

Unit 2_2

Today's goals

- **Analyze** the difference between peer observation and micro-teaching
- **Formulate** peer observation criteria
- **Compare** Guided Road Map (GRM) with AKIDE

Steps of today's lesson

- Peer observation
- Guided Road Map (GRM)
- Evaluation

Peer Observation

Difference between Micro-Teaching and Peer Observation

- Micro-teaching is defined as sharing a **part** of the course with peers and receiving feedback from peers or advisors.
- Peer observation, on the other hand, involves providing constructive suggestions among peers, reviewing, and giving feedback in accordance with **predetermined** criteria.

Peer observation encourages reflection

Being reflective > crucial to developing teaching and learning

Being observed > the opportunity to reflect, both before and after the observation

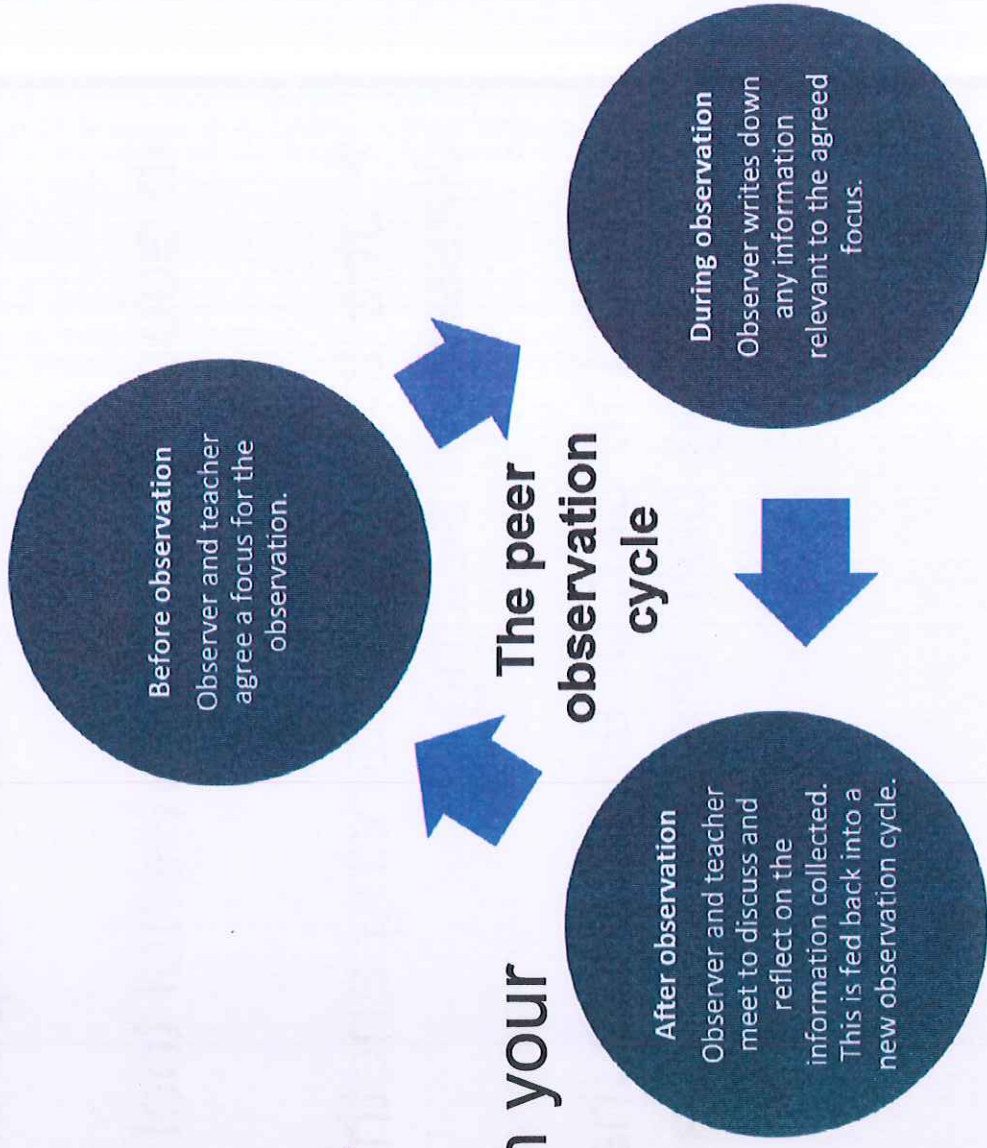
Being observed > the space to stop and think about how you teach

