll be introduced to the concept of Responsible Research and Innovation (RRI) and to its 6 dimensions.

Task 6 | Introduction to RRI

1. After reading **Text B – Responsible Research and Innovation**, **define** what RRI is according to your own understanding of it.

2. According to the European Commission, the process of scientific research and innovation (innovation being the result of scientific research) should be **Responsible**. To ensure that this responsibility is implemented, it is important that this process takes into account six aspects/dimensions:

Engagement | Gender Equality | Science Education | Open Access | Ethics | Governance

What does each of the 6 RRI dimensions suggest to you?

3. Working in pairs, make the **correct correspondence** between the RRI dimensions in column I and the statements in column II. Discuss with your classmates any differences between your answers. After the discussions, read **Text C**, which resumes the 6 RRI dimensions.

Column I	Column II
A. Engagement **B. Gender Equality** **C. Science Education** **D. Open Access** **E. Ethics** **F. Governance**	1. The engagement of all societal actors implies an equal and balanced involvement of both men and women.
	2. The joint participation of all societal actors - researchers, industry, policymakers and civil society - in the research and innovation process.
	3. Europe must not only increase its number of researchers, it also needs to enhance the current education process to better equip future researchers and other societal actors with the necessary knowledge and tools to fully participate and take responsibility in the research and innovation process.
	4. Mutual learning and agreed practices are needed to develop Responsible Research and Innovation joint solutions to societal problems and opportunities, and to pre-empt possible public value failures of future innovation.
	5. This will boost innovation and further increase the use of scientific results by all societal actors.
	6. This dimension is the umbrella for all the others. Policymakers also have a responsibility to prevent harmful or unethical developments in research and innovation. Through this key we will develop harmonious models for Responsible Research and Innovation that integrate public engagement, gender equality, science education, open access and ethics.
	7. It is essential to fight the low representation of women in research institutions and in decision-making processes on issues of science and technology.
	8. European society is based on shared values.
	9. In order to be responsible, research and innovation must be both transparent and accessible. This means giving free online access to the results of publicly-funded research (publications and data).
	10. This dimension should not be perceived as a constraint to research and innovation, but rather as a way of ensuring high quality results. Beyond the mandatory legal aspects, this aims to ensure increased societal relevance and acceptability of research and innovation outcomes.

Text B – Responsible Research and Innovation

WHAT IS RESPONSIBLE RESEARCH AND INNOVATION?
Research and innovation constantly change our world. From the Internet and mobile phones, to climate change and new cancer treatments, science and technology have the potential to transform our lives. These developments also create new risks and new ethical dilemmas. Responsible Research and Innovation (RRI) seeks to bring these issues into the open, anticipate the consequences and directions of research and innovation, and involve society in discussing how science and technology can help create the kind of world and future we want.

WHY RESPONSIBLE RESEARCH AND INNOVATION?
Increasingly powerful science and technology have granted humans unprecedented scope to intervene in our surroundings, from altering ecosystems and the Earth's climate at the global scale to manipulating the minute building blocks of matter and life itself. In addition, as a society we face great challenges –from healthy ageing to sustainability, from global health to resource security. Research and innovation have the power to tackle these challenges, but their success is not guaranteed. Research and innovation will always be at least partly unpredictable, but this does not excuse irresponsibility. Understanding and taking responsibility for these developments goes well beyond just science and scientists. Such developments profoundly affect all our lives. The direction and purpose of research and innovation, the distribution of its outcomes (both positive and negative), the uses of new technologies, and maintaining a focus on solving pressing problems are matters that we, as a society, need to discuss and choose together.

WHAT SHOULD RESPONSIBLE RESEARCH AND INNOVATION LOOK LIKE?
RRI is not one thing. It will vary across institutions, cultures and areas of science and technology. However, it will have one key, central feature: it will put the needs of ordinary citizens at its centre. Companies will still need to make profits in a market economy, but RRI will re-orientate research from "can this make money?" to "how can this fulfill the needs of society within the market?"

WHAT ABOUT 'FUNDAMENTAL' RESEARCH?
Fundamental research is not aimed at meeting the immediate, material needs of society. The deep insights into the world in which we live –from sub-atomic to universal scales, from the micro-biotic to the global environment– are a vital part of human culture. RRI applies to all stages and aspects of research, including fundamental research. It demands that the knowledge gained be open and accessible to all, and that its starting point be engagement with as many of the world's citizens who want to participate in creating that new knowledge as possible.

