IDENTITIES

Enlightening
Interdisciplinarity
in STEM
for Teaching

Biofuel activity

(positive and negative feedback)

Explorer Activity

Co-funded by the
Erasmus+ Programme
of the European Union

Grant Agreement n°2019-1-IT02-KA203-063184

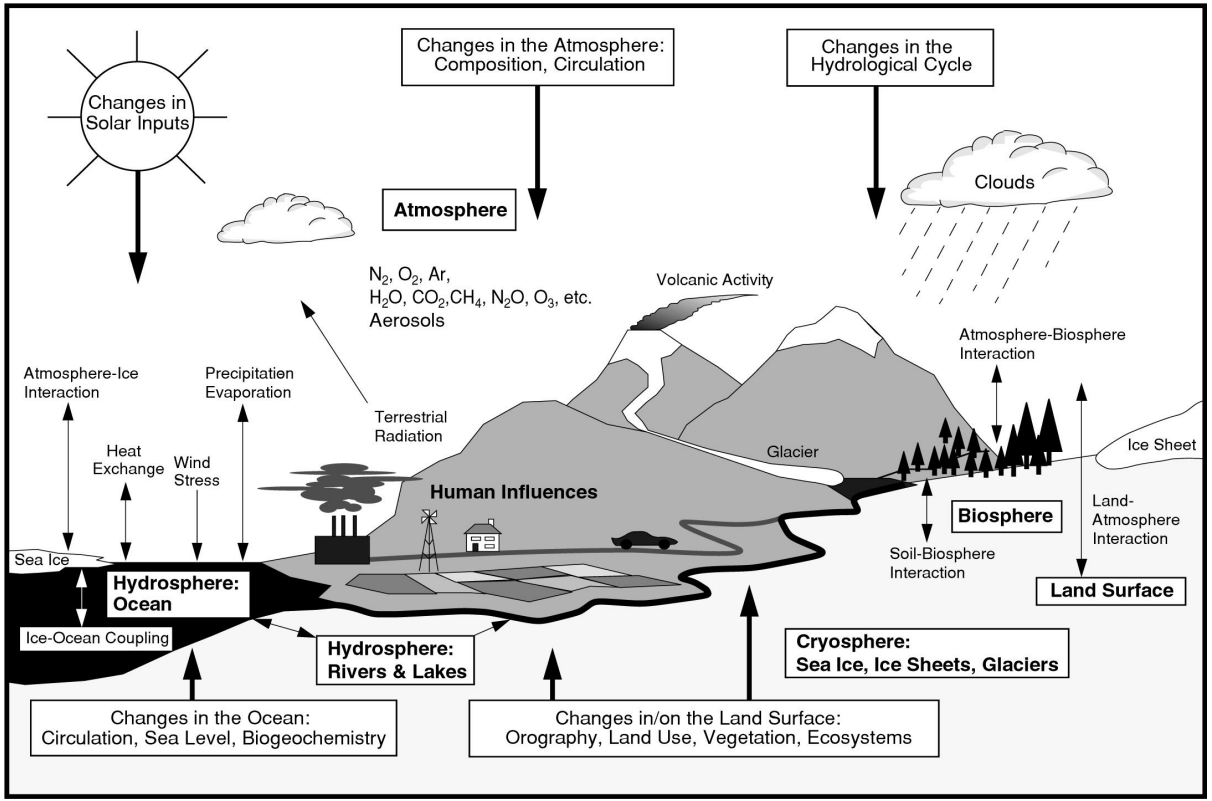
IDENTITIES

Enlightening
Interdisciplinarity
in **STEM** for Teaching

«The leading thread of the module»

"Climate Change is a complex STEAM theme, that intersects science and society and that, if it properly addressed at school, it can be a source of knowledge, from which a student can be guided to develop systemic thinking, skills of embracing ambiguity and uncertainty, competences of managing the tension between the need to feel at home and explore the unknown …"

Climate is a complex System



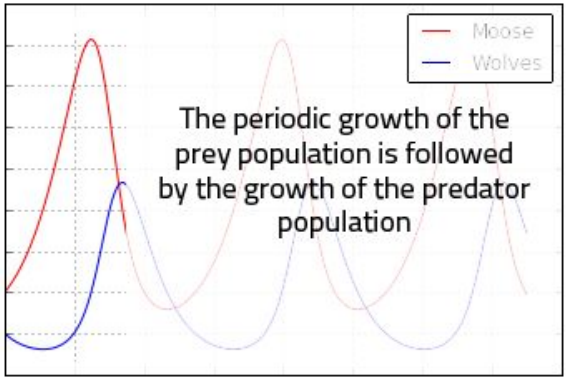
(Picture taken from WG1-IPCC report, 2001)

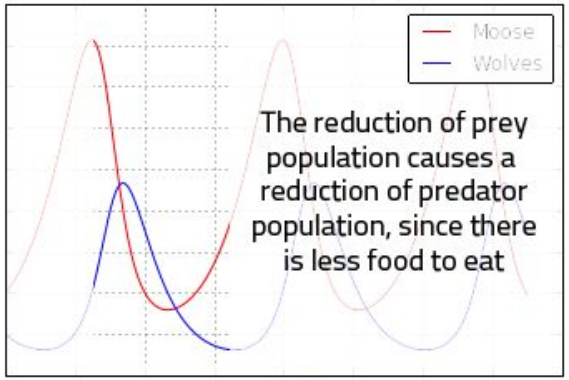
A complex system can be defined **complex** because:

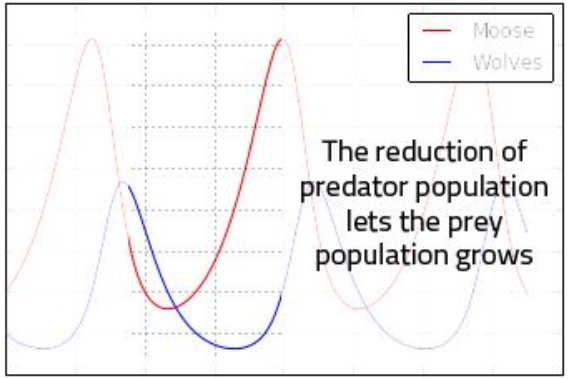
1) many processes are in place, described by many parameters
2) some of these processes are not linear
3) the processes influence each other
4) …

Within the climate system it often happens that the variation of one parameter influences another which in turn has an impact on the first.

When this happens, the system is said to follow a **circular causality** (**feedback loop**).







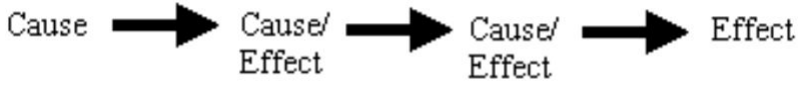
… the predator-prey dynamic

$$\frac{dx(t)}{dt} = ax(t) - by(t)x(t)$$

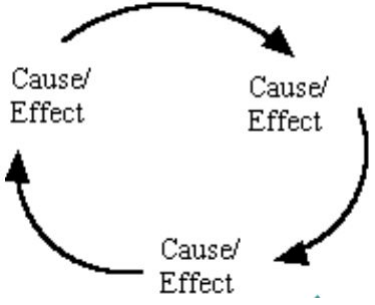
$$\frac{dy(t)}{dt} = cx(t)y(t) - dy(t)$$

From Linear to Circular Causality

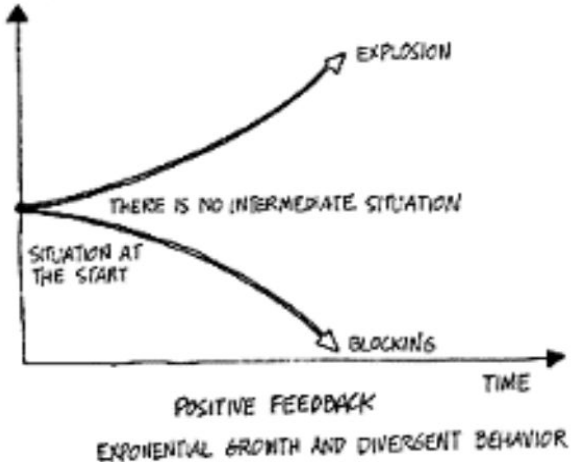
- TheLotka-Volterra model suggests that a linear model of causality is not effective for dealing with complex systems



- We have to introduce circular causality: the cause-effect relationship can be thought as a **circular loop**

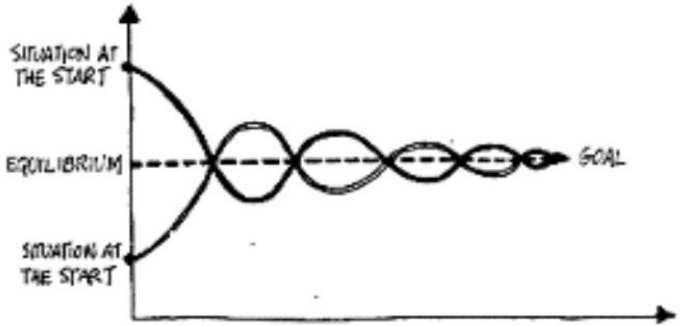


Feedback is an element of circular causality where the last effect of the causal chain returns at the first cause <u>amplifying</u> it (**positive feedback**) or <u>softening</u> it (**negative feedback**).



POSITIVE FEEDBACK

EXPONENTIAL GROWTH AND DIVERGENT BEHAVIOR



NEGATIVE FEEDBACK

MAINTENANCE OF EQUILIBRIUM AND CONVERGENCE

http://ed.ted.com/lessons/feedback-loops-how-nature-gets-its-rhythms-anje-margriet-neutel#watch

What does it means the sentence:

"feedback is what makes everything work" *?*

Positive and negative feedback are powerful forces that shape the behaviour of all biological systems.

Negative feedback provides **stability**.

Positive feedback stimulates **change** and is responsible for the sudden appearance of environmental problems and many other rapid changes in the world around us.

An example of feedback in the climate system: «Arctic feedback»

1. The surface of the ice varies during each year, in response to meteorological phenomena: it has a maximum at the end of the winter months and a minimum at the end of the warm period (around the month of September)
2. In the ice-covered region, much of the solar radiation is reflected back into space; in areas not covered, solar radiation penetrates the Arctic ocean, is absorbed and warms the ocean (the first 150 m)
3. The increase in water temperature facilitates the melting of the ice (**positive feedback**)
4. A few years ago, much of the Arctic ice was produced the previous year; this is a new fact which implies that the volume of Arctic ice is also shrinking fast.

