tEachiNG criticAl thinkinG on clImate chaNGe

Mieke De Cock

Funded by
the European Union

Agenda

- Wetenschapsonderwijs & klimaatverandering
- Tutorials rond (kritisch denken over) klimaatverandering:

  doel – opbouw – wetenschappelijke onderbouwing
- Voorbeeld tutorials & discussie

5 VRAGEN KLIMAAT

Recordjaar 2023 strandt op een zucht van 1,5 graad opwarming en toch moeten we die bovengrens niet opgeven

De Standaard – 9 januari 2024

HLN– 19 januari 2024

Hoe kan het nog zo koud zijn en sneeuwen in een opwarmend klimaat? Klimatoloog legt uit

SNOWBOARDEN

“Als snowboarder zie ik elke dag het effect van de klimaatopwarming”

De Standaard – 9 januari 2024

COMMENTAAR

Spaanse overstromingen zijn een waarschuwing: Europa moet zich schrap zetten voor meer klimaatgeweld

Tonie Mudde

is chef van de wetenschapsredactie van de Volkskrant.

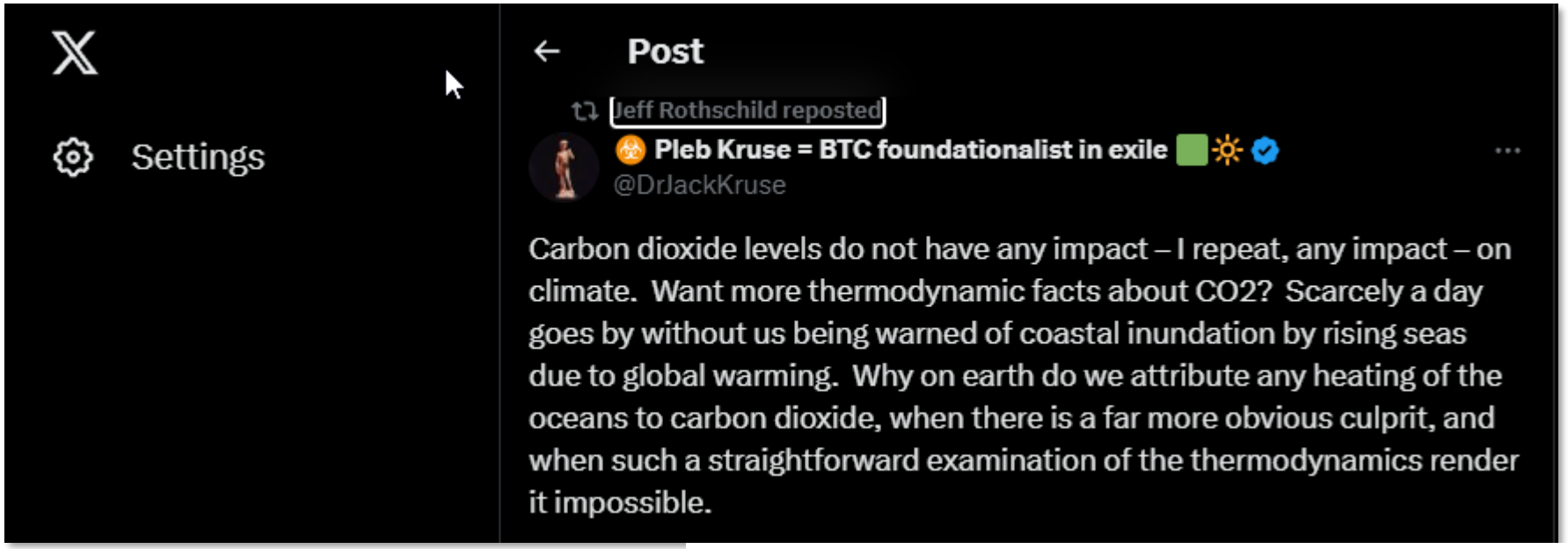
1 november 2024

de Volkskrant

Vrt.be

'We staan aan de rand van een onomkeerbare klimaatramp'

H2O ACTUEEL . 09 OKTOBER 2024



NATURE AND ENVIRONMENT | UNITED STATES OF AMERICA

Elon Musk tweets false climate claim

Ajit Niranjan
07/03/2023

The world's richest man has made public statements that deny basic science about the role of agriculture in heating the planet, say experts.

https://www.dw.com/en/elon-musk-climate-tweet-misinformation/a-66082443

KU LEUVEN

Europa stelt vragen over desinformatie Gaza op Tiktok en Meta

De Standaard

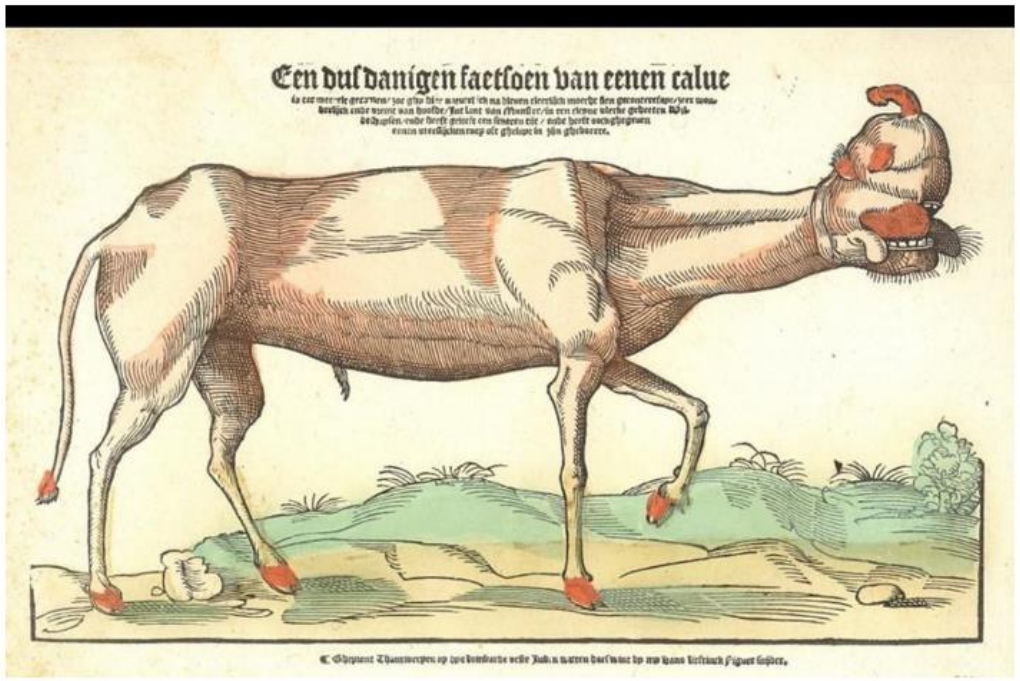
https://edition.cnn.com/2024/01/16/climate/climate-denial-misinformation-youtube/index.html

