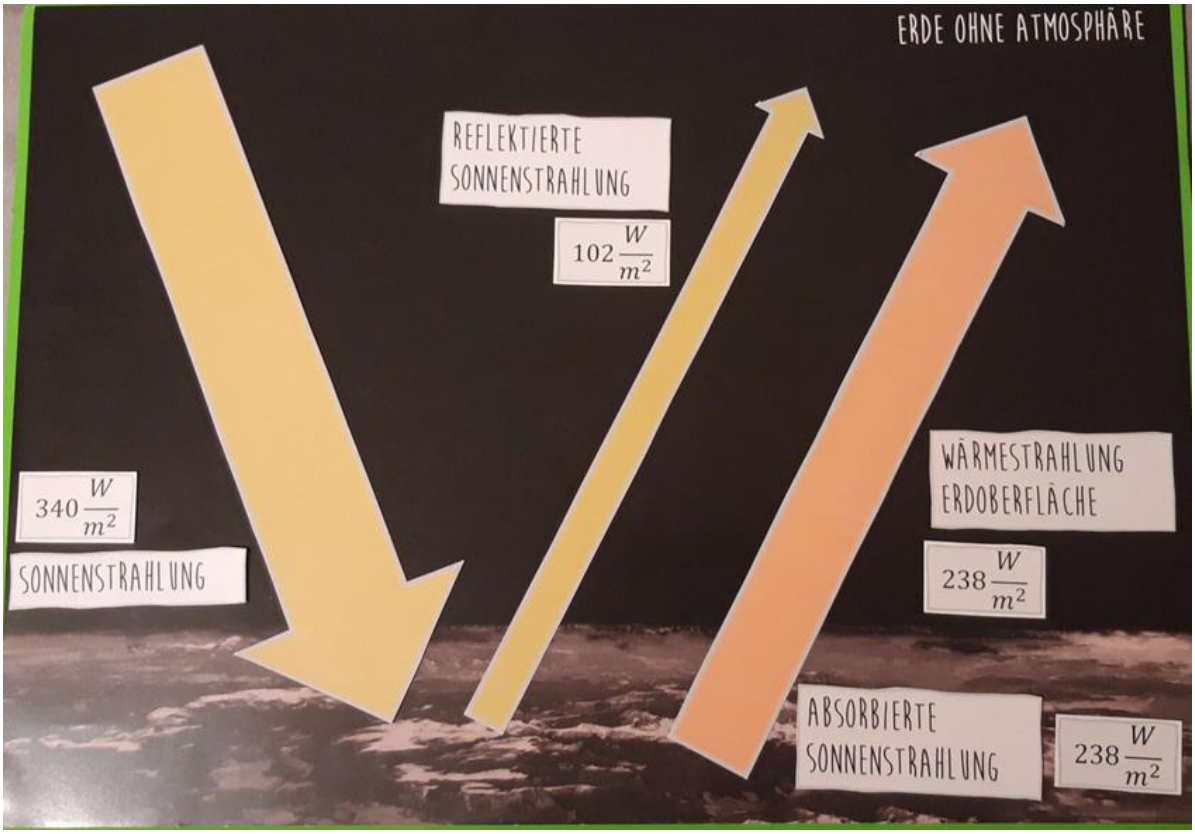
Activity 4 – The Keys of the Earth's temperature

What influence do greenhouse gases have on the Earth's temperature?

Moritz Strähle und Cecilia Scorza

Part 1: What would be the average temperature on an earth without atmosphere?

→ Placing arrows: Place the light grey bordered arrows and the light grey labels on the sheet "Earth with-out atmosphere" to match the background text.