Columbia Glacier c. 1980

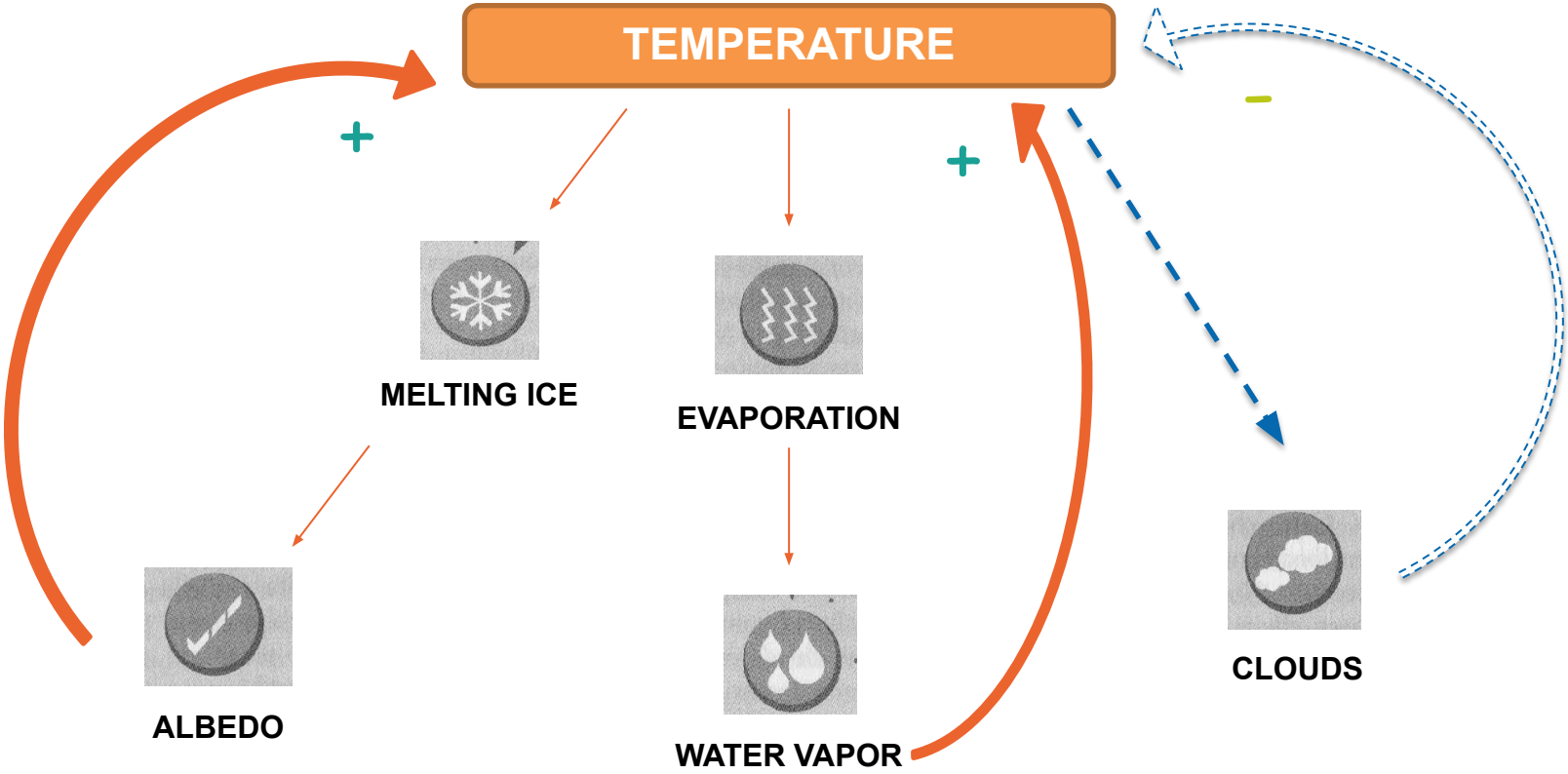
Columbia Glacier 2005

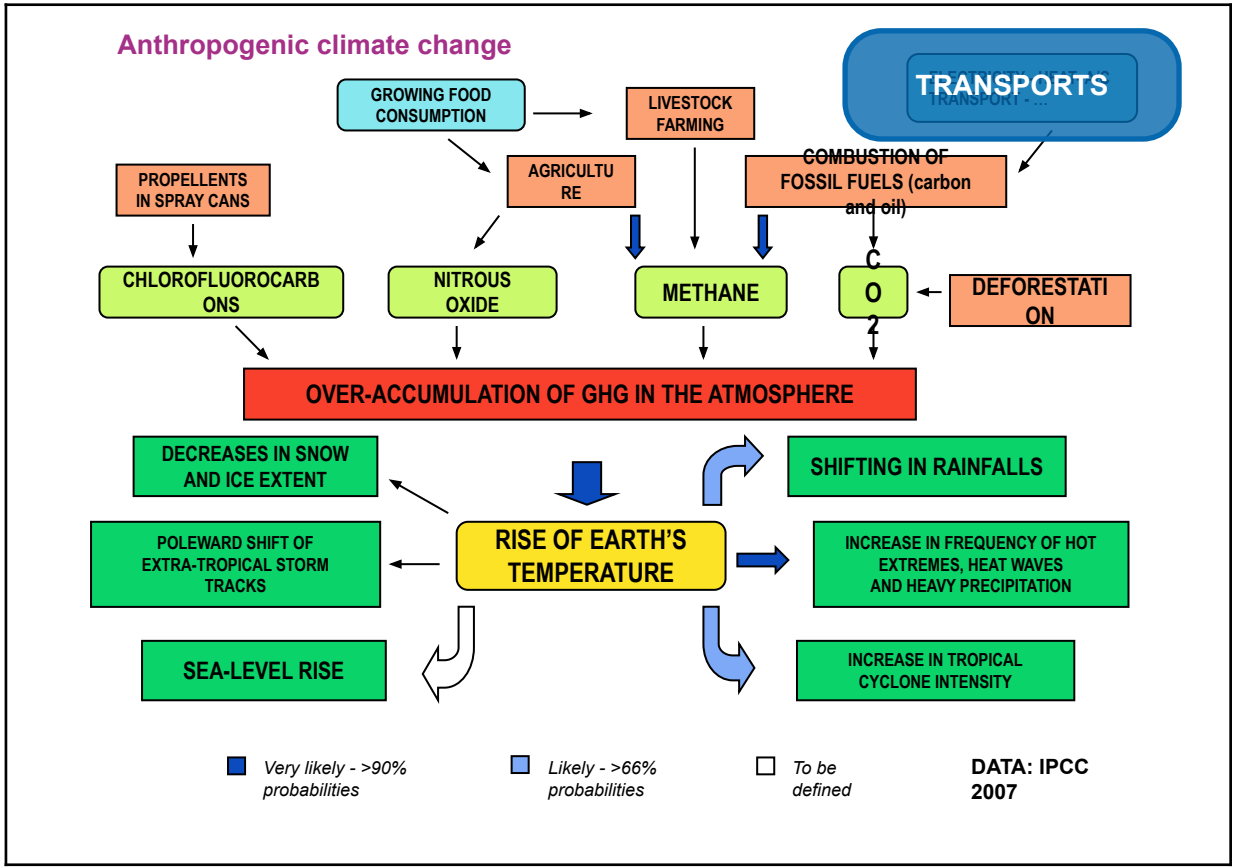
Arapaho Glacier 1898

Arapaho Glacier 2003

The Columbia Glacier flows down from the Chugach Mountains and into Prince William Sound about 40 miles west of Valdez, Alaska. Since the Columbia began retreating around 1980, the terminus has retreated approximately 15 kilometers. The Arapaho Glacier is in the Rocky Mountains in, Colorado.