Europa opent onderzoek tegen Meta in strijd tegen desinformatie

https://www.vrt.be/vrtnws/nl/2024/04/30/europese-commissie-opent-onderzoek-tegen-meta-in-strijd-tegen-fa /

De Standaard Nieuws Opinie Inspiratie Podcasts

Leuvense expo toont dat fake news en propaganda van alle tijden zijn



'Het monsterkalf' (1550). — © Collectie Stad Antwerpen, Museum Plantin-Moretus

Fake news is geen moderne uitvinding: al in de 16de eeuw kregen mensen ermee te maken. Net als met censuur en propaganda. Er is niets nieuws onder de zon, toont een expo in de Leuvense universiteitsbibliotheek.

UNESCO:
Education is crucial to promote climate action

Climate change education helps people understand and address the impacts of the climate crisis, empowering them with the knowledge, skills, values and attitudes needed to act as agents of change. UNESCO promotes climate change education as a key component of its work in education for sustainable development.

Climate change education | UNESCO

Agents of Change are not helpless victims but see the climate crisis as an **opportunity** for **necessary and feasible further developments and changes** (Hamann et al., 2023)

Doelstellingen van klimaat-onderwijs

- Lerenden in staat stellen om te **handelen in de klimaatcrisis** (Chang, 2022; UNESCO, 2023)
  - door **kennis, vaardigheden, waarden** en **attitudes** (Chang, 2022; UNESCO, 2023)
  - **Individueel** en in **groep, lokaal** en **wereldwijd** (Chang, 2022)
  - met oog op **mitigatie** en **adaptatie** (Chang, 2022; UNESCO, 2023)

- **kritisch denkvermogen ontwikkelen** voor een kritische en bewuste benadering van informatie (inclusief verkeerde informatie) (Chang, 2022)

- ontwikkeling van het vermogen om **bewuste, kritisch onderbouwde en beargumenteerde meningen en oordelen te vormen**, bijv. over klimaatbeschermingsmaatregelen (Eilks et al., 2011)


Klimaatverandering
engaging
Kritisch denken

tEachiNG criticAl thinkinG on clImate chaNGe

KU LEUVEN

RUHR UNIVERSITÄT BOCHUM

RUB

universität innsbruck

engaging

Funded by the European Union

TECHNISCHE UNIVERSITÄT DRESDEN

KU LEUVEN

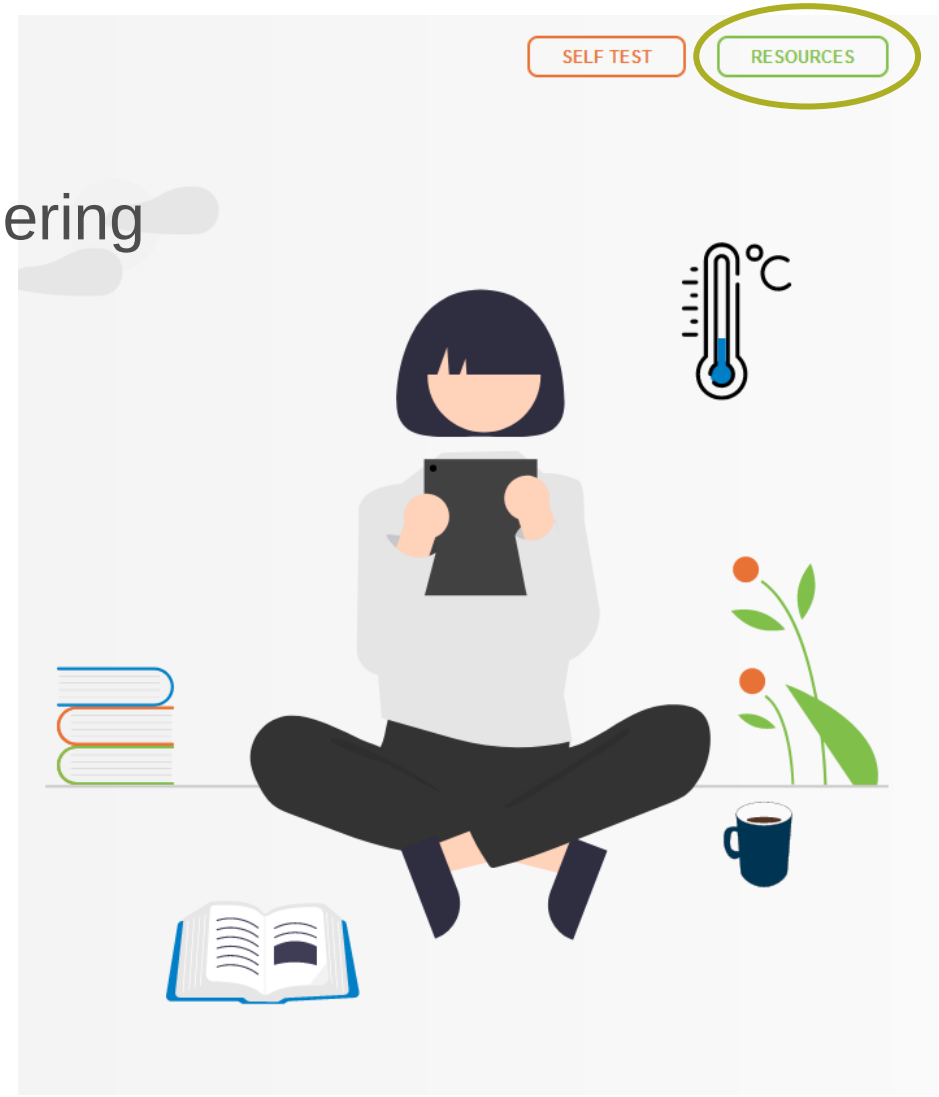
Doelstellingen

- ontwikkelen van test rond kritisch denken m.b.t. klimaatverandering
- ontwikkelen van lesmateriaal rond klimaatverandering
- ontwikkelen van lesmateriaal rond kritisch denken over klimaatverandering