WHOSE NEEDS, WHOSE CHALLENGES?
How, then, to uncover the needs of our fellow citizens? Over the last few decades, we have seen many experiments that foster involvement of the public in discussions and policy decisions regarding science, collaboration between scientists, ethicists and social scientists, open source and user-driven innovation, citizen science and more besides. We should encourage such experiments, join them up and encourage the institutions that fund, regulate and govern science and innovation to respond to them. RRI means experimenting further and improving upon existing practice. It means paying close attention to current developments, be they positive efforts by scientists to take responsibility for emerging technologies, or institutional and cultural barriers that are stopping progress. RRI also encompasses research ethics, gender and other forms of inclusion, open access to scientific data and publications, and scientific education. Scientists and innovators should be encouraged to take responsibility for the futures they help shape. But the responsibility is not individual, nor is it theirs alone. The challenge is to find collective ways to take care of the future.

Source: http://www.rri-tools.eu/

Text C – The 6 keys of RRI

CHOOSE TOGETHER

The first key is **Engagement** of all societal actors - researchers, industry, policymakers and civil society – and their joint participation in the research and innovation process, in accordance with the value of inclusiveness, as reflected in the Charter of Fundamental Rights of the European Union. A sound framework for excellence in Research & Innovation entails that the societal challenges are framed on the basis of widely representative social, economic and ethical concerns and common principles. Moreover, mutual learning and agreed practices are needed to develop Responsible Research and Innovation joint solutions to societal problems and opportunities, and to pre-empt possible public value failures of future innovation.

UNLOCK THE FULL POTENTIAL

The second key is **Gender Equality**. Engagement means that all actors – women and men – are on board. The under -representation of women must be addressed. Research institutions, in particular their human resources management, need to be modernized. The gender dimension must be integrated in research and innovation content.

CREATIVE LEARNING FRESH IDEAS

Our third key is **Science Education**. Europe must not only increase its number of researchers, it also needs to enhance the current education process to better equip future researchers and other societal actors with the necessary knowledge and tools to fully participate and take responsibility in the research and innovation process. There is an urgent need to boost the interest of children and youth in maths, science and technology, so they can become the researchers of tomorrow, and contribute to a science-literate society. Creative thinking calls for science education as a means to make change happen.

SHARE RESULTS TO ADVANCE

In order to be responsible, research and innovation must be both transparent and accessible. Our fourth key is to make **Open Access** a reality. This means giving free online access to the results of publicly-funded research (publications and data). This will boost innovation and further increase the use of scientific results by all societal actors.

DO THE RIGHT "THINK" AND DO IT RIGHT

Our fifth key is **Ethics**. European society is based on shared values. In order to adequately respond to societal challenges, research and innovation must respect fundamental rights and the highest ethical standards. Beyond the mandatory legal aspects, this aims to ensure increased societal relevance and acceptability of research and innovation outcomes. Ethics should not be perceived as a constraint to research and innovation, but rather as a way of ensuring high quality results.

DESIGN SCIENCE FOR AND WITH SOCIETY

The last dimension is the umbrella for all the others: it is **Governance**. Policymakers also have a responsibility to prevent harmful or unethical developments in research and innovation. Through this key we will develop harmonious models for Responsible Research and Innovation that integrate public engagement, gender equality, science education, open access and ethics.

Sources

European Commission (2012). Responsible Research and Innovation: Europe's ability to respond to societal challenges.

Sutcliffe, H. (2011). A Report on Responsible Research and Innovation for the European Commission. MATTER, London. Available in http://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf

Task 7

RRI in Climate Geoengineering | Part II – Geoengineering around the world: what, where and how?

What Geoengineering strategies have been implemented so far around the world? And were those examples of Responsible implementations?

Task 7 | Geoengineering around the world

Perform an information search about Climate Geoengineering strategies (or strategies for manipulating the weather) that have been implemented around the world – search for news in newspapers. If you have any difficulty, you can access the news examples given below.

Try to identify in the text of the news if all citizens were happy or in agreement with the measure, who was involved in the decision of implementing such measure, who should have been involved and why, and whether in your opinion such a measure was ethical (or not) and why. If this information is not present in the text, try to **formulate your own opinion**, answering them.