Examples of three kind of feedback within climate system





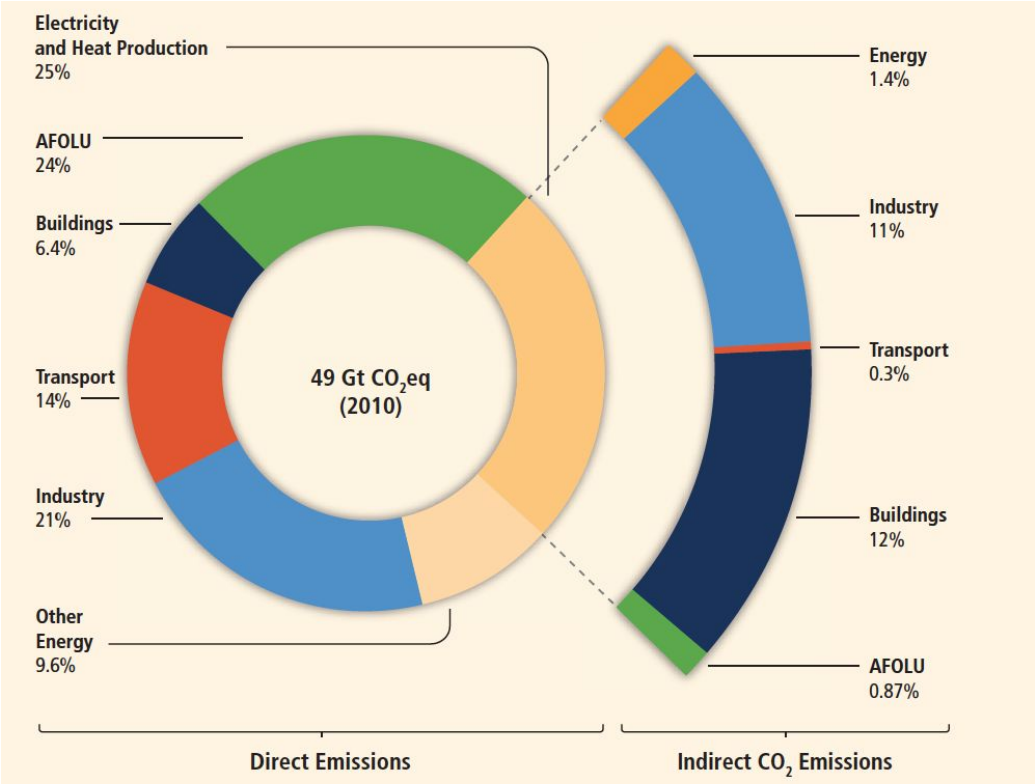
CAUSE

EFFECT

Greenhouse Gas Emissions by main Economic Sectors

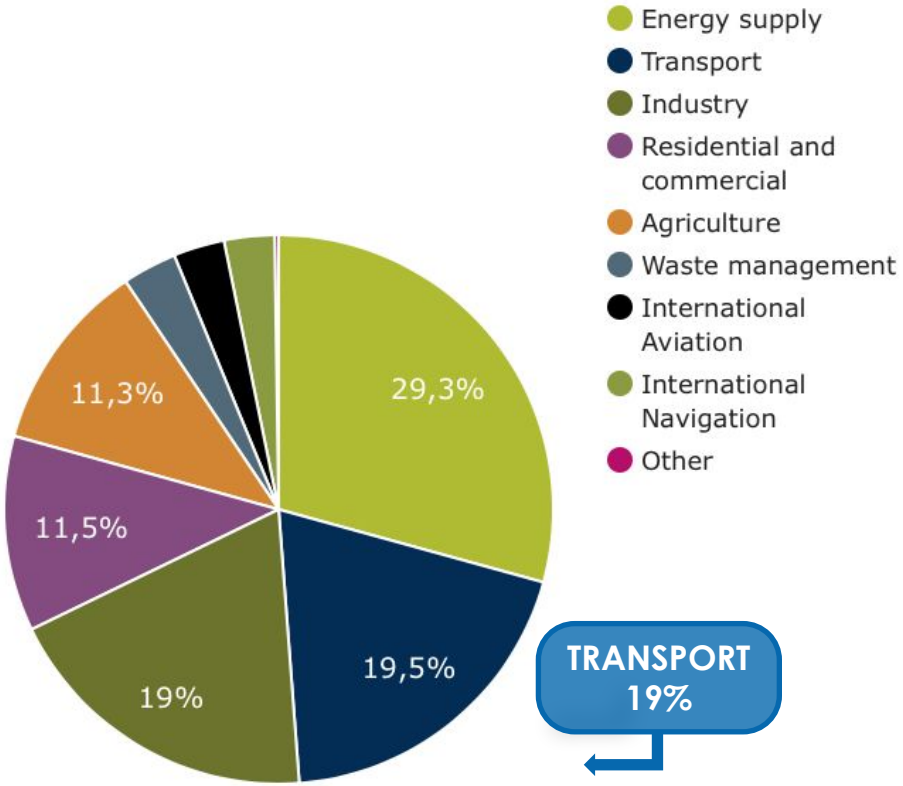
(IPCC 2014, data 2010)

TRANSPORT 14%



Dati: IPCC AR4 – WGIII (data 2010)

Greenhouse Gas Emissions by main Economic Sectors
(IPCC 2018, data 2014)

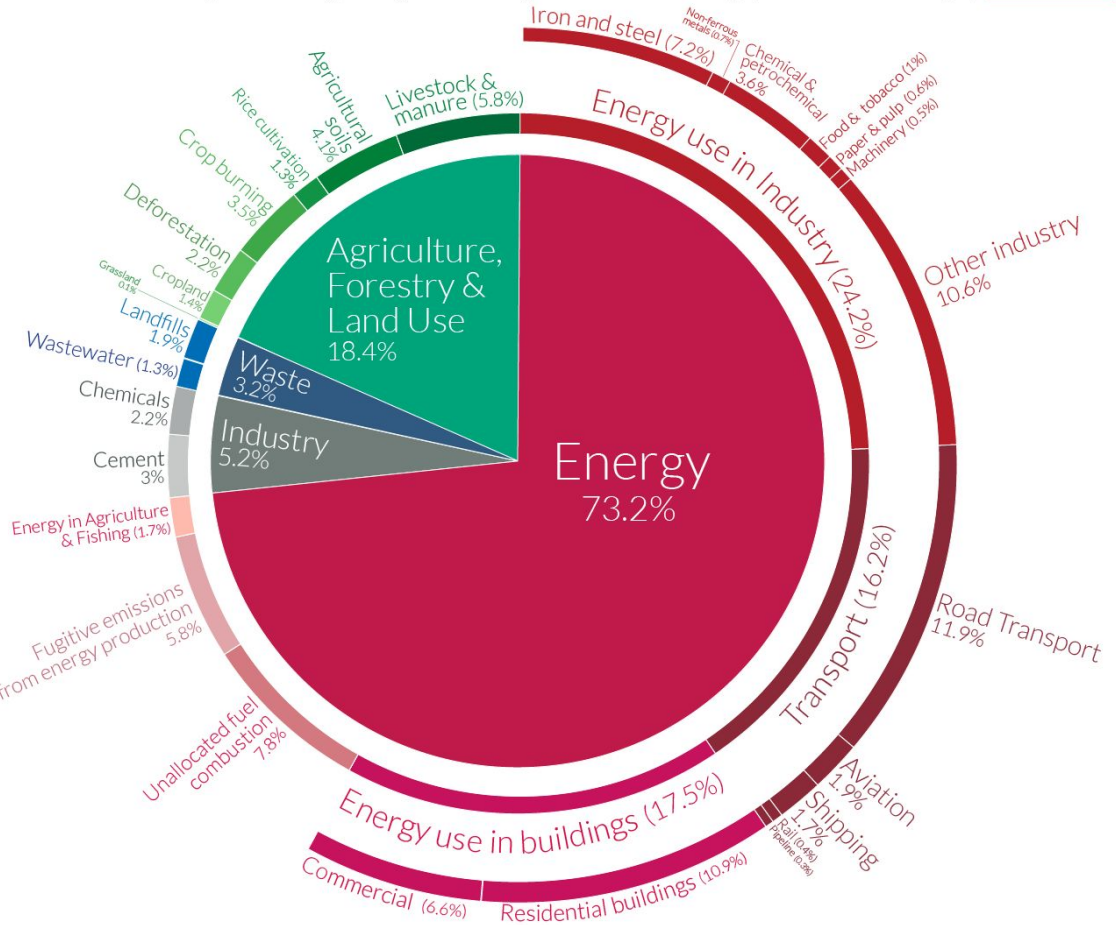


Dati: IPCC AR5 – WGIII (data 2014)

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



Greenhouse Gas Emissions by main Economic Sectors

(data 2016)

Source: Climate Watch, the World Resources Institute (2020).

I SEE

It's your time to imagine the futures

I SEE

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Use and Production of Bio-Fuels: Biodiesel

Use and Production of Bio-Fuels: Biodiesel

[…]

As to the reduction of emissions related to the mechanism of production of the biomass itself, using biodiesel brings about a reduction of two well-known greenhouse gases emission, CO (50%) and CO_2 (78,45%), since the carbon emitted during combustion is the one already existing in the atmosphere, fixed by vegetables during their growth. The carbon is not, as is the case with gasoline, the offset which has been sedimented under the earth's crust from time immemorial.

Besides, a 71% reduction of the emission of aromatic hydrocarbons is also reported; these compounds, that are naturally present both in oil and in carbon are extremely toxic to the environment, human beings and animals as well as to flora and are numbered among the substances responsible for the ozone hole.

Furthermore using biodiesel, sulfur dioxide (SO_2) emissions are almost totally eliminated; yet, these, once entered the atmosphere, interact with oxygen and water vapor and form sulfuric acid[4].

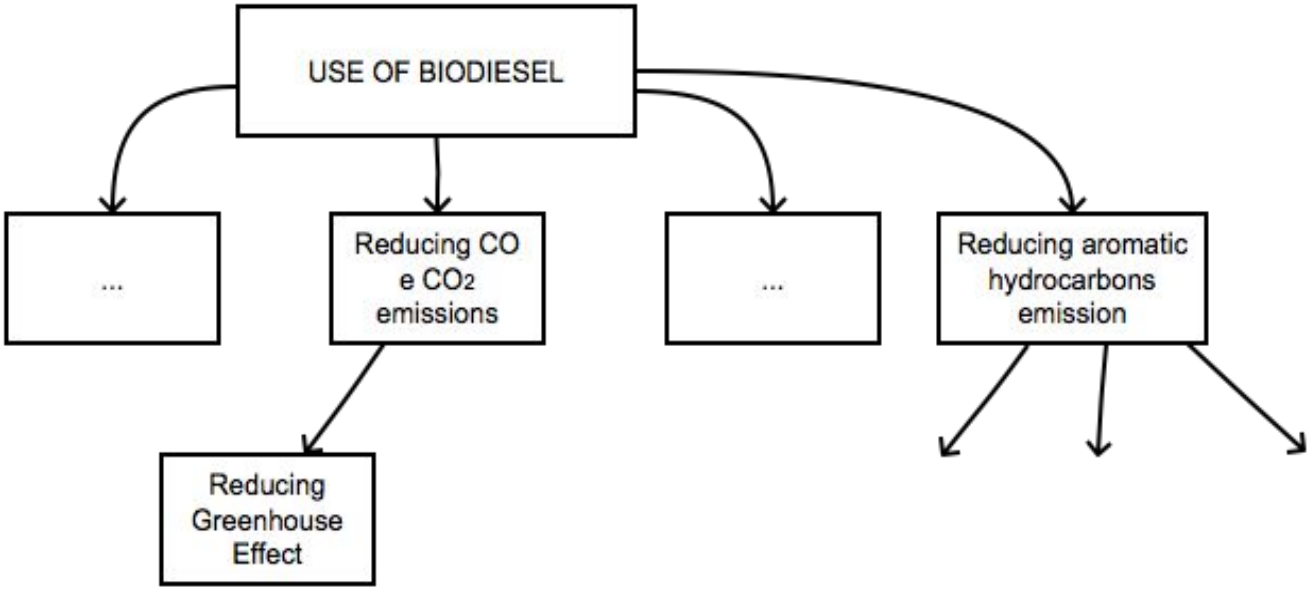
[…]

An example of effect of the production process is the following: he conversion of terrains destined to the growing of plantations into areas where biodiesel is produced implies an increase of the price of raw materials in the Third World (compared to high transport costs of food imported from other Countries), resulting in the increase of food insecurity[7] both from the point of view of availability and of access to food.