Lesmateriaal

- Tutorials: Conceptueel inzicht in klimaatverandering

- 5 *concept areas* (Schubatzky et al. 2021):
  - atmosfeer van de Aarde
  - onderscheid weer en klimaat
  - klimaat als systeem
  - koolstofcyclus
  - broeikaseffect



Leerlingendenkbeelden

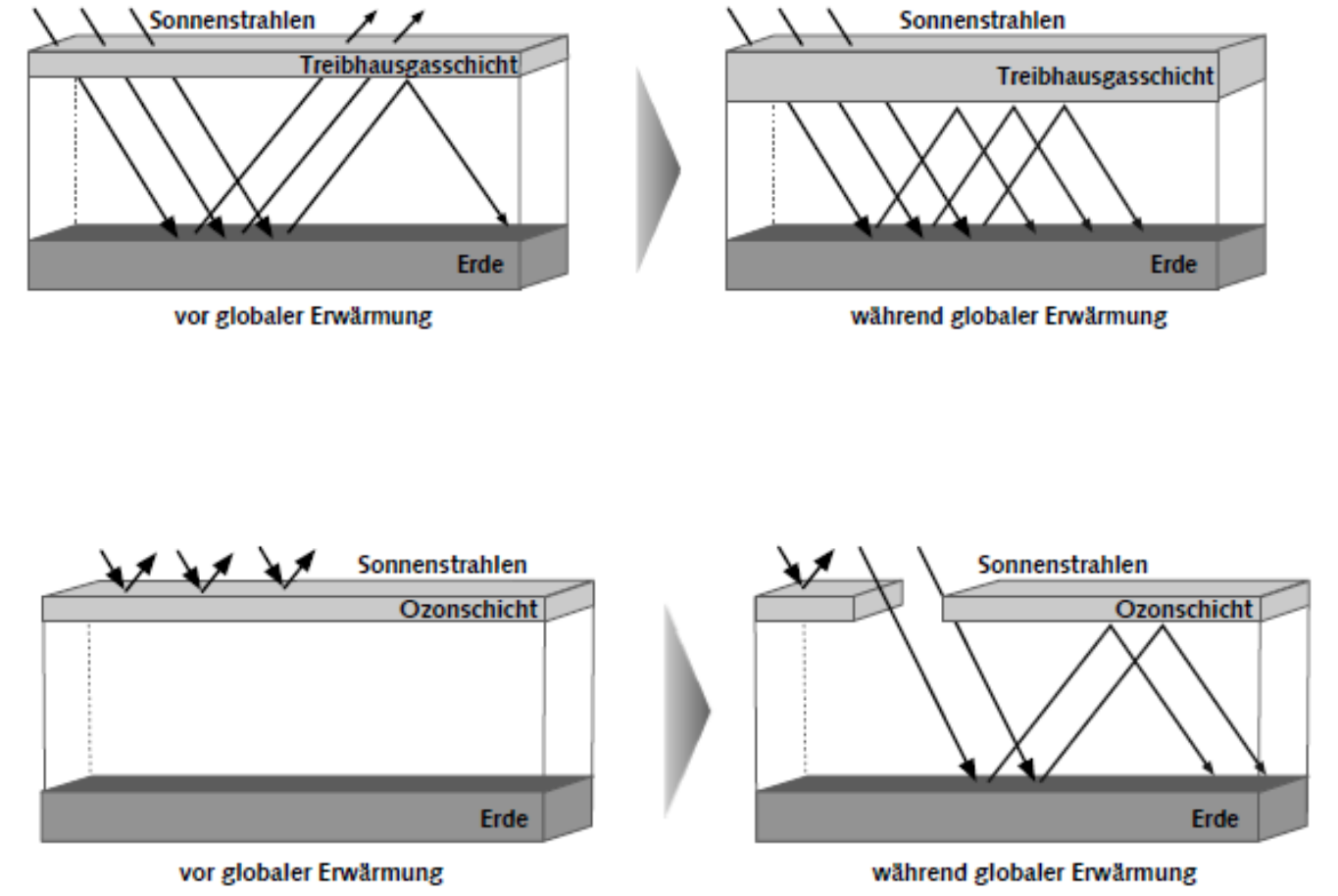
- Overschatting van de hoeveelheid broeikasgassen in atmosfeer
- Verwarring ozongat – broeikaseffect
- Weinig bekend met natuurlijk broeikaseffect
- Herkennen waterdamp niet als broeikasgas
- Koolstofdioxide als oorzaak van ozon laag depletion
- …

Schubatzky et al., 2024

bold, the adequate answer of each item is in italic.

Item Code	Item/Answer	Number of Respondents	Percentage of Respondents
GE1	**Which statement best describes the greenhouse effect on Earth?**		
GE1	*Solar radiation passes through the atmosphere and warms the ground. Thermal radiation emitted by the Earth is absorbed by the greenhouse gases in our atmosphere. The thermal radiation is then transmitted back towards the Earth, as well as in other directions. This causes the Earth to warm up even more.*	*93*	*19%*
GE1	Solar radiation passes through the atmosphere and warms the ground. The ground reflects this solar radiation. This radiation is reflected back to Earth by the greenhouse gases in our atmosphere. This causes the Earth to warm up even more.	159	32%
GE1	Greenhouse gases damage the ozone layer in our atmosphere. In doing so, they create and enlarge the hole in the ozone layer. The ozone hole allows more solar radiation to reach the Earth's surface. This causes the Earth to warm up even more.	148	30%
GE1	Greenhouse gases in our atmosphere concentrate the incoming sunlight. The concentrated sunlight causes the Earth to warm up even more.	38	8%
GE1	Greenhouse gases provide good insulation due to their dense concentrations. Greenhouse gases rise to the furthest extent of the atmosphere, reducing the heat exchange between the Earth and space. This causes the Earth to warm up even more.	64	13%