Then, present the news and your thoughts on it to your classmates.

News

Here are some examples of news concerning weather manipulation strategies that were implemented around the world:

Rjukan sun: the Norwegian town that does it with mirrors
http://www.theguardian.com/world/2013/nov/06/rjukan-sun-norway-town-mirrors
Using Giant Mirrors to Light up Dark Valleys
http://www.theatlantic.com/photo/2013/10/using-giant-mirrors-to-light-up-dark-valleys/100613/
Italy village gets 'sun mirror'
http://news.bbc.co.uk/2/hi/europe/6189371.stm
China's largest cloud seeding assault aims to stop rain on the national parade
http://www.theguardian.com/environment/2009/sep/23/china-cloud-seeding
Weather Engineering in China
https://www.technologyreview.com/s/409794/weather-engineering-in-china/

Task 8

RRI in Climate Geoengineering | Part II – Discussion session on Climate Geoengineering

In this task class will have a discussion session on Climate Geoengineering. In order to be prepared for the discussion, you will need to read the given texts that relate RRI (and some of its dimensions) and Climate Geoengineering.

Task 8 | Discussion session

Prepare for a discussion on Responsible Climate Geoengineering reading the following texts (1 to 6). When reading them, try to formulate your own opinion on how must Climate Geoengineering should be in order to be Responsible, according to the 6 RRI principles. Take notes if needed, they might be very helpful for the discussion session!

Text 1: Why engage the public with Geoengineering?

Engaging in wider dialogue on complex and uncertain technologies such as Geoengineering is critical for supporting democratic ideals, making better informed choices and enhancing the legitimacy of decision making. It is vital to 'open up' to broad participation from publics and stakeholders as well as experts, and to reflect on the assumptions and uncertainties bearing on their judgments. Engagement activities have already begun 'upstream', or in advance of, significant research and development, during a period of unique clarity where value disputes are not shrouded by scientific claims. Engaging at this time can support the 'responsible innovation' of Geoengineering, by enabling societal values to influence the future trajectory of innovation. The second of the Oxford Principles underscores this need to engage those who would be affected by Geoengineering research activities.

http://geoengineering-governance-research.org/perch/resources/cgg-briefing-note-5publicsge-1.pdf

Text 2: What are the concerns with Geoengineering?

The idea of reflecting more sunlight back into space raises a lot of ethical, moral and legal questions. If you do use particles you have to keep doing it. If you stop it, or it fails, the climate will bounce back but very quickly – quicker than the climate change that would have occurred. That causes a lot of concerns. You'd be affecting the global climate with an intentional intervention – so who is responsible for that? What if there are side effects? Taking CO2 out of the atmosphere raises [fewer] big ethical questions, but there is still a set of questions about what we do with all this CO2 we are going to store … what kind of burden are we placing on future generations?

Adapted from: https://www.theguardian.com/science/2014/nov/06/geoengineering-ethical-problems-cleaning-air-climate-change

Text 3: How should Geoengineering research be governed?

Governance mechanisms are always needed for Geoengineering research which is open to the environment, to ensure that:

• Geoengineering should be regulated as a public good and in the public interest:
• There should be participation in decision-making at the appropriate level, depending on the type and location of activity, from computer-based research to outdoor research in a locality, or to experiments on a national or international scale;
• There should be full disclosure and open publication of all research results (in the light of the experience of failure to publish unfavorable clinical trial results);
• There should be independent assessments of the research and particularly of impacts;
• The governance arrangements need to be clear in advance.

http://geoengineering-governance-research.org/perch/resources/cgg-briefing-note-6geresearch-1.pdf

Text 4: Geoengineering and environmental ethics

The fantastic idea of Geoengineering — the intentional large-scale manipulation of the environment to counter act the negative impacts of global climate change — is starting to be taken seriously in science and policy circles. For some scientists and policymakers, concern about the efficacy of political efforts to avoid dangerous climate change is beginning to make these schemes look less fantastic. For example, in 2009 the Royal Society issued a report on Geoengineering, and the United States Congress's Committee on Science and Technology held hearings. In response to growing interest in Geoengineering, in 2010 the United Nations Framework Convention on Biological Diversity agreed to a largely symbolic moratorium on Geoengineering research. Currently, the general public is by and large unaware of Geoengineering proposals. However, there are signs that initial sparks of disagreement over the science and ethics of Geoengineering will develop into a raging international controversy in coming decades. That is, unless political efforts become successful at reducing green house gasses.