[…]

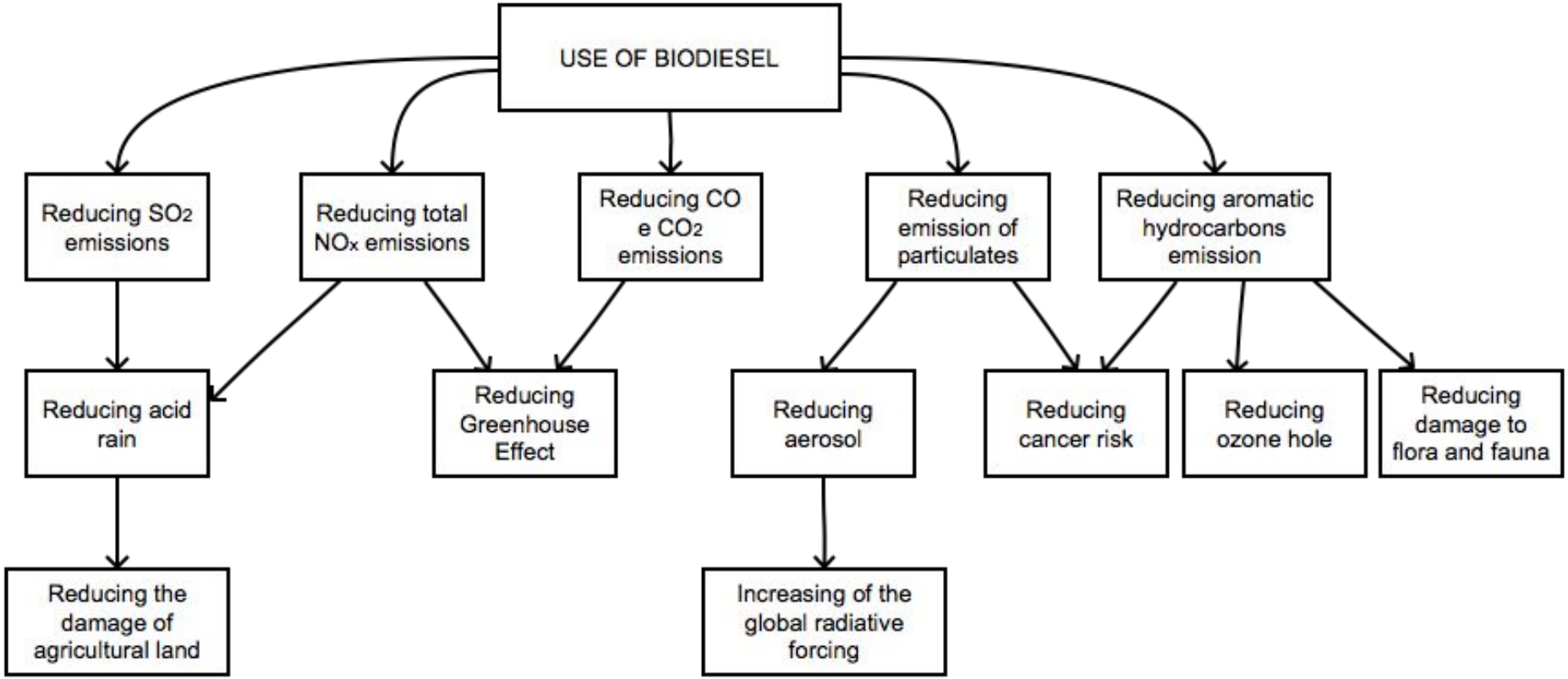
TASK N.1 (10 min)

Read the part of the text titled **“Use of Biodiesel”** and draw the map by completing it and adding the boxes you think are necessary.

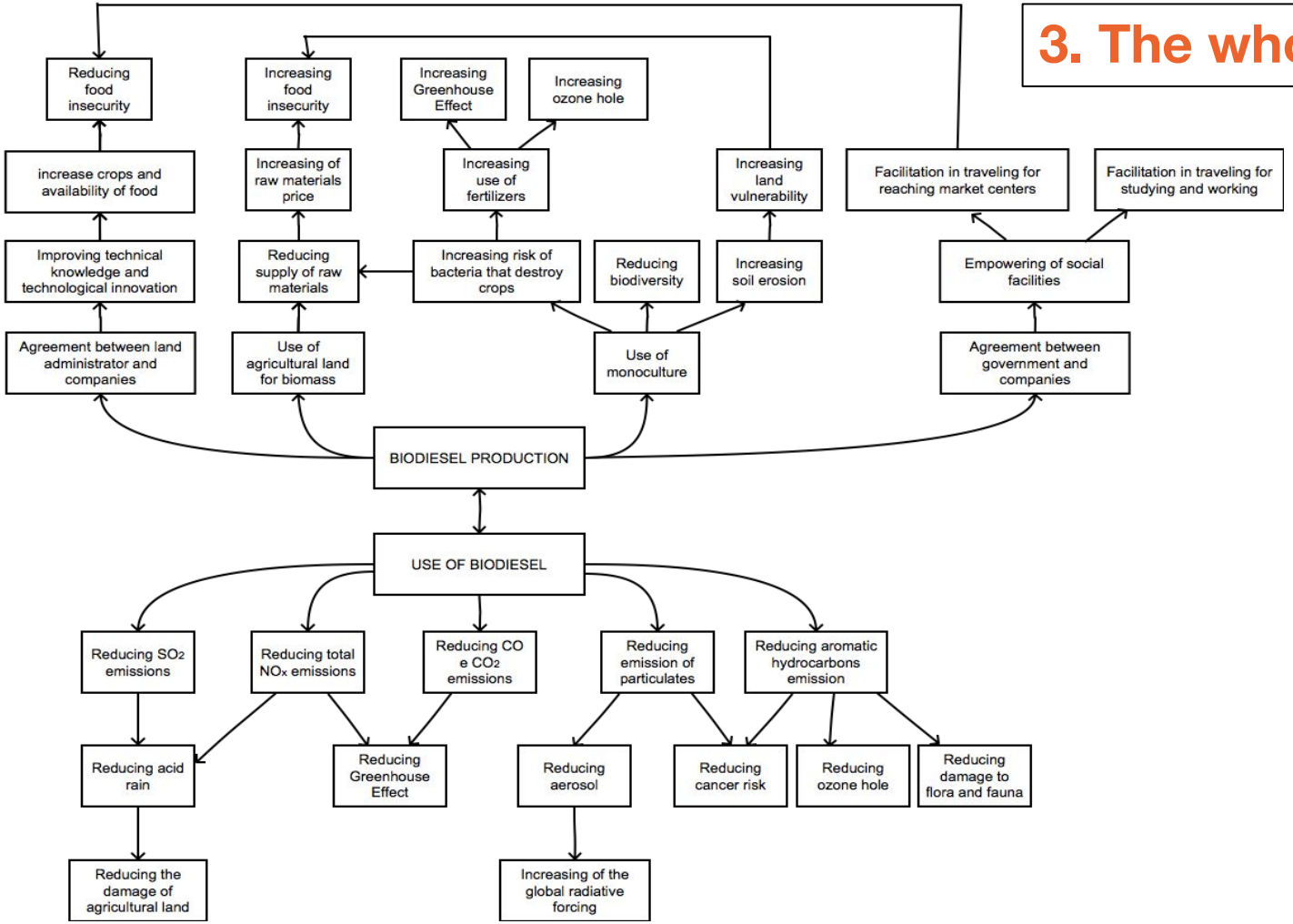

USE OF BIODIESEL
...
Reducing CO e CO_2 emissions
...
Reducing aromatic hydrocarbons emission
Reducing Greenhouse Effect

TASK N.2 (5 min)

Here the complete map built on the text. Please, compare it with the map you have drawn and discuss differences and similarities.


USE OF BIODIESEL
Reducing SO_2 emissions
Reducing total NO_x emissions
Reducing CO e CO_2 emissions
Reducing emission of particulates
Reducing aromatic hydrocarbons emission
Reducing acid rain
Reducing Greenhouse Effect
Reducing aerosol
Reducing cancer risk
Reducing ozone hole
Reducing damage to flora and fauna
Reducing the damage of agricultural land
Increasing of the global radiative forcing

3. The whole map



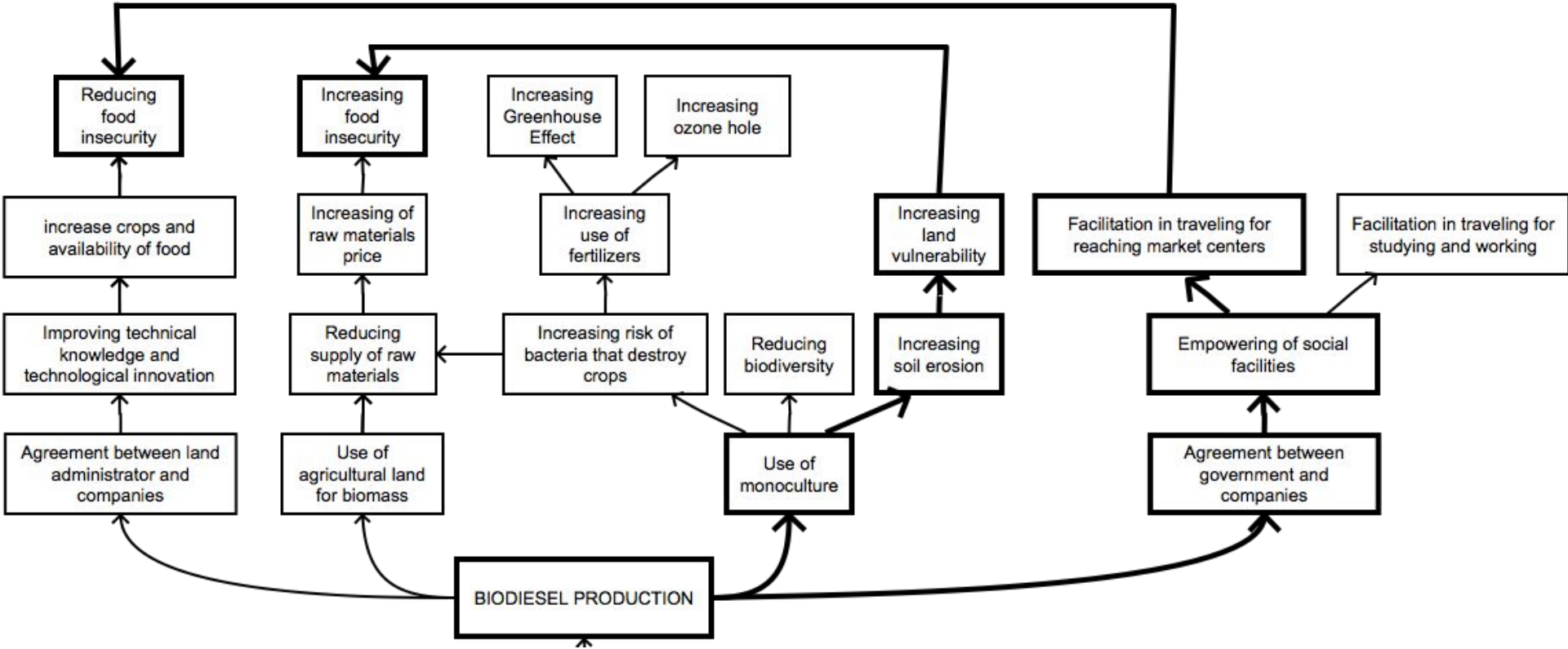
TASK N.4 (10 min)

Read the text about the **production of biodiesel** and compare it with the map.