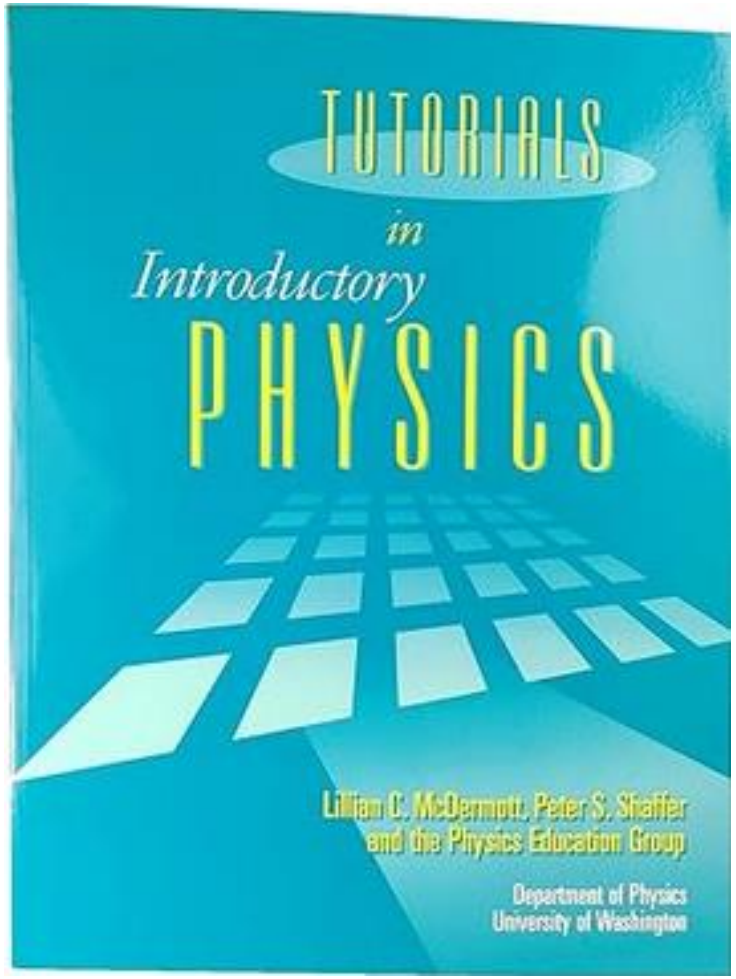
Schubatzky et al., 2024



(Niebert, 2010)

Tutorials over Klimaatverandering

- *Qualitative problems addressing typical student difficulties* (McDermott & Shaffer 2002)
- leerlingen leggen redenering uit
- verdiept inzicht van leerlingen/studenten (Benegas & Flores 2014, Finkelstein & Pollock 2005, Heron et al. 2004)



Docentenhandleiding

Leerdoel

Kernidee

Leerlingendenkbeeld

Wetenschappelijke onderbouwing

Achtergrondinformatie en vervolgideeën

Atmosfeer 1: Broeikasgassen zijn spoorgassen

Benodigde tijd: 20 minuten

Informatie voor leraren/docenten

Leerdoel

De leerlingen/studenten kunnen in eigen woorden uitleggen waarom broeikasgassen op Aarde ook 'spoorgassen' worden genoemd.

In eigen woorden uitleggen = concepten beschrijven met behulp van je eigen kennis (hier "spoorgassen") op een duidelijke en begrijpelijke manier, en ze indien nodig contextualiseren met aanvullende informatie

Kernidee

Broeikasgassen maken minder dan 1 % uit van de atmosfeer van de Aarde. Het zijn dus spoorgassen.

Behandeld leerlingendenkbeeld

In het onderzoek van Schubatzky et al. (2024) denken de meeste leerlingen dat het aandeel van broeikasgassen in de atmosfeer 30% of meer is.

Wetenschappelijke onderbouwing

- Schubatzky, T., Wackermann, R., Wöhlke, C., & Haagen-Schützenhöfer, C. (2024). How well do German A-Level Graduates understand the Scientific Underpinnings of Climate Change? Sustainability 16(17), 7264.
- Tabel: Hoeveelheden van verschillende gassen in de atmosfeer [1]:

Chemical makeup of the atmosphere EXCLUDING water vapor

GAS	SYMBOL	CONTENT
Nitrogen	N_2	78.084%
Oxygen	O_2	20.947%
Argon	Ar	0.934%
Carbon dioxide	CO_2	0.039%
Neon	Ne	18.182 parts per million
Helium	He	5.24 parts per million
Methane	CH_4	1.79 parts per million
Krypton	Kr	1.14 parts per million
Hydrogen	H_2	0.55 parts per million
Nitrous oxide	N_2O	0.35 parts per million
Carbon monoxide	CO	0.18 parts per million
Xenon	Xe	0.09 parts per million
Ozone	O_3	0.07 parts per million
Nitrogen dioxide	NO_2	0.02 parts per million
Iodine	I_2	0.01 parts per million
Ammonia	NH_3	trace

Chemical makeup of the atmosphere INCLUDING water vapor

WATER VAPOR	NITROGEN	OXYGEN	ARGON
0%	78.084%	20.947%	0.934%
1%	77.30%	20.70%	0.92%
2%	76.52%	20.53%	0.91%
3%	75.74%	20.32%	0.90%
4%	74.96%	20.11%	0.89%

In the Earth's desert regions (30°N/S) when dry winds are blowing, the water vapor contribution to the composition of the atmosphere will be near zero.

Water vapor contribution climbs to near 3% on extremely hot/humid days. The upper limit, approaching 4%, is found in tropical climates.

The table (left)(above) shows the changes in atmospheric composition with the inclusion of different amounts of water vapor.