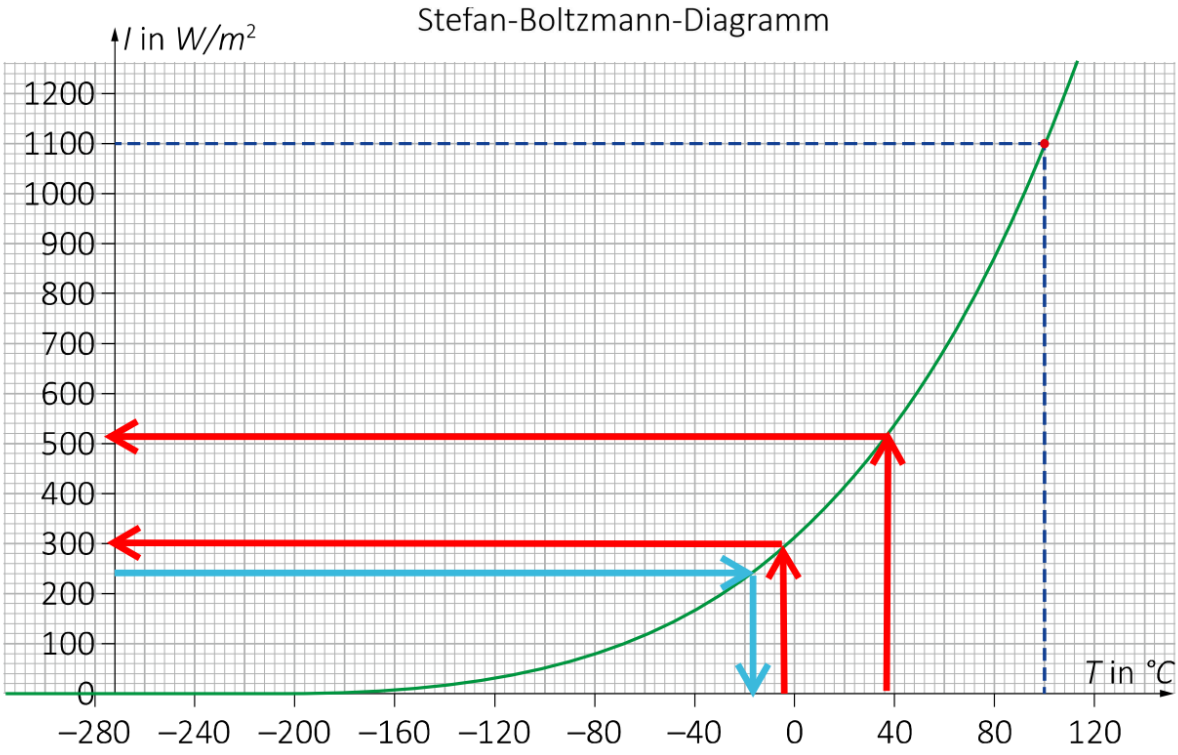


→ In the diagram on the next page, you will find a graphical representation of the Stefan-Boltzmann law. We will now try to get familiar with it! First complete the missing temperature values in the table (esti-mate) and then enter them into the diagram. Now read the values of the corresponding radiation in-tensity of these objects in the diagram and complete them in the table as well. Follow the example of boiling water.

Object	Temperature °C	Intensity W/m^2
Boiling water	100	1100
Human body	37	520
Ice cubes	-5	300

→ If you have placed and assigned the arrows and labels correctly, you will know that, on average, the Earth absorbs $238\,\frac{W}{m^2}$ of solar radiation and radiates this energy away again (radiation equilibrium). Now use the diagram inversely to determine the average temperature of an earth that radiates infrared radiation with this intensity and enter it in the diagram accordingly

With a radiation intensity of 238 W/m^2, the earth without atmosphere is at ***-16°C***



? Interpret the result and compare it to reality: Is it possible to align the average temperature of the Earth you have determined with your experiences? What is the reason for this?

So, without an atmosphere, it would be very cold on Earth! This is contrary to our experience, where most of the year in Germany there is a pleasant or high temperature, with the exception of winter maybe.

The average temperature of the earth is altogether life-friendly 15°C, which does not fit with these values. So the atmosphere must be responsible for the big temperature difference!

The natural greenhouse effect is therefore necessary for life - but its amplification by human intervention is connected to great dangers.