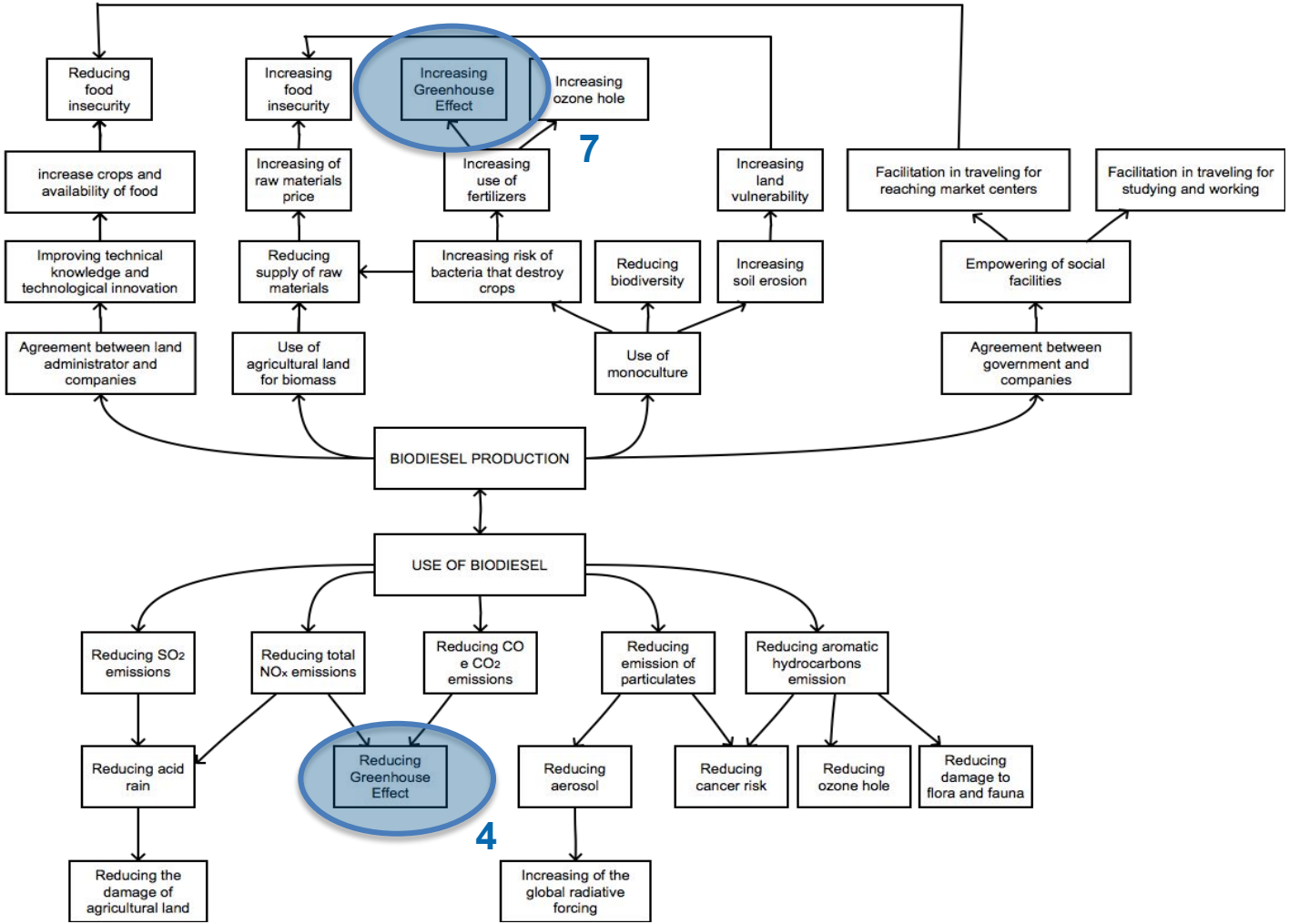
Explain the causal reasoning represented by the **arrows** that go from the *biodiesel production* to the *increasing/reducing of food insecurity* through:

i) the increasing of land vulnerability;

ii) the facilitation in travelling for reaching market centres.


Reducing food insecurity
Increasing food insecurity
Increasing Greenhouse Effect
Increasing ozone hole
increase crops and availability of food
Increasing of raw materials price
Increasing use of fertilizers
Increasing land vulnerability
Facilitation in traveling for reaching market centers
Facilitation in traveling for studying and working
Improving technical knowledge and technological innovation
Reducing supply of raw materials
Increasing risk of bacteria that destroy crops
Reducing biodiversity
Increasing soil erosion
Empowering of social facilities
Agreement between land administrator and companies
Use of agricultural land for biomass
Use of monoculture
Agreement between government and companies
BIODIESEL PRODUCTION

This is a complex map …


Reducing food insecurity
Increasing food insecurity
Increasing Greenhouse Effect
Increasing ozone hole
7
increase crops and availability of food
Increasing of raw materials price
Increasing use of fertilizers
Increasing land vulnerability
Facilitation in traveling for reaching market centers
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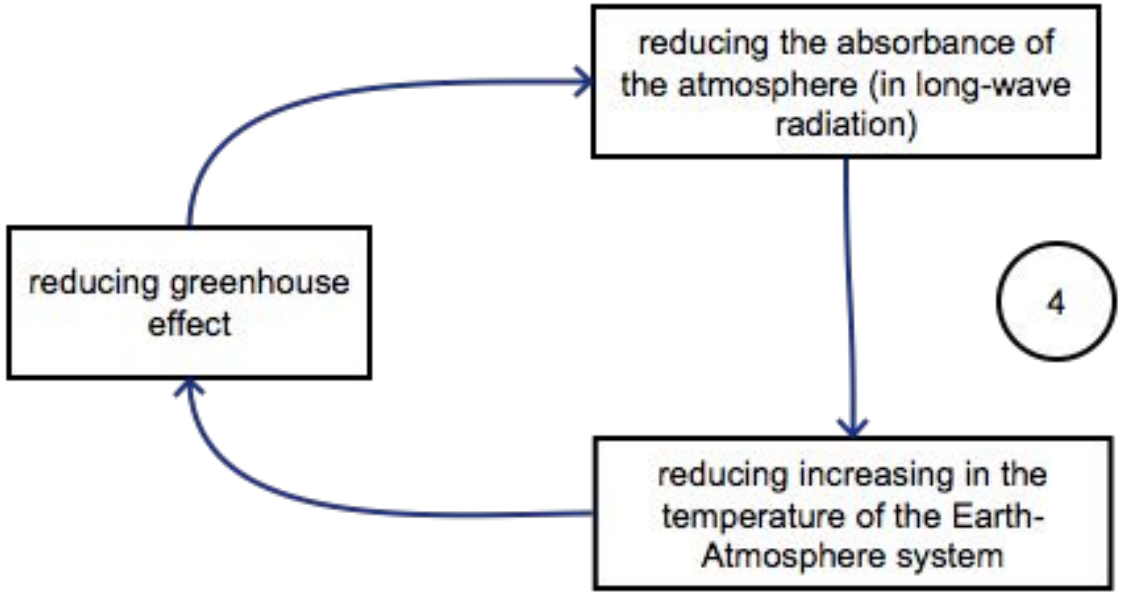
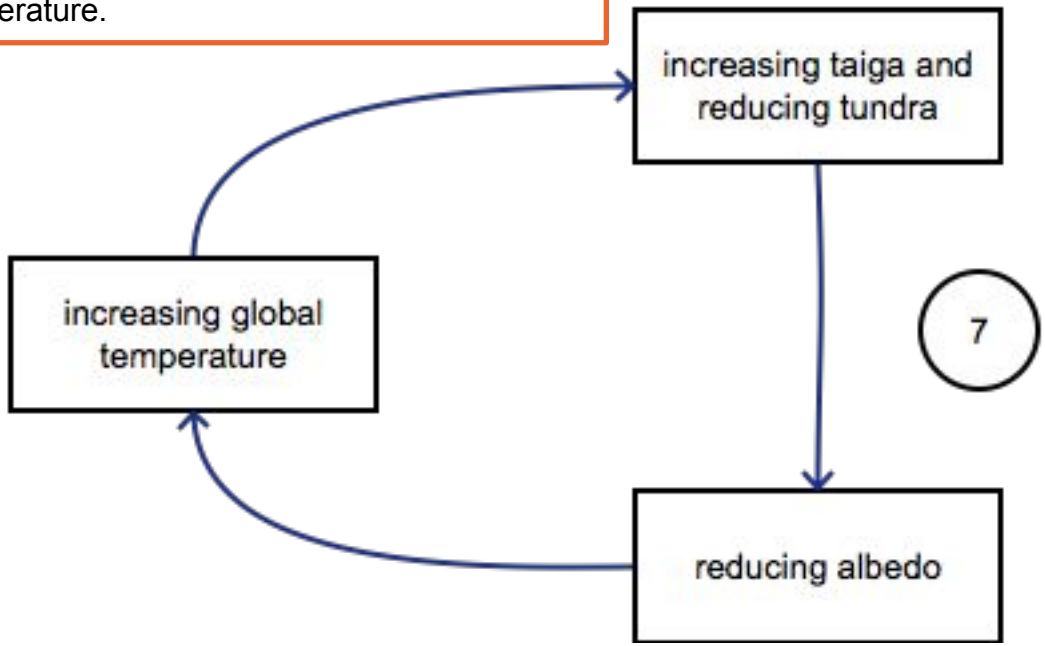
BIODIESEL PRODUCTION
USE OF BIODIESEL
Reducing SO2 emissions
Reducing total NOx emissions
Reducing CO e CO2 emissions
Reducing emission of particulates
Reducing aromatic hydrocarbons emission
Reducing acid rain
Reducing Greenhouse Effect
4
Reducing aerosol
Reducing cancer risk
Reducing ozone hole
Reducing damage to flora and fauna
Reducing the damage of agricultural land
Increasing of the global radiative forcing

4 - Reduction of CO and CO2 emissions results in a decrease of GHE, hence a decrease in atmospheric absorbance with respect to IR radiation – longwave radiation (corresponding to radiation from earth), which results in a reduction of the increasing of the temperature of the earth-atmosphere system and, consequently, a further reduction of the greenhouse effect (through a lower evaporation of water vapor, one of the worst greenhouse gases).