Peer observation encourages reflection

You should also

> reflect on your strengths

> share good practice with your colleagues



Peer observation – a powerful tool

In education > a powerful tool for teacher **development**

> one teacher observing another teacher within their classroom setting

> with the aim of enhancing their teaching practice, and benefiting both the observed and the observing teacher

Task 1

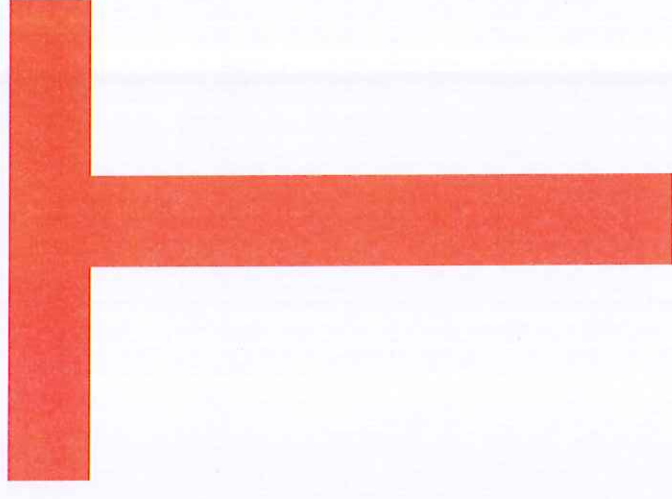
Task: On Google Drive, Unit 2_2, you will find the file 'Peer Observation Preparation'. This form serves to plan the preparatory meeting. Please analyze it. Create a preparation. Formulate the planned objectives for one of your lessons which you would like to be observed.