Scientists have speculated on a wide array of Geoengineering schemes that fall into two sets of strategies. One set aims at massive efforts to remove CO_2 from the atmosphere to reduce the green house effect. The other set of strategies has been called solar radiation management (SRM). To date, no Geoengineering proposal has been researched to the point of becoming a policy option. The question at hand is: should we even begin serious, sustained research programs?

Until recently, high-level scientific and policy discussions about Geoengineering research have been largely off the table. There is a consistent concern that significant research efforts could cause some leaders to see Geoengineering as a cheap solution to the climate crisis. This attitude might undermine efforts to get at the root of the problem. In addition to this potential "moral hazard," numerous ethical issues have been raised. The list of issues deals with moral questions in areas such as the governance of research and possible deployment, the unequal sharing of risks, the distributions of harms and benefits, the possibility of unilateral deployment, and the effects on the environment.

Adapted from: http://www.nature.com/scitable/knowledge/library/geoengineering-and-environmental-ethics-80061230

Text 5: Where's the justice in Geoengineering?

Geoengineering is a technology that promises great power. But, as Spiderman was reminded by his Uncle, with great power comes great responsibility. This isn't a new insight. It reflects long established political understanding. Voltaire apparently said it first, while Lincoln commented "if you want to test a man's character, give him power".

Why? Because power brings capability and choice to affect many lives (for good or for ill). Yet the idea that 'power corrupts' is not just a cliché. So we develop ethics programs, and accountability mechanisms as counter-balances.

https://www.theguardian.com/science/political-science/2015/mar/14/wheres-the-justice-in-geoengineering

Text 6: Will Geoengineering make people give up cutting their carbon footprint?

If you thought there was a machine that could magically remove carbon dioxide from the atmosphere and bury it underground, would you be less likely to worry about reducing your own carbon footprint?

The question is not entirely hypothetical. Geoengineering is the catch-all term for a suite of technologies that could one day be used to alter the Earth's climate and combat global warming. Most of them are unlikely to ever see the light of day: they are considered too risky, too unpredictable, or too reckless to be taken seriously by the scientific community.

As Geoengineering has gradually moved on to the policy agenda, debates about the ethics of meddling with the global thermostat have become more prominent. Central among these is whether Geoengineering might undermine fragile public and political support for the more pressing business of reducing carbon emissions.

This is what is known by economists and philosophers as a 'moral hazard' argument: the phenomenon whereby people who feel insured against a particular risk are more likely to exhibit risky behavior. Will the prospect of Geoengineering make people feel 'insured' against the risks of climate change, and indulge in 'riskier' environmental behavior themselves?

http://www.theguardian.com/environment/2014/nov/17/geoengineering-co2-carbon-dioxide-earth-climate

5

Elaborate
Exchange
Empower

Task 9

RRI in Climate Geoengineering | Part III- Take action!

Is it possible for a *Responsible* Climate Geoengineering? If so, how? In this task you'll have to develop an interactive exhibition that will be presented to the community, with the purpose of warning other citizens about the importance of RRI in Climate Geoengineering. Are you ready for some action?

Task 9 | Take action!

1. Read **Text D** "**On the final interactive exhibition: why and how?"** below.

2. Taking into account all you've learned so far concerning the topic of Climate Geoengineering, and also having in mind your own fundamented opinion about it, you now need to build a Manifest entitled "Responsible Climate Geoengineering: is it possible? If so, how?" which represents a set of guidelines on Responsible Research and Innovation on Geoengineering – to be presented to the community in the final exhibition that the class has to prepare.

This final exhibition is **very important**, since it serves as a platform for you and your classmates share with others what you've learned and also share your own opinions and concerns about the topic.

Class should be **divided in groups**, each with preferably 6 students since there are 6 dimensions of RRI. **Each student is responsible for one dimension**.

After deciding on what the Manifest should look like, each group member will then establish a **relation between Geoengineering and his/her RRI dimension**, contributing to the final object.

Each object built by each group must have the 6 RRI dimensions.

Remember the RRI dimensions?