7 - The increase in global temperature also involves an expansion of the taiga and a decrease in the tundra; because the taiga has an albedo lower than the tundra, since the taiga is dark green and absorbs much radiation while the tundra has a bright color and absorbs less; so, the reduction of the albedo results in an increasing of of the temperature.

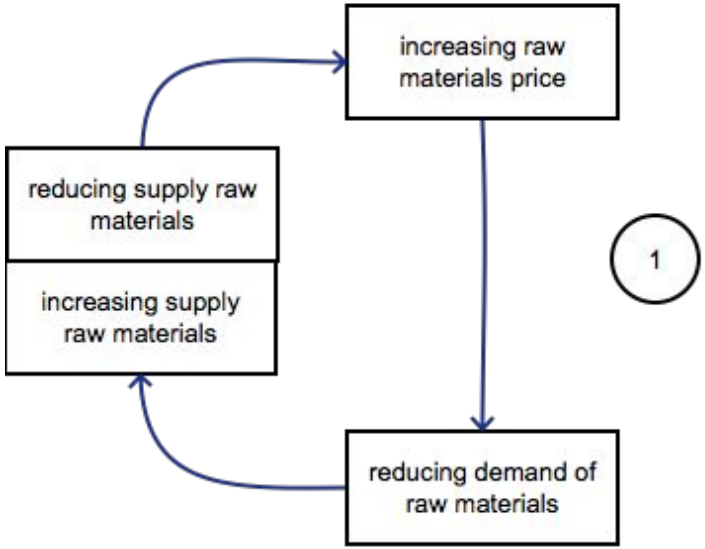


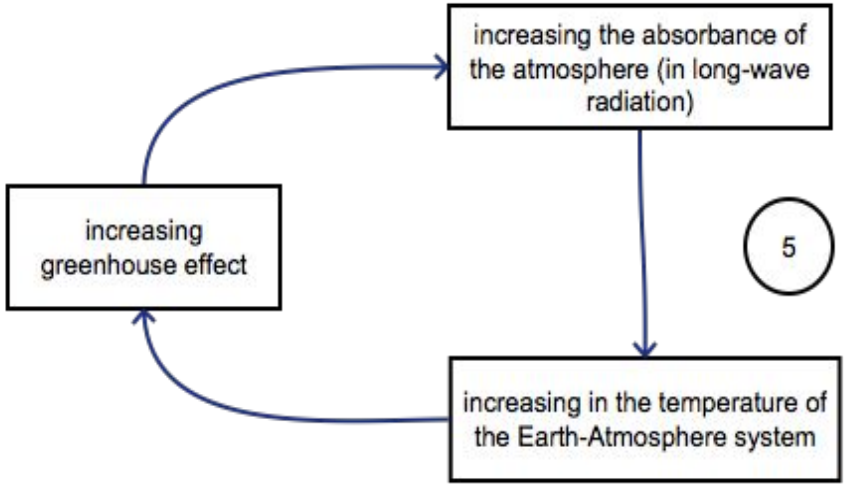
TASK N.5 (20 min)

a) Here two examples of feedback loops. See the schemas, analyse the loops, explain them, say if they are positive or negative and situated them in the map.

b) Looking at the whole map, choose an area and try to identify and/or invent other two feedback loops different from the example you already have (better if you would able to invent one example of positive feedback and one of negative feedback).

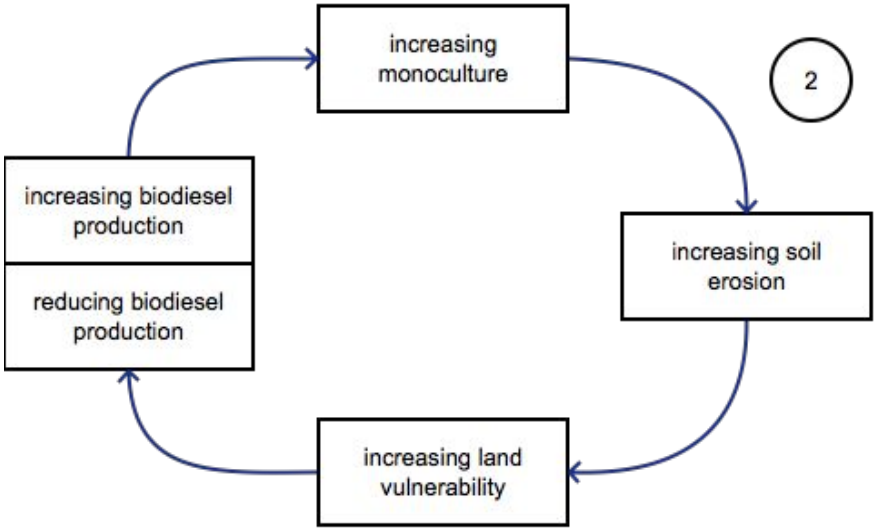
c) At the end of this exercise, share and discuss your work with the other groups.

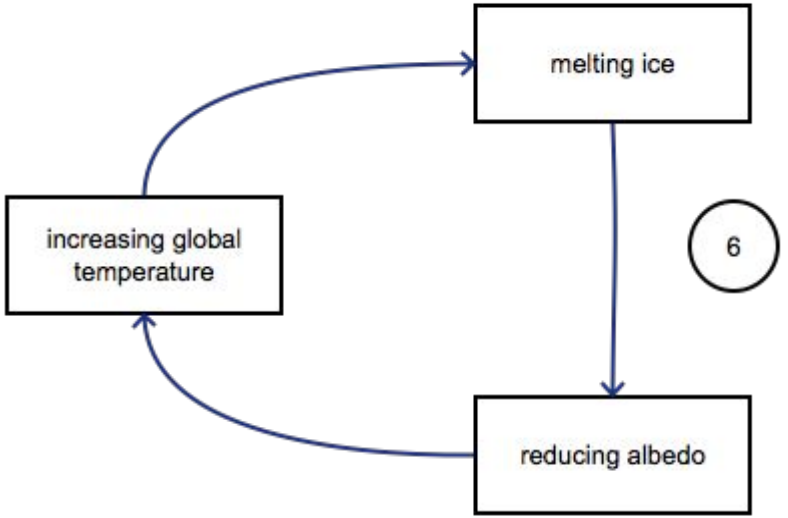




1 - The use of cultivated land for biomass reduces those available for cultivation; As a result, negative feedback is triggered because the low supply of raw materials entails an increase in their prices, which reduces demand by increasing the supply. This results in a damping of the root cause of the cycle.

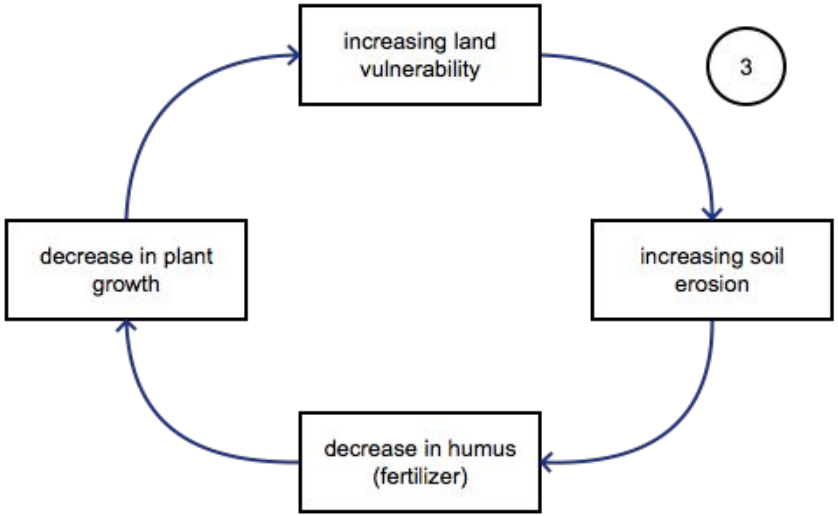
5 - Reduction of fine dust emissions results in a reduction of atmospheric aerosol, resulting in an increase in atmospheric absorbance, and consequently there is an increase in global temperature and greenhouse effect; This latter effect further contributes to the increase in atmospheric absorbance.

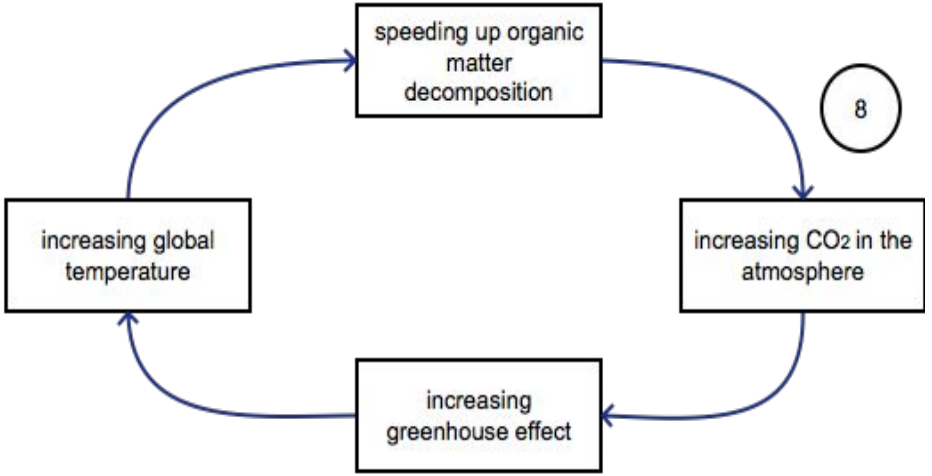




2 - The use of monoculture triggers a positive feedback on soil progressive erosion, which results in a degradation of cultivated land and, necessarily, a reduction in biodiesel production.