Interaction pattern: Individual work

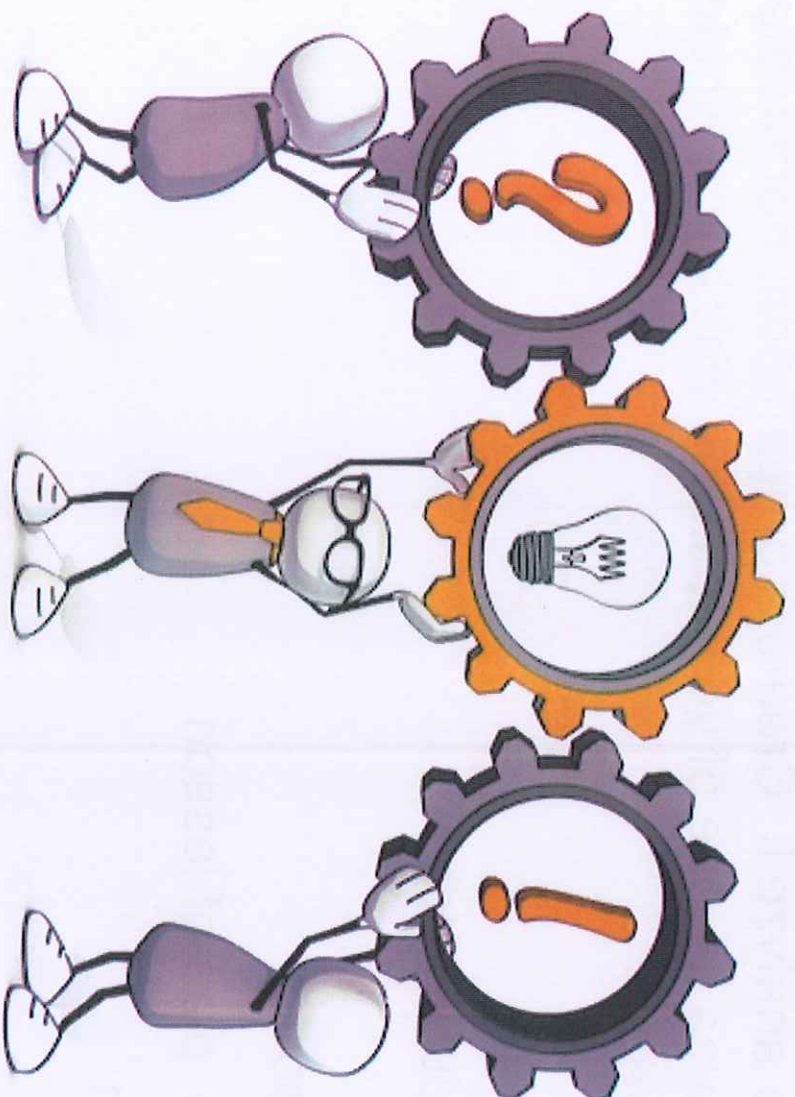
Location: Classroom

Product: Notes, plan of lesson

Time: 30 min.



Time for statements, reflections, questions



Steps of today's lesson

- Peer Observation ✓
- Guided Road Map (GRM)

Guided Road Map (GRM)



What is a **GRM** (**G**uided **R**oad **M**ap)?

- A learning unit for **self-study** (also known as Mastery Learning)
- Often covers an entire topic (several hours)
- Students learn alone, in pairs or in groups
- Mastery tests (**without** grades) measure learning success
- Success in mastery tests → next learning steps
- The fastest receive additional tasks (additum)
- The slow ones may catch up in homework
- Teacher is present and has the **role of a coach**

Task 2

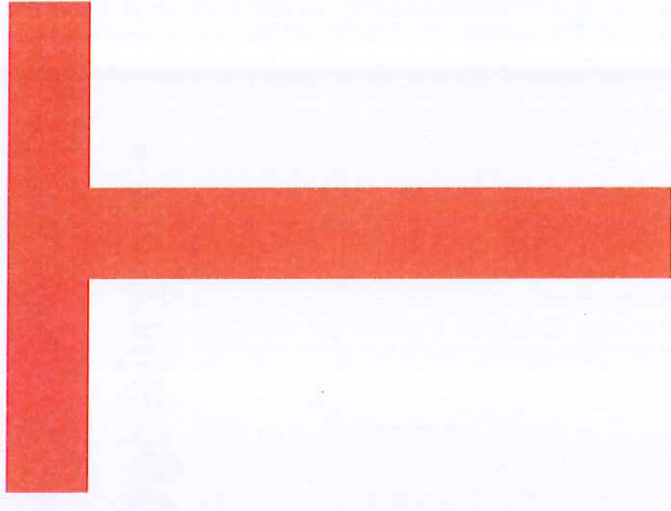
Task: In the script Unit 2_2 you will find two GRMs. Please browse through «Globalisation, global warming» and through the ETH GRM (the pdf is on Google Drive).
It makes **no sense** to read all the texts. Try to concentrate on the **structure and components**. After that, try to concentrate on the **mastery tests**.

Interaction pattern: Individual work

Location: Classroom

Product: Notes, keywords

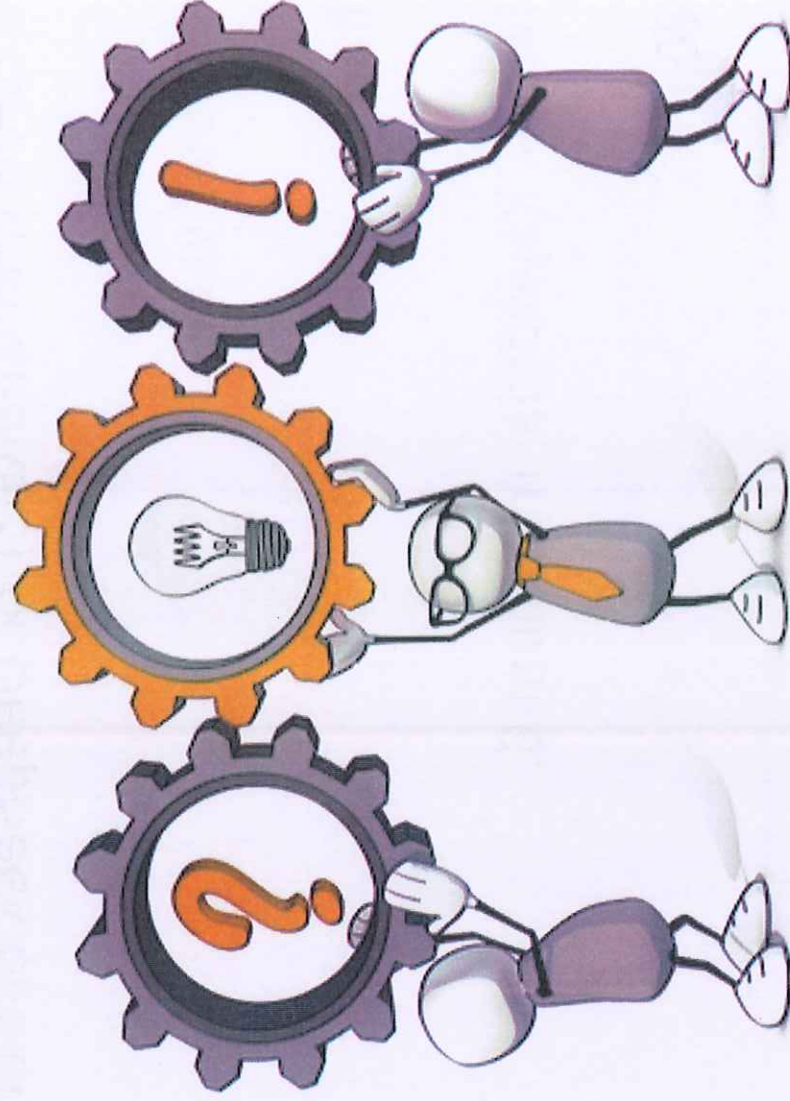
Time: 40 min.