- Engagement
- Gender Equality
- Science Education
- Open Access
- Ethics
- Government

The objects of the Manifest can have different formats: a collaborative eBook, a set of cartoons, a comic strip or a comic book, a digital or physical poster, a video, a game, etc. It is important that each group chooses a **different format for its object** as a warrant of a more **rich and appealing exhibition**.

Here are some options:

DIGITAL POSTER | Glogster | http://edu.glogster.com/?ref=com
GAMES | Fold Play | http://foldplay.com/foldplay.action
EBOOK | http://bookbuilder.cast.org | http://simplebooklet.com
PHYSICAL BOOK | http://www.makingbooks.com | http://wp.robertsabuda.com/make-your-own-pop-ups/
VIDEO | moviemaker
COMICS | Pixton | http://www.pixton.com/

Task 9 | Exhibition evaluation: visitors' perceptions

In order to assess the impact of your work on visitors' understanding of the topic and on their awareness regarding RRI in Climate Geoengineering, you will need to produce an online questionnaire (using GOOGLE FORMS) whose url will be delivered to each visitor at the end of the exhibit (for instance, you can use QR codes printed in a card that will be delivered to the visitors, enabling them to access the online questionnaire). As alternative you can have several pc stations, at the end of the exhibition, allowing visitors to answer the questionnaire at place or you can have the questionnaire in paper and the visitors can fill at the end of the exhibition.

This evaluation is of extreme importance. This creates a great opportunity for you and all your classmates to **reflect on your work** and the **achievement of goals** regarding the empowerment dimension of the module.

GOOGLE DOCS https://docs.google.com/

QR CODE GENERATOR https://www.the-qrcode-generator.com/

Text D "On the final interactive exhibition: why and how?"

What is the purpose of the final exhibition?
Throughout the set of tasks in this module you've learned a lot about Climate Change and Climate Geoengineering: not only the scientific aspects of this theme but you've also developed the notion that this is a cutting-edge scientific theme that concerns all elements of our Society. Hence, you are now in a privileged position in what refers to knowledge about this issue (we are sure that you know more about Climate Geoengineering than the average citizen – or, at least, more than your parents or grandparents!). Since you are also part of this Society and you are certainly capable of acting along with your peers in helping solving some of its problems, you have the responsibility of alert others about this theme (Climate Geoengineering) and try to teach them and pass them your own fundamented opinions. Hence, the purpose of this final exhibition is for you and your classmates take an active role in our Society and share your knowledge with others, in an engaged and enthusiastic way.

Who should be responsible for its development?
Well, that obvious: you and your classmates! With the help of your teacher(s), of course. But it is intended that you play an active and central role in developing this exhibition, because it's YOUR exhibition. Hence, not only you should gather knowledge that allows for your fundamented opinion (opinion that you are going to express through the exhibition), but you should think about the objects you will need to build (together they will build up the class Manifest) in order to be appealing and promote the engagement of the visitors with the topic. Also you should need to think about some practical issues, like where and when the exhibition will take place, how much space will be needed, what materials you will need to build the objects, etc.

It should be interactive: what does this mean?
Very simply, it means that it should catalyze for the interactions between visitors themselves and between visitors and the objects. Hence, try to build objects different from the more common ones, more appealing (games are great options since they captivate the audience and promote interaction between the participants) and that can stimulate discussions between the visitors, and stimulate for their reflection about the theme. Ask questions – more and less obvious, that appeal for knowledge but also for visitors' own opinion about the issues! Let them participate in the exhibition by leaving their own mark: allow them to leave their comments about the topic, or change something in the exhibition as a way of leaving their own mark or opinion.

Whom should we invite for the exhibition?
Having in mind the purpose of the exhibition, we would dare say: everyone! Younger and older students from your school (and other schools), your teachers and families. But also, representatives from other social actors like the Government, Scientists, Industries, NGOs, Media, etc. The purpose is to create awareness on the topic and have a real impact, so you should try to invite them also. Ask for help from your teachers but also from your parents, contact journals, your city hall, universities, and research centers. Ask for help from the school principal – but don't wait for others to do this part. If you and your classmates don't move, don't expect others will.

How can we assess the impact of our exhibition on visitors? Wait… is it important to do that?
Starting from the end of the question: of course! You and your classmates have put so much effort into this project and this exhibition in order to create awareness on others about the topic, that you really should be wanting to know if your goals were (or not) achieved – were visitors able to learn something from the exhibition? What have they learned? Did they like the exhibition? What do they think were the best and worst parts of it? Did their opinion about the topic changed after experiencing your exhibition? These are all questions that you can ask them, in person or through a questionnaire. So, our advice is that you and your classmates build a questionnaire and print it out, and ask visitors to fill in at the end of the exhibition. Then, analyze the results and discuss if your goals were achieved, and what could you improve for the next time!