Achtergrondinformatie voor leraren/docenten en vervolgideeën

Kleine percentages broeikasgassen hebben een groot effect! Hoewel het percentage broeikasgassen in de atmosfeer minder dan 1% bedraagt, zorgen ze ervoor dat de gemiddelde temperatuur op Aarde +15°C bedraagt (vóór de industrialisatie). Zonder broeikasgassen zou de gemiddelde temperatuur op Aarde veel lager zijn, -18°C, en zou het leven zoals wij dat kennen onmogelijk zijn.

De bovenstaande tabel toont de samenstelling van droge lucht. Dit is opzettelijk gedaan omdat de

KU LEUVEN

Docentenhandleiding

Leerdoel

Atmosphere 1 – Greenhouse Gases are Trace Gases
Time required: 20 minutes

Information for teachers:

Learning Goal: Students can explain in their own words why greenhouse gases on Earth are referred to as trace gases.

Explain = Describe concepts using your own knowledge (here, understanding "trace amounts") in a clear and comprehensible way, and if necessary, contextualize them with additional information.

Kernidee	**Key Idea:** Greenhouse gases in the Earth's atmosphere make up less than 1%. Thus, they are trace gases.

Leerlingen-denkbeeld

Addressed Student Misconception: According to Schubatzky et al. (2024), most students think the percentage of greenhouse gases in the atmosphere of the Earth is 30% or more.

Wetenschappelijke onderbouwing

Scientific evidence:

- Schubatzky, T., Wackermann, R., Wöhlke, C., & Haagen-Schützenhöfer, C. (submitted). How well do German A-Level Graduates understand the Scientific Underpinnings of Climate Change? *Sustainability*

Table 1: Portions of gases in the atmosphere [1].

Chemical makeup of the atmosphere EXCLUDING water vapor

GAS	SYMBOL	CONTENT
Nitrogen	N_2	78.084%
Oxygen	O_2	20.947%
Argon	Ar	0.934%
Carbon dioxide	CO_2	0.035%
Neon	Ne	18.182 parts per million
Helium	He	5.24 parts per million
Methane	CH_4	1.70 parts per million
Krypton	Kr	1.14 parts per million
Hydrogen	H_2	0.53 parts per million
Nitrous oxide	N_2O	0.31 parts per million
Carbon monoxide	CO	0.10 parts per million
Xenon	Xe	0.09 parts per million
Ozone	O_3	0.07 parts per million
Nitrogen dioxide	NO_2	0.02 parts per million
Iodine	I_2	0.01 parts per million
Ammonia	NH_3	trace

Chemical makeup of the atmosphere INCLUDING water vapor

WATER VAPOR	NITROGEN	OXYGEN	ARGON
0%	78.084%	20.947%	0.934%
1%	77.30%	20.70%	0.92%
2%	76.52%	20.53%	0.91%
3%	75.74%	20.32%	0.90%
4%	74.96%	20.11%	0.89%

In the Earth's desert regions (30°N/S) when dry winds are blowing, the water vapor contribution to the composition of the atmosphere will be near zero.

Water vapor contribution climbs to near 3% on extremely hot/humid days. The upper limit, approaching 4%, is found in tropical climates.

The table (left)(above) shows the changes in atmospheric composition with the inclusion of different amounts of water vapor.

Achtergrond informatie & follow-up

Background information for teachers and follow-up possibility:

Small amounts of greenhouse gases have a large effect! Although the percentage of greenhouse gases in the atmosphere is less than 1%, they cause a mean global temperature of +15 °C (before industrialization). Without greenhouse gases the mean global temperature would be –18 °C, and water-based life as we know it would be impossible.

The table above shows the composition of dry air. This is done deliberately, because the amount of water vapour in the atmosphere is highly variable both in time and region on Earth. Water vapor percentage can get above 1% locally, but on average is below 1%. So, the statement that all greenhouse gases together have less than 1% remains true.

In summary, greenhouse gases are present in the Earth's atmosphere only in traces), and yet have a strong influence on Earth's climate via the

Venus, CO_2 is very abundant with a percentage of 96% and a phere. Consequence is a gigantic greenhouse effect with soil 00 °C. On Mars, the percentage is similar but the atmosphere in hich leads to a weak greenhouse effect and average tempera- examples shall illustrate that CO_2 is not always a trace gas, but proper amount it enables life.

nts for elaboration:

r examples of little quantities having a strong influence: Poison; fier; transistor; etc.

- rent kinds of greenhouse gases: CO_2, CH_4, …
- There is a connection between water vapour and CO_2: According to the Clausius-Clapeyron-equation, air can hold more water vapour when it is warmer. In times of global warming, the CO_2 concentration in the atmosphere steers the water vapour content via the temperature.
- The number of CO_2-molecules in the atmosphere is in the order of more than 10^{23} molecules. Small percentage does not necessarily mean small amount.

Tutorial

Leerdoel

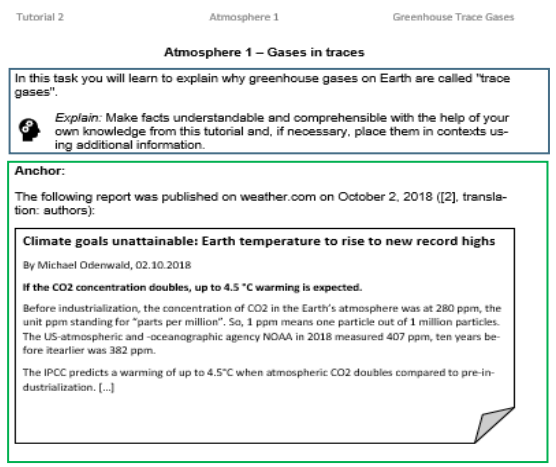
Anker

Leertaak (voorbeeld)

Concept cartoon

Terugblik

Evt aanvulling



Tutorial 2 Atmosphere 1 Greenhouse Trace Gases

Atmosphere 1 – Gases in traces

In this task you will learn to explain why greenhouse gases on Earth are called "trace gases".

Explain: Make facts understandable and comprehensible with the help of your own knowledge from this tutorial and, if necessary, place them in contexts using additional information.