What do we need for a Guided Road Map?

- Knowledge of **task formulation**
- Imagination for **different possibilities** of work assignments
- The first time: lots of time and ... **passion**
- Word processing programme
- Knowledge in dealing with digital media

Time for statements, reflections, questions



Task 3

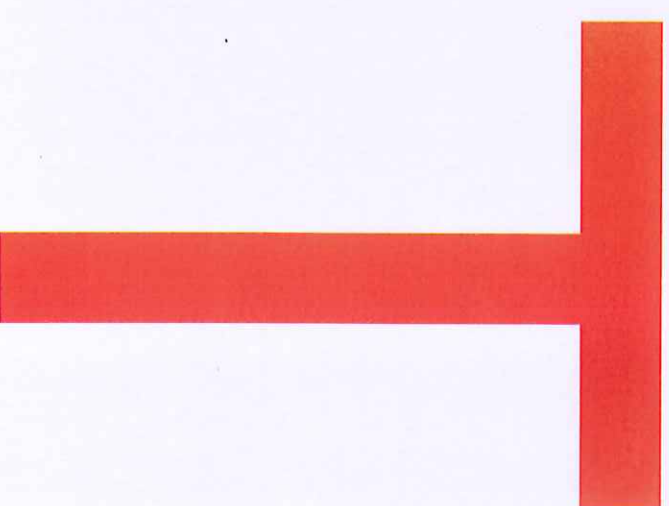
Task: Which contents are necessary for a GRM? How can you create a GRM with ChatGPT or DeepSeek or Perplexity or...?

Interaction pattern: Partner work

Location: free

Product: Notes, keywords, minimum 6.

Time: 20 min.



Contents of a GRM

- Title page (topic, responsible teacher, year, ...)
- Tasks (of course)
- Theory
- Links to websites or video clips, audio clips
- Pictures, fotos
- Empty writing fields
- Graphic learning and reading aids
- Mastery checks/tests



Into a single GRM brochure, you can ...

- integrate theory into the script
- integrate task to obtain theory from a website and summarize it in a text
- integrate graphics that are to be interpreted
- based on facts, assign the task of graphically implementing texts and theories
- require text analysis
- integrate assignments worked on in groups or with a partner
- integrate tasks to retrieve video clips
- include optional tasks
- include addenda for those who are quick
- include mastery checks etc. etc. etc.