Rubrics

You'll find the rubric for the exhibit object on page 63 and for the exhibition on page 64. Don't forget to check them before you develop your work.

6

Evaluate

Rubrics

Evaluate

Next you'll find the rubrics aimed at the evaluation of the concept map, the presentation, the exhibit object and the final exhibition. They are to be used by both teacher and students, hence it is important to consult them before you start the tasks. When you are aware of the evaluation criteria, you're able to perform at your best!

Concept map

	3	2	1	
1. Understanding of concepts and terminology	Shows an excellent understanding of the concepts and sub-concepts. The concepts and sub-concepts are used accurately.	Shows a good understanding of most concepts and sub-concepts, but makes up to two inaccuracies	Shows a weak understanding of most concepts and sub-concepts, or makes up more than two inaccuracies	___/3
2. Relationships between concepts	The map identifies all the important concepts and reveals complex thinking about the significant relationships between them.	The map identifies several important concepts and awareness about the most significant relationships between them	The map identifies few important concepts revealing little reflection about them or presenting some inaccurate relationships	___/3
3. Arrangement of Concepts	Very well organized map with a logical format. Main concept is easily identifiable; Non-linear structure (sub-concepts properly branching from the main idea) providing a very complete vision and interconnection of ideas.	Most of the map is easy to read; the main concept is easily identifiable; non-linear structure (most sub-concepts branching properly from the main idea) providing a complete and interconnected view of the main ideas.	Poorly organized map (confusing); the main concept is not clearly identified; the sub-concepts are not consistently branching off from the main idea; the map does not provide a complete view or interconnected ideas	___/3
4. Images and videos	Images and videos used are perfectly suited to the context and facilitate the understanding of the topic.	Most of the images and videos used fit the context and facilitate the understanding of the topic..	The images and videos are used inappropriately and excessively and do not facilitate the understanding of the topic.	___/3
5. Design	Great visual aspect; effective use of color and space to organize ideas or sub-themes and / or emphasis.	Good visual aspect; most of the time, color and space are used effectively to organize ideas or sub-themes and / or emphasis.	Disorderly aspect; weak visual aspect; weak use of color and space.	___/3
			Total	**___/15**

Presentation

	4	3	2	1	
1. Scientific Correction	Presentation revealing excellent domain of concepts and information	Presentation without any incorrections a the level of concepts or information	Presentation with some inaccuracies at the levels of concepts or information	Presentation with several errors at the level of concepts or information	___/4
2. Justification of argumentation	All group members reveal a deep knowledge of the content of their work and justification of argumentation	Most group members reveals a good knowledge of the content of their work and justification of argumentation	Several group members have a poor knowledge of the content of their work OR are unable to justify the arguments	The group members are not sufficiently prepared to defend aspects of their work; They do not have the knowledge or skills needed	___/4
3. Correction of the speech	Speech very well articulated and without grammatical inaccuracies or pronunciation and correct use of scientific language	Speech reasonably well articulated and without grammatical inaccuracies or pronunciation and scientific language	Grammatical lapses and difficulties of pronunciation and scientific language	Difficulty of speech and grammatical incorrectness, pronunciation and scientific language	___/4
4. Articulation between the group members	Excellent relationship between the various elements of the group; Logic and extremely well organized presentation	Good articulation among most group members. However, some of the elements did not prepare the presentation with the other menbers	Weak coordination between the various elements of the group. It is evident that some of them have not prepared the presentation	There is no link between the various elements of the group; unorganized presentation	___/4
5. Clarity and objectivity	Clear and objective exposition and evidence of the fundamental aspects	Clear exposition, but with some superfluous aspects	Clear exposition, but not objectiive; They were presented many superfluous aspects	Unclear exposition, not objective and no evidence of the fundamental aspects	___/4
6. Presentation of the information	The information is presented and unread	The information is presented but accompanied by some notes reading	Most of the information is read instead of being presented	The information is read instead of being presented	___/4
7. Ability to raise interest	Well-rehearsed presentation, without mishaps and effective in attracting attention and audience interest	Presentation with a few mishaps but effective in attracting attention and audience interest	Presentation with some mishaps and not always effective in attracting attention and audience interest	Presentation with mishaps and ineffective in capturing the attention or interest of the audience	___/4
8. Audiovisual support	It is used audiovisual elements of great quality to support or enhance the content of the presentation (pictures, diagrams / graphics, videos)	It is used audiovisual elements of quality but not properly exploits	It is used some audiovisual elements of poor quality	It is not used any visual element to support or enhance the content of the presentation (pictures, diagrams / graphics, videos)	___/4

Presentation (cont.)