Anchor:

The following report was published on weather.com on October 2, 2018 ([2], translation: authors):

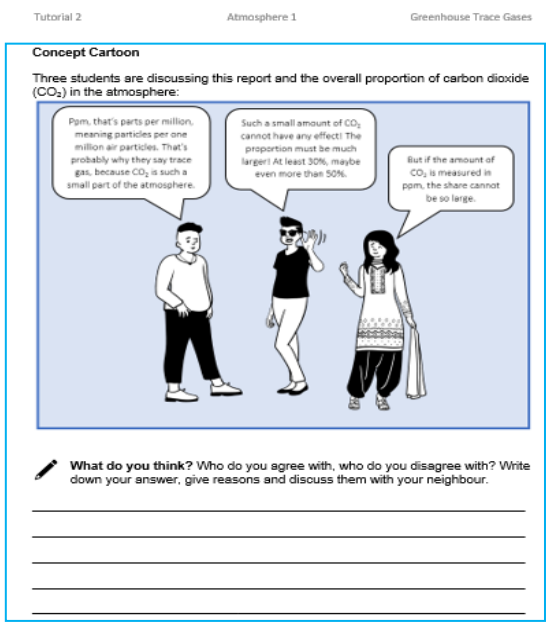
Climate goals unattainable: Earth temperature to rise to new record highs

By Michael Odenwald, 02.10.2018

If the CO2 concentration doubles, up to 4.5 °C warming is expected.

Before industrialization, the concentration of CO2 in the Earth's atmosphere was at 280 ppm, the unit ppm standing for "parts per million". So, 1 ppm means one particle out of 1 million particles. The US-atmospheric and -oceanographic agency NOAA in 2018 measured 407 ppm, ten years before itearlier was 382 ppm.

The IPCC predicts a warming of up to 4.5°C when atmospheric CO2 doubles compared to pre-industrialization. [...]

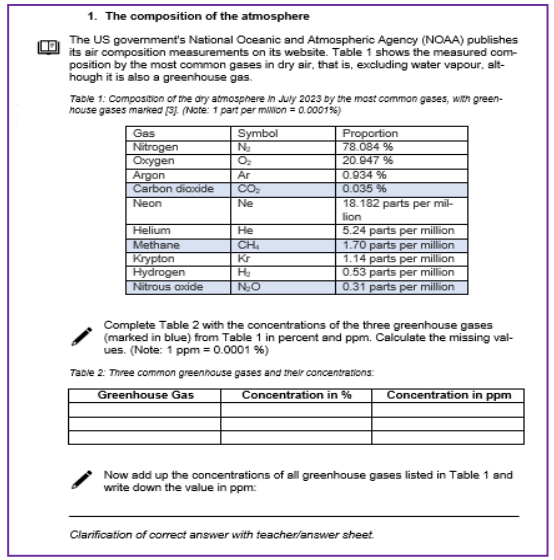


Tutorial 2 Atmosphere 1 Greenhouse Trace Gases

Concept Cartoon

Three students are discussing this report and the overall proportion of carbon dioxide (CO_2) in the atmosphere:

What do you think? Who do you agree with, who do you disagree with? Write down your answer, give reasons and discuss them with your neighbour.



1. The composition of the atmosphere

The US government's National Oceanic and Atmospheric Agency (NOAA) publishes its air composition measurements on its website. Table 1 shows the measured composition by the most common gases in dry air, that is, excluding water vapour, although it is also a greenhouse gas.

Table 1: Composition of the dry atmosphere in July 2023 by the most common gases, with greenhouse gases marked [3]. (Note: 1 part per million = 0.0001%)

Gas	Symbol	Proportion
Nitrogen	N_2	78.084 %
Oxygen	O_2	20.947 %
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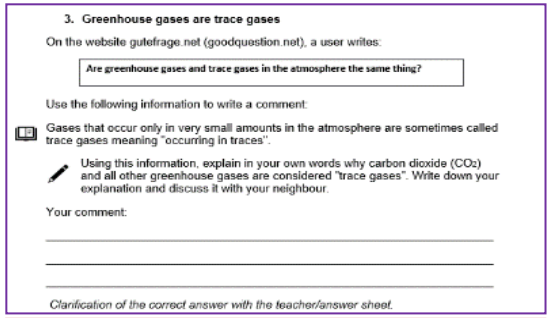
Complete Table 2 with the concentrations of the three greenhouse gases (marked in blue) from Table 1 in percent and ppm. Calculate the missing values. (Note: 1 ppm = 0.0001 %)

Table 2: Three common greenhouse gases and their concentrations:

Greenhouse Gas	Concentration in %	Concentration in ppm

Now add up the concentrations of all greenhouse gases listed in Table 1 and write down the value in ppm:

Clarification of correct answer with teacher/answer sheet.



3. Greenhouse gases are trace gases

On the website gutefrage.net (goodquestion.net), a user writes:

Are greenhouse gases and trace gases in the atmosphere the same thing?

Use the following information to write a comment:

Gases that occur only in very small amounts in the atmosphere are sometimes called trace gases meaning "occurring in traces".

Using this information, explain in your own words why carbon dioxide (CO_2) and all other greenhouse gases are considered "trace gases". Write down your explanation and discuss it with your neighbour.

Your comment:

Clarification of the correct answer with the teacher/answer sheet.

4. Back to the beginning

Go back to the concept cartoon. Evaluate your initial assessment using the information from this tutorial. Write down your evaluation, give reasons and discuss them with your neighbour. *(Think-Pair-Share)*

(Think-Pair-Share or directly in the plenary.)

Additional information: As you read at the beginning of the report, the concentration of carbon dioxide (CO2) is currently increasing. This is also true for other greenhouse gases. For example, the concentration of carbon dioxide (CO2) was already at 407 ppm in 2018. Despite their low prevalence, greenhouse gases have a significant impact on the climate.

Tutorial

Leerdoel

Atmosphere 1 – Gases in traces

In this tutorial, you will learn to explain why greenhouse gases on Earth are called "trace gases".

Explain: Make facts understandable and comprehensible with the help of your own knowledge from this tutorial and, if necessary, place them in contexts using additional information.