Advantages and disadvantages of a GRM

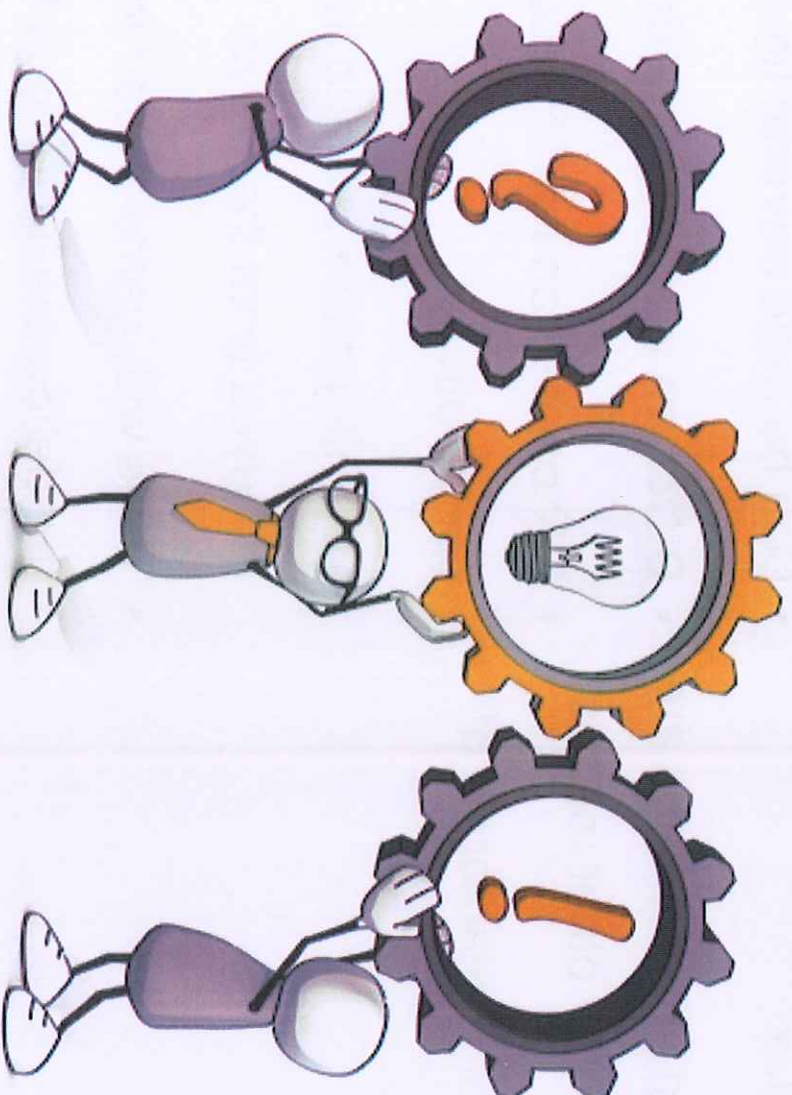
Disadvantages

- Elaboration is complex
- Unattractive learning programmes are face to face teaching by other means
- require knowledge of digital forms of learning

Advantages

- Can be used **several** times
- **Different** learning speeds are possible
- QR codes can lead to audio, video and text contributions
- Learning materials and information can be retrieved from the server
- Trials with *game-based learning* and tasks with the deliberate inclusion of *ChatGPT* are possible

Time for statements, reflections, questions



Task 4

Task: Read and summarise in the script U2_2 page 10-11 in keywords. After that find in U2_2 the GRM_open questions test. Answer the questions.

Interaction pattern:

Individual work

Location:

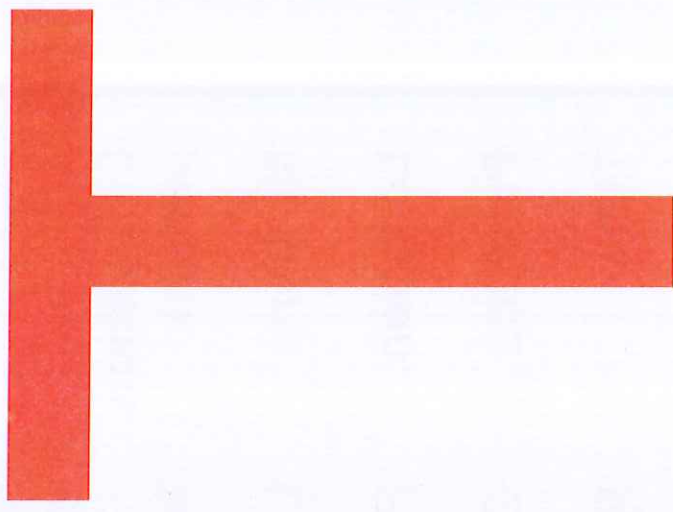
Classroom

Product:

Answers

Time:

20 min.