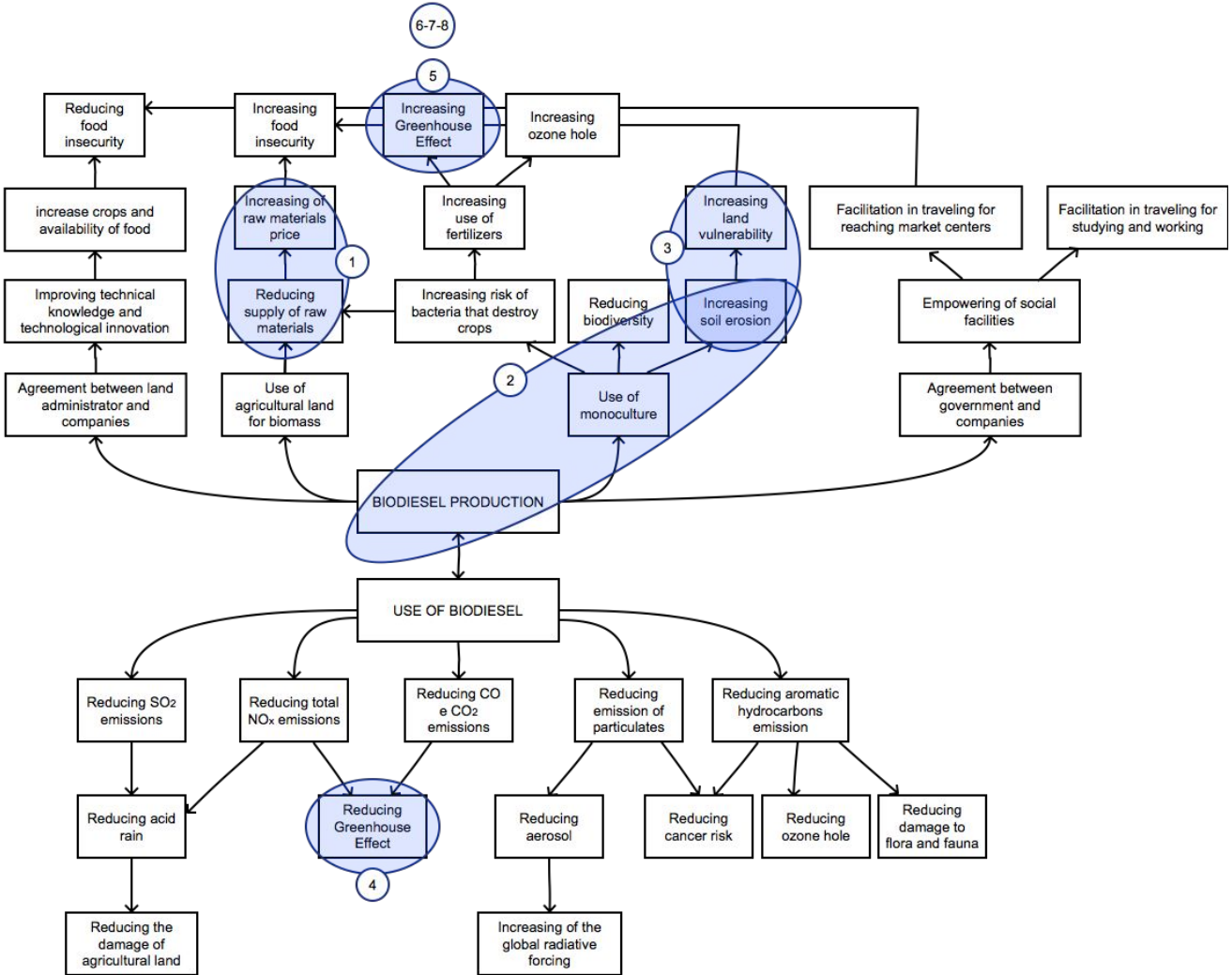
6 - The increase in global temperature involves the melting of the ice and, since the ice albedo is much greater than the albedo of water (in other words, ice is more white than water, reflecting more radiation than all Water that absorbs more), there is a further increase in temperature.





3 - The use of single-cultivation has an increase in soil erosion, resulting in a decrease in humus as a fertilizer, which results in a reduction in plant growth and an increase in soil vulnerability, which again results in An increase in soil erosion, thus enhancing the root cause.

8 - The rise in temperature has as a consequence a faster speed of decomposition of the organic substance to the ground, a substance which, however, can not be held to the ground due to the high temperature and is therefore released into the atmosphere; An increase in CO2 in the atmosphere generates an increase in the greenhouse effect and therefore triggers the feedback cycle leading to a further increase in temperature.


6-7-8
5
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Reducing aromatic hydrocarbons emission
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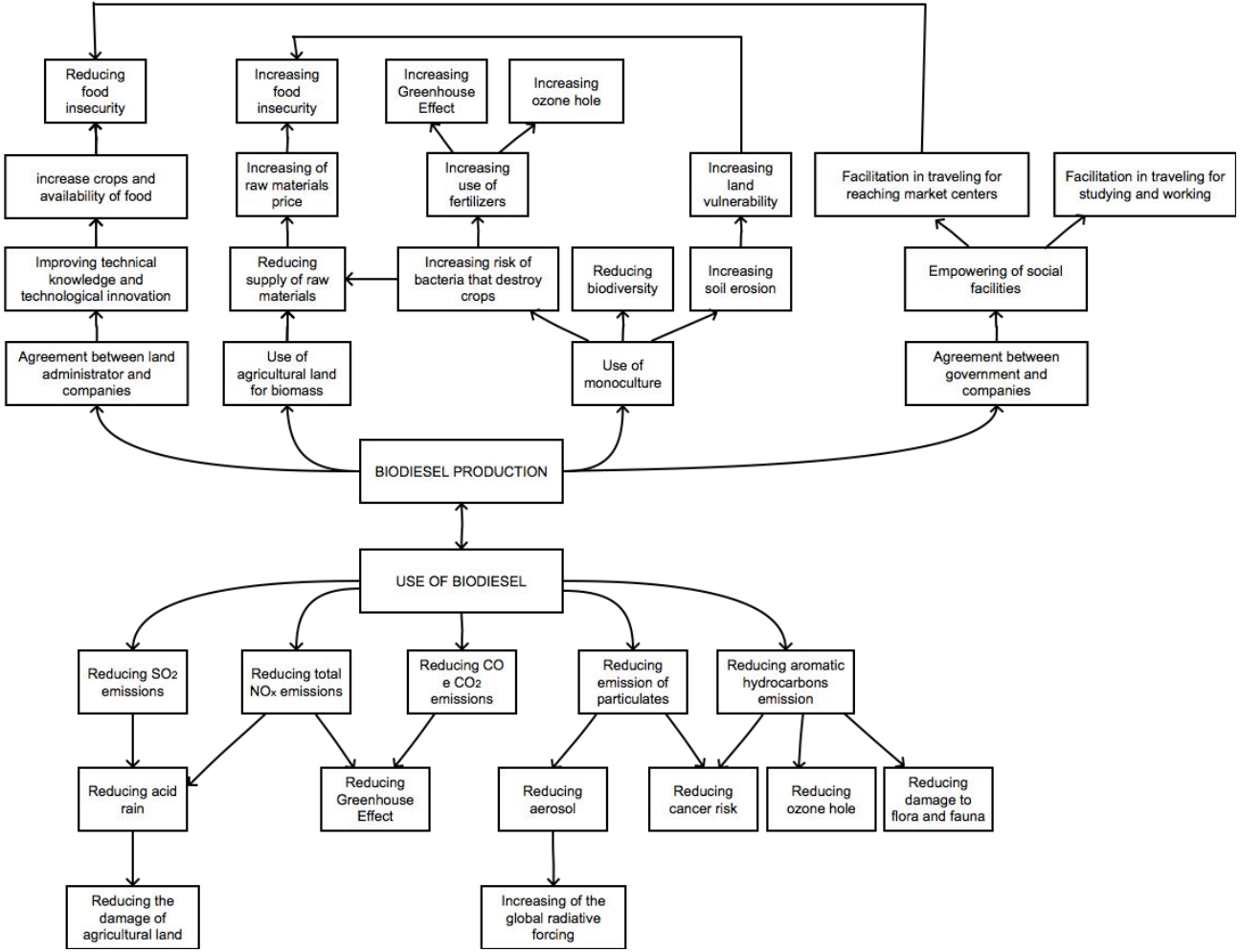
Reducing damage to flora and fauna
4
Reducing the damage of agricultural land
Increasing of the global radiative forcing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<u>Claim 1</u>: The biodiesel story exemplifies why climate change require us to change our ways of reasoning.

Let's discuss such a claim.

<u>Claim 2</u>: Through this activity you have been guided to build and to use a causal map to analyse a scientific text.

What is a causal map? In what sense can it be used as an analytic tool?

<u>Claim 3</u>: Imagine to be a decision maker …

How you would you embed the concept of positive and negative feedback for imagining/building/interpreting futures scenarios …?

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«The leading thread of the module»

"Climate Change is a complex STEAM theme, that intersects science and society and that, if it properly addressed at school, it can be a source of knowledge, from which a student can be guided to develop systemic thinking, skills of embracing ambiguity and uncertainty, competences of managing the tension between the need to feel at home and explore the unknown …"

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ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

UNIVERSITAT DE
BARCELONA

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

UNIVERSITÀ
DI PARMA

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Erasmus+ Programme
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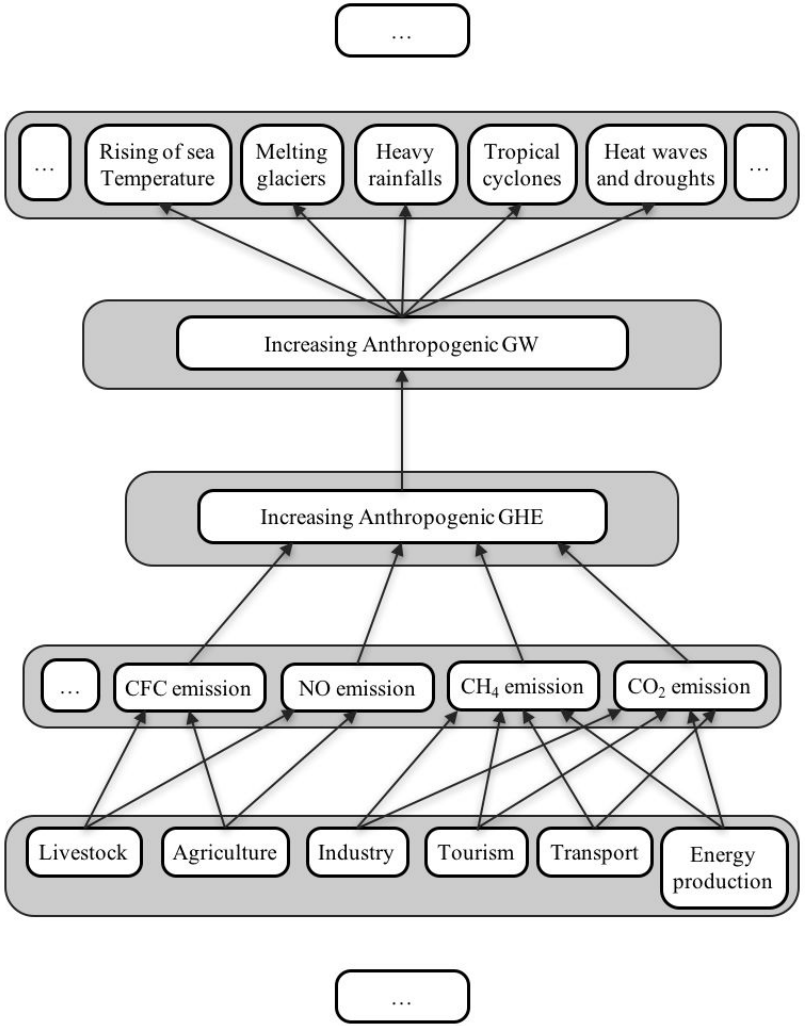
Grant Agreement n°2019-1-IT02-KA203-063184