Tutorial

Anker

Anchor:

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(Modified) Anchored Instruction: Situated learning with „newspaper learning tasks“

- Authentic contexts for learning
- Anchor medium describes context in a narrative and affectively appealing way (an interesting story is told)

(Kuhn et al. 2011)

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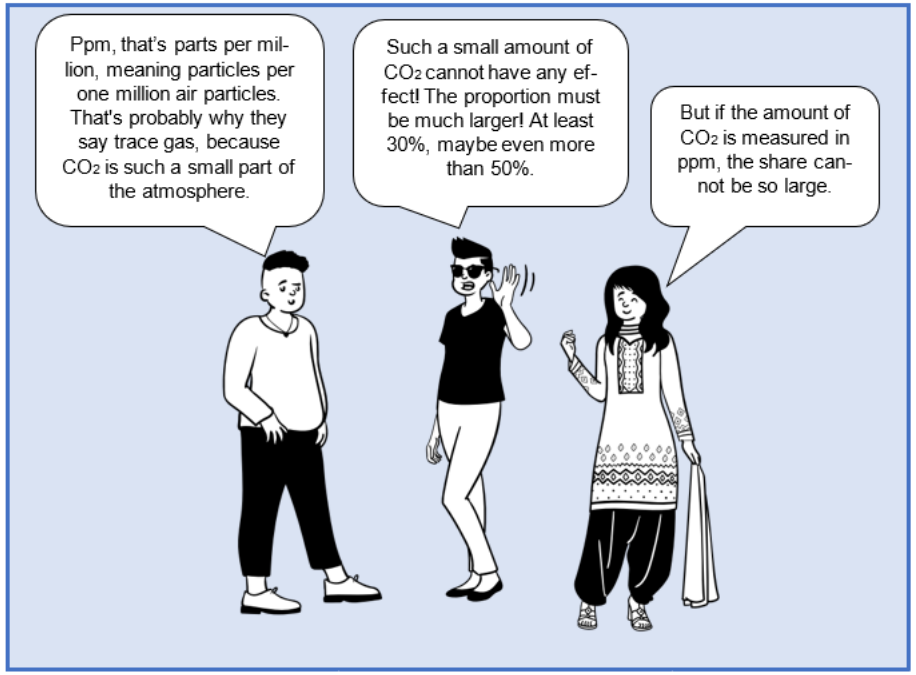
Tutorial

Concept Cartoon

Three students discuss this report and the overall proportion of carbon dioxide (CO_2) in the atmosphere:



What do you think? Which statement(s) do you agree with, which statement(s) don't you agree with? Write down your answer, give reasons and discuss them with your neighbour.

Concept cartoon

Concept Cartoons

- Possibility to respond to learners' ideas
- Fostering conceptual understanding
- Meaningful real-life contexts
- Activating pre-knowledge

(Feige & Lembens 2020)

Concept Cartoon

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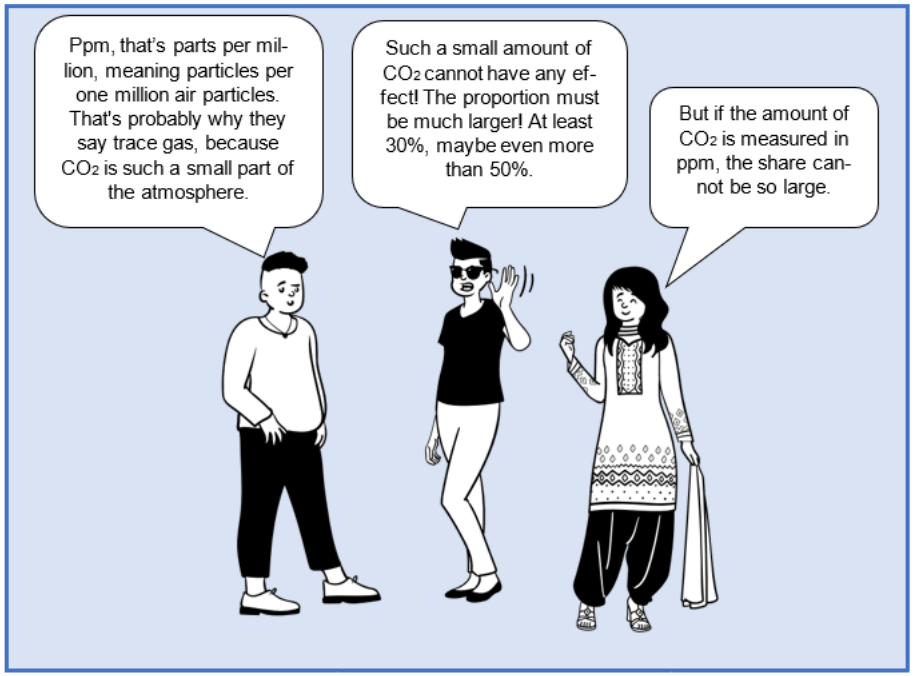

What do you think? Which statement(s) do you agree with, which statement(s) don't you agree with? Write down your answer, give reasons and discuss them with your neighbour.

Tutorial

Leertaken

1. The composition of the atmosphere

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Greenhouse Gas	Concentration in %	Concentration in ppm

Now add up the concentrations of all greenhouse gases listed in Table 1 and write down the value in ppm:

_____

(Clarification of correct answer with the teacher/answer sheet.)

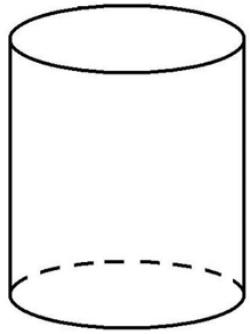
2. The proportion of greenhouse gases

Is the percentage of greenhouse gases in the atmosphere greater or less than 1%? Decide using the information from table 2.

_____

_____

In the box, sketch the relative proportions of nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), and all the other gases together. Discuss your solution with your neighbour.



Clarification of correct answer with teacher/answer sheet.

You now know that the proportion of greenhouse gases in the atmosphere (excluding water vapor) is _____%. The proportion of carbon dioxide (CO_2) in the atmosphere is even only _____%.

(Clarification of correct answer with the teacher/answer sheet.)