Term paper

Task: Please create a Guided Road Map for 3-4 lessons in your classroom, a 3-4 hour workshop. Work with your module descriptions. The subject can be related to this or to the next semester. People from the same faculty can work in groups. Use ChatGPT or other AI tools for this task. Be careful when **formulating the prompts**. Use precise instructions that include the AKIDE plan. Make sure that ChatGPT suggests sensible **time** allocations for the tasks and steps of the lesson plan.

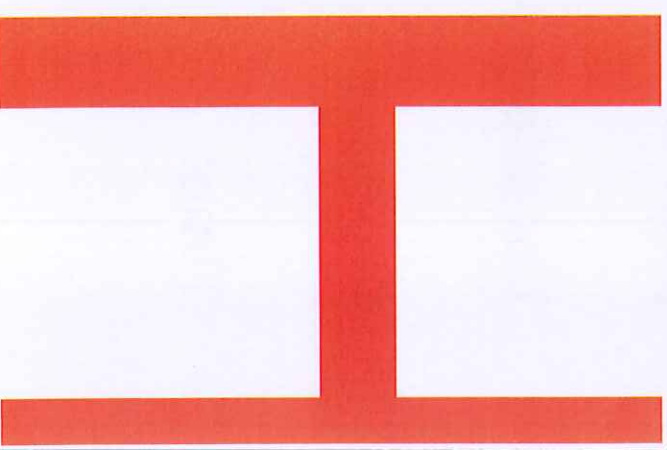
Interaction pattern: Individual/group work

Medium: Laptop, module description

Location: Free, private

Product: GRM for 3-4 lessons

Time: Recommended: 60 min.



Steps of today's lesson

- Peer observation ✓
- Guided Road Map (GRM) ✓
- Evaluation ✓

And what about today's goals?

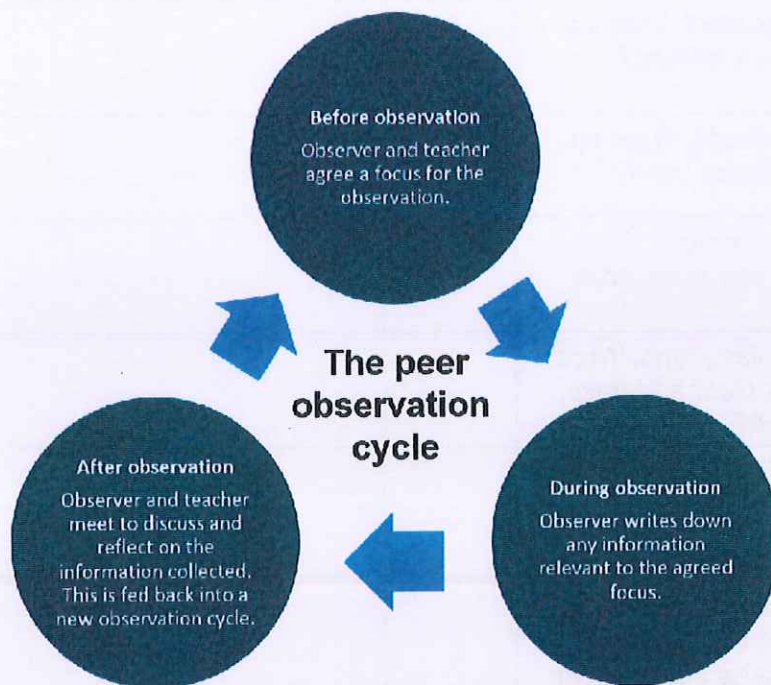


- **Analyze** the difference between peer observation and micro-teaching
- **Formulate** peer observation criteria
- **Compare** Guided Road Map (GRM) with AKIDE

Thank you for your attention!