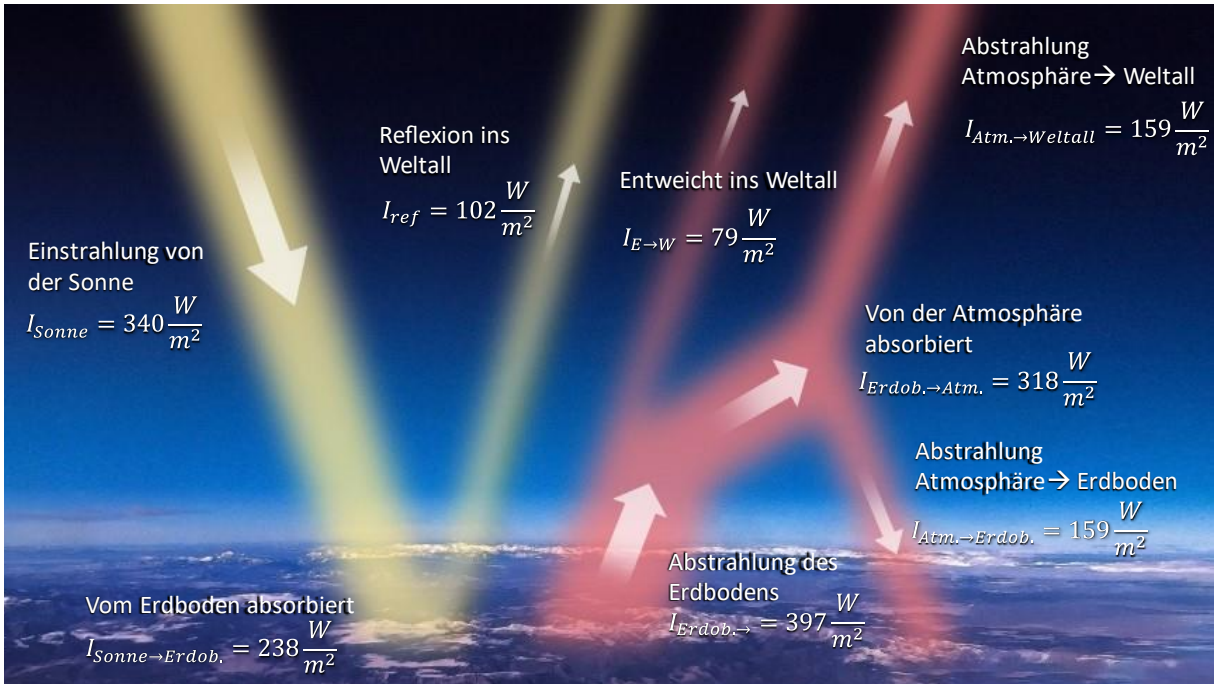
? Not an easy additional question: Do you have any idea why it would be much colder on an earth without an atmosphere?

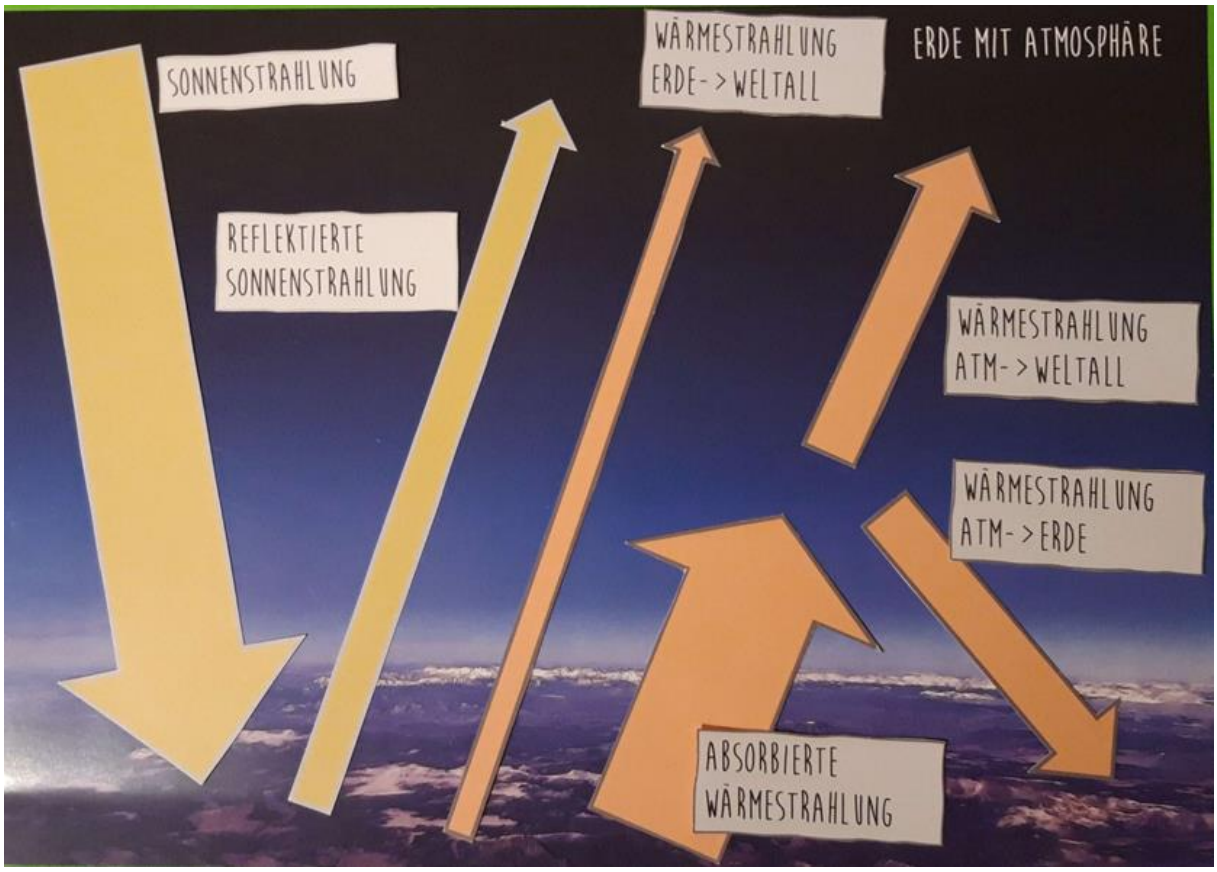
Without atmosphere life on earth would not be possible, i.e. there would be no plants, animals, humans. The earth would be iced! There would be massive ice surfaces, where now forests, cities and other dark surfaces are.