Analysis of a scientific text, conversion into causal map

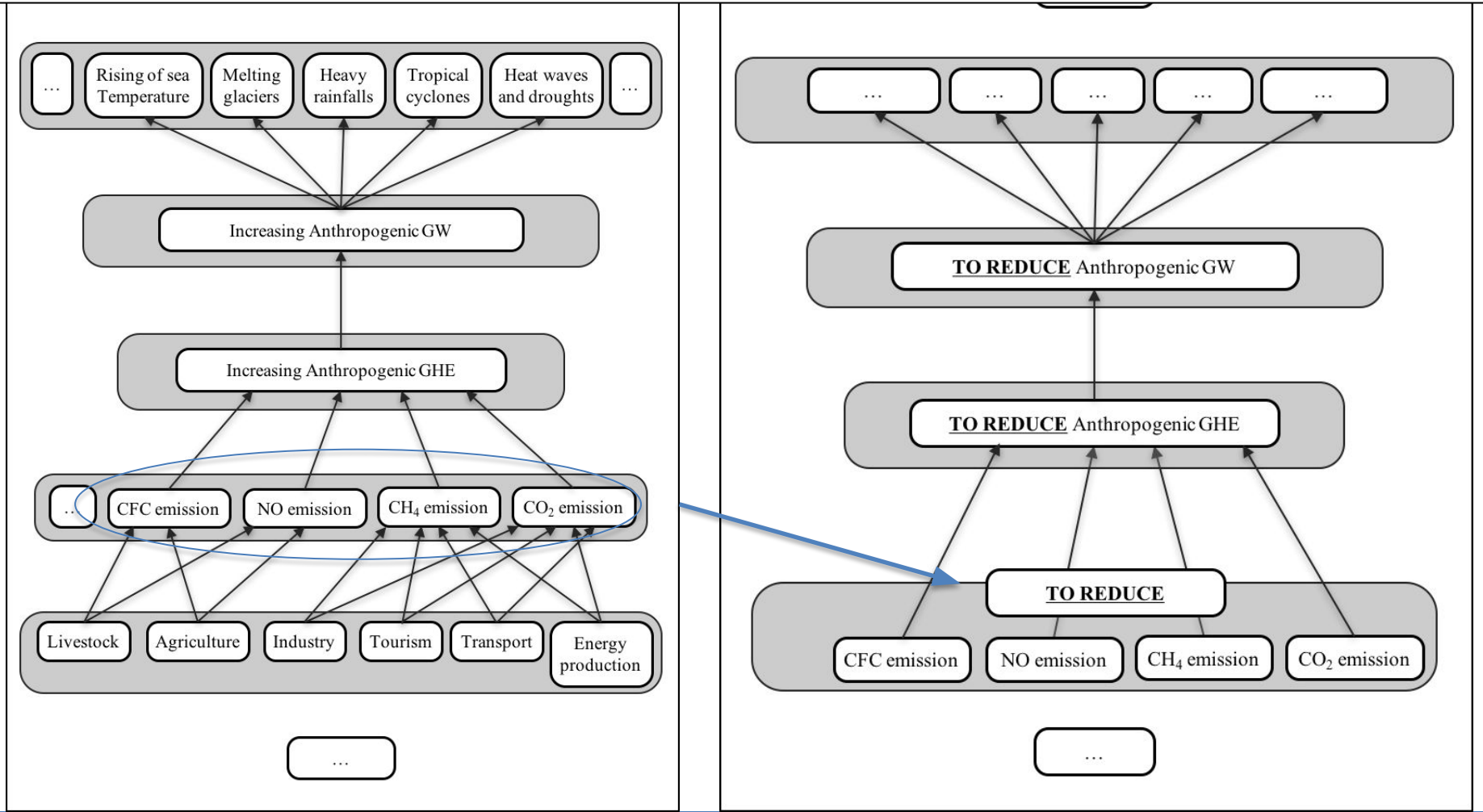
I. Construction of the ***Problem Tree***

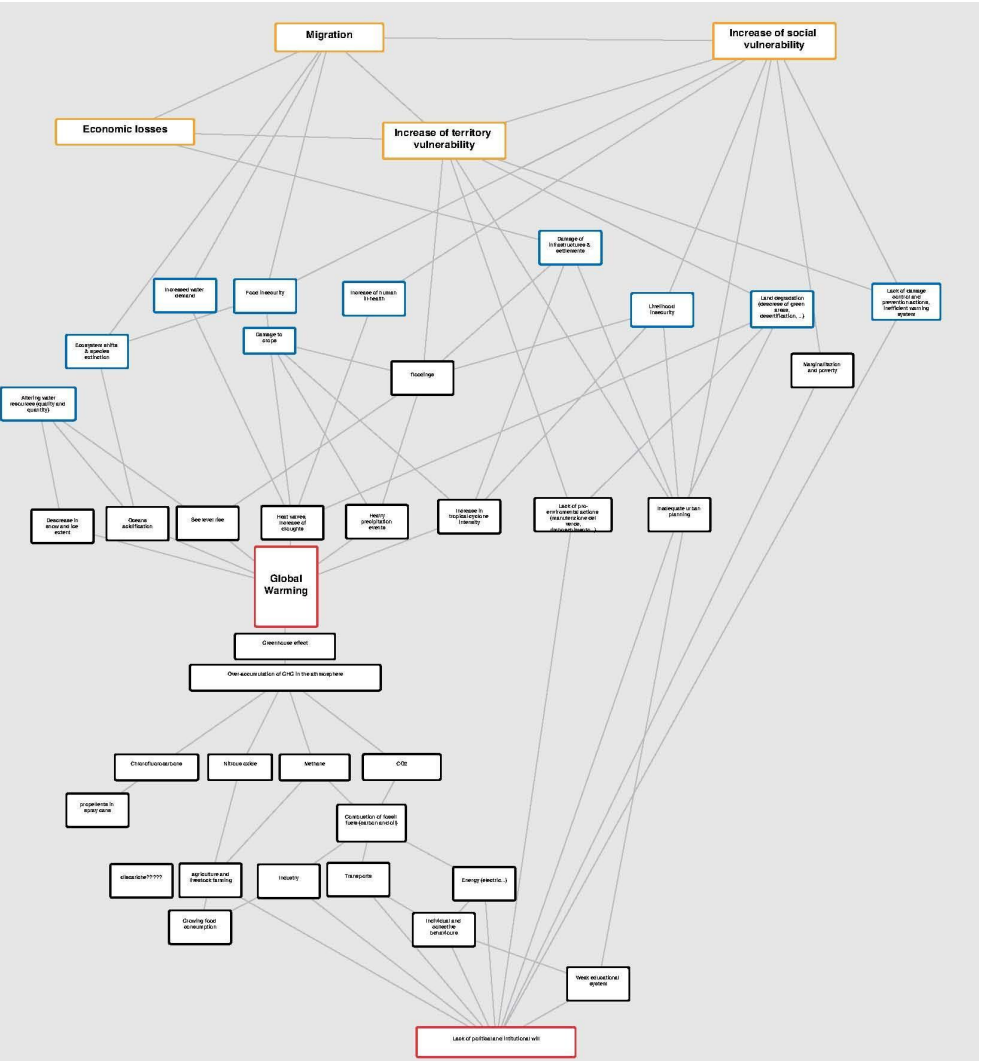
THE GLOBAL WARMING ISSUE

Global warming, in climatology, indicates an increase in the average temperature of Earth's surface and recorded in different phases of the climatic history of the Earth. The expression is now almost always used to mean heating due to the anthropogenic (i.e. human) contribution, decisive in the heating phase of the last 100 years. The fifth report of the *Intergovernmental Panel on Climate Change* (IPCC) in 2014 estimated that the average global surface temperature has increased by 0.85 [0.65-1.06] °C in the period 1880-2012. Most of the phenomena that cause the rise in temperature since the mid-twentieth century are considered, within the IPCC report, anthropogenic. These phenomena are responsible for an increase of the natural phenomenon of the greenhouse effect. The natural greenhouse effect is part of the complex of thermal equilibrium adjustment mechanisms of a planet (or satellite) surrounded by an atmosphere, which, if it contains certain gases called greenhouse gases, produces in fact the overall effect of mitigating the temperature the global average surface of the planet, isolating partially by large swings in temperature or that would subject the planet in their absence. To give an idea of the phenomena regarding the Earth, in the absence of greenhouse gases, by the equation of balance between in- and outgoing radiation is one which average surface temperature of the Earth would be of about -18 °C whereas, thanks to the presence of greenhouse gases, the actual value is about +14 °C, enabling life as we know it. The greenhouse effect that increases the natural greenhouse effect is that phenomenon due to the emission of greenhouse gases by human activities, including industry, agriculture, livestock, transport, power plants for civilian purposes. In particular industries, transport, energy production facilities and even tourism activities contribute to increasing emissions of carbon dioxide (CO2) and emissions from fossil fuels such as methane. Agriculture and livestock, that are more and more intensive activities because of the growing food demand, contribute most to the emission of nitrous oxide and methane. Most production of methane is in fact due to the fermentation of typical livestock manure, that also grew significantly, and the fermentation of crops to submergence (for example rice). To the list of greenhouse gases should be added the chlorofluorocarbons (CFC), the only man-made gas, mainly used in the production of spray cans. This type of cans, now banned from production in different countries, have been the subject of debate between eighty and two thousand years as they are considered responsible for the depletion of the ozone layer in the atmosphere. […]



II. Transformation of the *Problem Tree* in an *Objective Tree*





The text (and hence complete causal map), as well as the problem of GHGs emissions, includes:

- problems relating to political negotiations;
- urban, territory and social vulnerability,
- climate migrations,
- the lack of scientific literacy,
- insufficient citizenship engagement, and so on.