Peer Observation Guided Road Map (GRM)



Micro-Teaching / Peer Observation

Observation Category	Criterion	Rating (1-5)	Comments / Observations
1. Lesson Structure and Planning	Clarity of learning goals: Were the learning goals clearly stated?		
	Coherence of structure: Was the lesson logically and well-structured?		
	Time management: Was the time effectively utilized?		
2. Didactic and Methods	Variety of methods: Were appropriate methods used?		
	Learner engagement: Were learners actively involved in the lesson?		
	Clarity of explanations: Were explanations clear and easy to understand?		
3. Competence-Oriented Didactics	Real-life application: Were tasks or activities designed to simulate real-world contexts?		
	Development of practical skills: Did the lesson focus on developing skills learners can apply in practice?		
4. Interaction and Communication	Eye contact and body language: Was there sufficient eye contact and supportive body language?		
	Clarity of speech: Was the language clear and precise?		
	Response to questions/comments: Were questions and comments handled well?		
5. Use of Teaching Aids	Use of media or materials: Were appropriate aids or materials used effectively?		
	Technical handling: Was the technology confidently handled?		

6. Subject Knowledge	Accuracy of content: Were the contents factually correct?		
	Depth of content: Was the content appropriately deep for the context?		
7. Overall Impression and Professionalism	Enthusiasm and demeanor: Did the teacher appear engaged and professional?		
	Learning atmosphere: Was a conducive learning atmosphere created?		
8. Positive Learning Environment	Supportive atmosphere: Did the teacher create a supportive and positive atmosphere?		
	Appreciation for learners: Did the teacher show respect and appreciation for learners?		
9. Creativity and Innovation	Creative teaching methods: Were creative approaches or methods used?		
	Motivation strategies: How well did the teacher motivate learners?		
10. Emotional Intelligence and Empathy	Empathy for learners: Did the teacher show empathy and respond to learners' emotions?		
	Self-reflection: Did the teacher demonstrate self-reflection during the lesson?		
11. Building Learners' Confidence	Boosting learners' confidence: Did the teacher make an effort to boost learners' confidence?		
12. Use of Formative Assessment	Use of checks for understanding: Did the teacher use strategies to assess learners' understanding throughout the lesson?		
13. Effective Feedback	Constructive feedback: Was feedback constructive and aimed at helping learners improve?		
	Encouragement: Did the feedback encourage and motivate learners?		

	Timeliness of feedback: Was feedback provided promptly, allowing learners to adjust or improve?		

Peer Observation - Guide

The key questions in the section below (in italics) are intended as a guide for the observer. They are **not intended to be an exhaustive list** to be followed in all situations. The relevance of the items listed will vary according to the type of lesson and/or discipline, and additional issues may need to be considered.

<p>Introductory phase <i>How was an orientation provided (in terms of content, time, organisation, methodology, social aspects)? Were the learning objectives communicated? Was there a link to previous courses or to the overall theme of the course? Are students informed about the content and methodology of the course? Are visualisations of the topic shown (e.g. advance organiser, concept map, etc.) to support students' learning? How is the content adapted to the time frame and level of the students?</i></p>	
<p>Teaching <i>How structured is the presentation of the content, e.g. organisation, timeline, identification of main themes? How consistent and comprehensible is the approach? Conclusion: How was the end of the lesson structured? Was orientation given? Other key words: evaluation, summary, take-home message, outlook, guidance for self-study.</i></p>	
<p>Student involvement / activities <i>How are students involved in the learning process? What kind of interaction is predominant? How appropriate is the change of learning activities, e.g. from knowledge transfer to a more active approach to learning? How is the learning atmosphere in the lecture/class (serious, humorous, un/concentrated, enthusiastic, tired, tense...)? How are students' questions, objections, wishes, contributions dealt with?</i></p>	

<p>Methods and approach <i>What methods are used? Are the methods used appropriate to the learning objectives? How are the methods introduced /implemented? Are the methods used appropriate for the setting? Action competence oriented? How are different media used? Is there a change between different social forms such as plenary, individual work, pair work and group work? How is this organised?</i></p>	
<p>Presentation <i>How clear is the lecture? How varied is the lecture? What aspects of body language are noticeable (facial expressions, gestures, posture, body tension, movement)? What aspects of the voice are noticeable (tone, articulation, modulation, pace, volume)? What about eye contact with students?</i></p>	

General

Was there a review of learning or achievement of learning objectives? To what extent were the methods and procedures used appropriate to the learning objective? How did the communication and interaction between teachers and students facilitate learning? Was there an awareness of the different needs of students?