Because of the high reflectivity (albedo) of these bright, white surfaces the earth would reflect more solar radiation than with the present dark surfaces. The radiation equilibrium changes with it also and the earth radiates less heat radiation => lower temperature according to Stefan-Boltzmann.

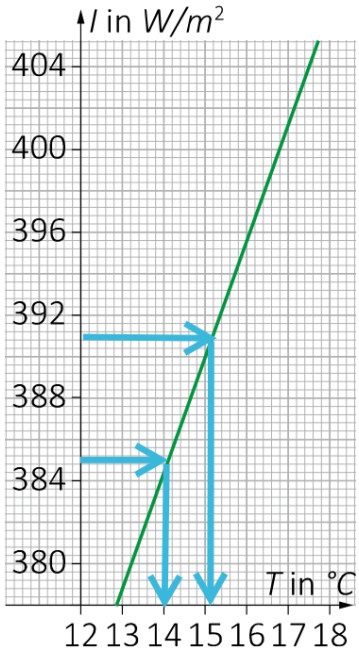
Part 2: What temperature on Earth does the natural greenhouse effect cause?

→ Laying arrows: Study the background text and lay out the light grey and dark grey bordered arrows on the "Earth with atmosphere" sheet.





→ The atmosphere is thus (in addition to the Sun) a second source of radiation, which (with our assumptions) emits radiation with an intensity of 147 W/m^2 towards the ground. This energy is now additionally absorbed by the ground, which radiates again with greater intensity. What is the value of this radiation intensity and what is the temperature of the ground for this? Use the diagram on the right, which is an enlargement of the diagram above.



Hint: *Add up the two radiation intensities absorbed by the earth.*

$0{,}7 * 340 W/m^2 + 147 W/m^2 = 238\, W/m^2 + 147\, W/m^2 = 385 W/m^2$
corresponds to 14°C

Part 3: How strong is the anthropogenic greenhouse effect?

? In the following example, we assume that the atmosphere absorbs slightly more radiation from the Earth: 78% instead of 76%. As a result, it heats up more and therefore also radiates with higher intensity. In this case, this would correspond to an additional 6 W/m^2 . What is the average temperature for the Earth with this additional energy source, that irradiates the Earth?

Info: The Intergovernmental Panel on Climate Change (IPCC) uses computer models to provide scenarios (possibilities) for the future climate. The scenarios vary from RCP 2.6 to RCP 8.5, with the figure indicating an additional radiation intensity of 2,6 W/m^2 respectively 8,5 W/m^2 from the atmosphere towards the Earth's surface.

$238\, W/m^2 + 6\, W/m^2 + 147\, W/m^2 = 391 W/m^2$ corresponds to 15°C