Tutorial

4. Back to the beginning

Go back to the concept cartoon. Evaluate your initial assessment using the information from this tutorial. Write down your evaluation, give reasons and discuss them with your neighbour. *(Think-Pair-Share)*

(Think-Pair-Share or directly in the plenary.)

Terugblik

Tutorial

Additional information: As you read at the beginning of the report, the concentration of carbon dioxide (CO_2) is currently increasing. This is also true for other greenhouse gases. For example, the concentration of carbon dioxide (CO_2) was already at 407 ppm in 2018. **Despite their low prevalence, greenhouse gases have a significant impact on the climate.**

Evt aanvulling

tEachiNG criticAl thinkinG on clImate chaNGe

KU LEUVEN

Kritisch denken – 5 deelaspecten

Gebaseerd op Halpern Critical Thinking Assessment

- Verbal reasoning
- Thinking as hypothesis testing
- Argument analysis
- Understanding likelihood & uncertainty
- Decision making & problem solving

4. Analysing arguments

We cannot overestimate the importance of the skill to analyse arguments. Given the huge number of claims and statements made on the internet, it is important to scrutinize the logic and the structure the author uses. A good argument consists of a clear stated claim, evidence that supports the claim and a clear reasoning that links evidence an

Read the following social media post:

a. Evaluate the statement of Tonald Drump: what is the claim, what is the evidence, and how are claim and evidence linked?

_____

_____

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_____

b. Comment on this post using the information from this tutorial. Structure your comment such that it becomes a clear convincing argument, including a claim, evidence and clear reasoning.

_____

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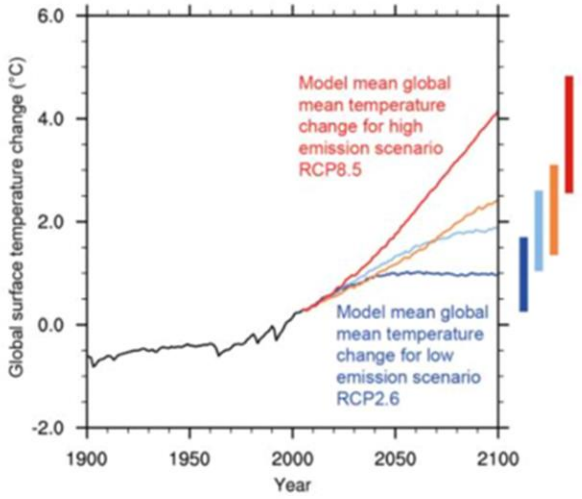

Observed and projected changes in global average temperature under four emissions pathways. The vertical bars at right show likely ranges in temperature by the end of the century, while the lines show projections averaged across a range of climate models. Changes are relative to the 1986-2005 average. Source: IPCC, 2013 EXIT , FAQ 12.1, Figure 1.

Figure 4: I
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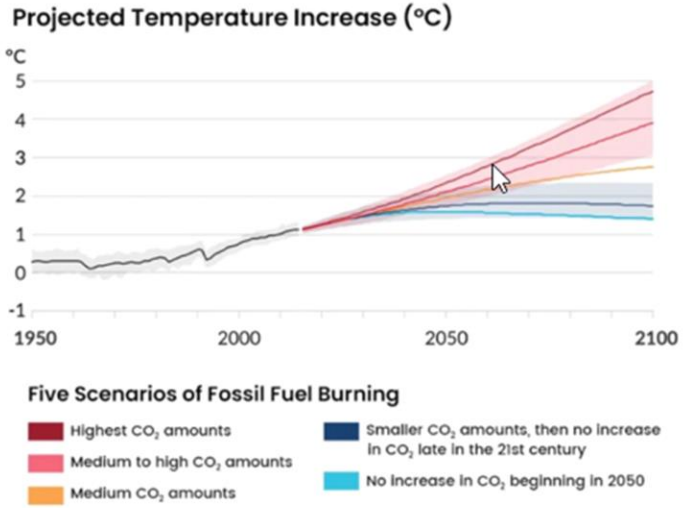

Figu

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Compare both graphs:

- Describe and compare the meaning of the black and colored lines.

_____

_____

- Explain the meaning of the coloured bars in Figure 4.

_____

_____

Next to the figure, 'likely ranges' are mentioned. What does this mean?

_____

_____

Compare the meaning of the uncertainty to the meaning of the use 'it is uncertain whether I will arrive on time' in everyday life.

_____

_____

- Explain the meaning of the shaded zones in Figure 5.

_____

_____

Classroom discussion (under supervision of the teacher). Clarification of correct answer

5. Back to the beginning

Go back to the concept cartoon. Evaluate the three statements in the concept cartoon by using the information on good arguments. *(Think-Pair-Share)*

Student 1: The carbon budget is the amount of carbon we can produce and still limit global warming to 1,5°. More carbon (carbon dioxide) in the atmosphere can cause global warming above 1.5°. Therefore, we should reduce carbon production.

Premises:

- _____
  _____
  _____
- _____
  _____

Turnstile: _____

Conclusion: _____

Waar staan we?

- 10 tutorials over klimaatverandering
  - Atmosfeer (2)
  - Broeikaseffect (3)
  - Weer en klimaat (2)
  - Klimaat als system (1)
  - Koolstofcyclus (2)

- 10 tutorials over kritisch denken m.b.t. klimaatverandering
  - Verbal reasoning
  - Argument analysis
  - Hypothesis testing
  - Likelihood & uncertainty

Aan de slag

met enkele tutorials – ter kennismaking

Het broeikaseffect

Weer en Klimaat

Conceptuele focus

Kritisch denken ingebed

Bespreking

Feedback?

Volgende stappen

- Concept tutorials zijn getest

  → positief resultaat qua concept kennis & attitude towards CC teaching

Wanting to teach by learning about about climate change? Investigating pre-service teachers' climate change knowledge and its impact on their intention to teach

Volgende stappen

- Concept tutorials zijn getest

  → positief resultaat qua concept kennis & attitude towards CC teaching
- verdere uitwerking en testen van CT tutorials

- vertaling + ter beschikking stellen op website
- nascholingsinitiatieven

- internationale zomerschool voor leraren

https://www.engagingforclimate.eu/nl/

KU LEUVEN

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