	4	3	2	1	
9. Creativity	Extremely creative presentation both in terms of methodology and of the used materials	Presentation with various creative aspects in terms of methodology and of the used materials	Presentation little bit creative in terms of methodology and of the used materials	Uncreative presentation both in terms of methodology and of the used materials	___/4
10. Time management	Excellent management of time available for the presentation	The presentation exceeds slightly the time period that was intended for it	The presentation considerably exceeds the time period that was intended for it	Does not respect the time at all	___/4
11. Use of the voice	Audible speech throughout the presentation, good articulation of voice with audiovisual media	Audible speech for most of the presentation, with inflection and expression	Speech by large swings in voice volume, but expressionless	Speech inaudible, with monotonous, uninflected and expressiveness voice	___/4
				Total	**___/28**

Exhibit object

	4	3	2	1	
1. Scientific Accuracy	Object revealing excellent domain of concepts and information	Object without any inaccuracies at the level of concepts or information	Object with some inaccuracies at the levels of concepts or information	Object with several errors at the level of concepts or information	___/4
2. Message	Clear and objective message, emphasizing the most important topics	Clear message, but with some superficial aspects	Clear message, lacking objectivity; many superficial aspects	Message not clear, lacking objectivity, and without emphasizing the main topics	___/4
3. RRI	There is a very explicit relationship between the topic and RRI	There is an explicit relationship between the topic and RRI	The relationship between the topic and RRI is not explicit	RRI is absent	___/4
4. Dimensions of RRI	All 6 dimensions of RRI are present	4 or 5 dimensions of RRI are present	2 or 3 dimensions of RRI are present	Only one dimension of RRI is present or none	___/4
5. Interactivity [objetc raise questions, promote individual and collective reflection, promote interaction between visitors, allow visitors to leave their mark?]	The object is very interactive	The object is moderately interactive	The object allows for little interactivity	The object is not interactive	___/4
6. Activism [object's ability to alert the visitor and motivate to action]	Very explicit	Moderately explicit	Little	Absent	___/4
7. Graphic aspect	Very aesthetically pleasant	Moderately aesthetically pleasant	Not very aesthetically pleasant	The object is not aesthetically pleasant	___/4
				Total	**___/28**

Exhibition

	Excellent 5	Very Good 4	Adequate 3	Needs Improvement 2	Not Acceptable 1
ORGANIZATION: Information is well-organized for the visitor					
The big idea of the exhibit is clear					
There is a coherent relation between the objects throughout the exhibit					
Exhibit components make sense when viewed alone and together					
CONTENT: Information is clear, complete, and accurate and generates interest in the subject					
The exhibit makes it possible to develop the main idea					
There is a explicit connection between the exhibit and RRI					
The exhibition presents information, generates curiosity, changes ideas or feelings about the topic and/or motivates action					
The information presents scientific correction					
PRESENTATION: The visual appeal, organization and structure of the exhibit make visitor interpretation easy					
The overall graphic appearance of the exhibit fits to the theme					
The overall graphic appearance of the exhibit facilitates the understanding of the message					
EFFECT: The exhibit attracts visitors, holds their attention, and teaches the intended message.					
The exhibit is engaging; it attracts visitors and holds their attention					
The exhibit changes visitors' perspectives by enriching what they already know, teaching them something new, changing their ideas or feelings about the topic, or motivating them to action					

Adapted from D'Acquisto, Linda. (2006). Learning on display: Student-Created museums that build understanding. Alexandria, VA: Association for Supervision & Curriculum Development. pp. 116-117

Total score: _____

What do you elect as the most positive aspect of the exhibit and why?

What do you elect as the least positive aspect of the exhibit and why?

How could we improve? List one or two aspects