Summary

I liked that a lot, you should keep that:

You could show less of it, you could optimise it:

What I can learn from you:

Peer Observation

[https://www.education.vic.gov.au/Documents/school/teachers/teachingresources/practice/Peer observation feedback and reflection practical guide for teachers.pdf](https://www.education.vic.gov.au/Documents/school/teachers/teachingresources/practice/Peer%20observation%20feedback%20and%20reflection%20practical%20guide%20for%20teachers.pdf)

Guided Road Map

A guided roadmap in education is a concept that provides learners with structured and individualized learning guidance to systematically guide them through their educational and developmental goals. It involves clear planning, monitoring of learning progress, and making adjustments to achieve learning objectives efficiently.

ETH Zurich has adopted a similar method to help students achieve their academic goals while providing flexibility and personal choice. Here is how it basically works:

1. Individualized learning paths

Learners receive personalized learning plans that are tailored to their needs, interests, and prior knowledge. Students can choose their courses and projects to best suit their professional or academic goals.

2. Clear milestones

The roadmap includes specific learning objectives and milestones. These provide students with a clear idea of which competencies or skills should be achieved at which point in time.

3. Continuous support and feedback

Regular feedback and guidance from tutors or lecturers is a central component. At ETH Zurich, for example, there are often mentoring programs or regular meetings with advisors to evaluate progress and adjust the plan if necessary.

4. Adaptive learning platforms

At universities like ETH Zurich, digital learning platforms are often used that offer adaptive content based on data and progress. These systems can help learners identify weaknesses and provide personalized exercises or content based on them.

5. Career preparation

In addition to academic goals, there are often elements that prepare students for the professional world. Projects, internships and workshops teach practical skills that facilitate the transition to the working world.

1. Grading

Grading in a guided roadmap can be done in different ways, depending on the specific program or course. The most common methods of assessment are:

Tests and exams: These can be written or oral exams. They can take place at the end of a module or as a final exam.

Homework or projects: Often, progress is also assessed by submitting projects, written work or other assignments.

Participation and engagement: In some courses, participation and engagement during the learning phases are also assessed.

Self-assessment and peer reviews: Some programs also include elements of self-reflection or peer review.

2. Examinations

Examinations can take various forms:

Midterm exams: These are held halfway through a course to check learning progress.

Final exams: At the end of the program or course, there is often a final exam.

Module-based exams: Each module within the roadmap can conclude with its own exam.

Quizzes and small tests: There may also be smaller quizzes and tests during the learning process to check progress.

8. Feedback and support

The Guided Roadmap often offers regular feedback so that learners know how they can improve. Tutors, mentors or teachers are available to help with questions or problems.

Conclusion

The Guided Roadmap is a well-thought-out method of structuring learning and setting clear assessment standards. Grades are often awarded based on exams, assignments and commitment, with regular feedback to encourage. The “Guided Roadmap” helps students not only to organize their studies efficiently, but also to pursue their personal and professional goals in a structured way.



Globalization

Sequence 2: Global warming

Subject:	Aspects:	Art:	Level GER:	Author:	Version:
General education	Economy, ethics, culture, ecology, politics	Task booklet	B1	A. Hundertpfund	Version 1.2

Introduction

Global warming" flagship program

The air concerns us all; after all, we depend on it like fish depend on water. Increasing allergies, asthmatic illnesses in children, watery eyes in summer, crumbling art monuments, etc. show that the quality of our air is not at its best.

Since the beginning of industrialization at the start of the last century, we have been changing the composition of our air. As **air pollution is interrelated with the climate** and we only have a single atmosphere at our disposal, we have long been talking about a **global problem**.

Reasons enough to get to grips with the wide-ranging **topic of climate change**. From the first chapter "Structure of the Earth's atmosphere" to the end "Measures against air pollution", the topic is introduced *step by step* and accompanied by clear instructions throughout the material.

The guidance program was originally designed by **ETH**. I have adapted it for my lessons. I have omitted one chapter (the original chapter 3) completely and greatly shortened the original chapter 4 (new: chapter 3). The original can be found on the ETH server.¹

The time budget required for studying and solving the tasks is estimated at 8 lessons.

As you have noticed, you are constantly addressed as "you". This is because the ETH guidance program largely determines the tone. I have retained the form of address for my contributions and know that you will understand this.

Materials required:

Environmental Protection Act (EPA): <http://www.gesetze.ch/sr/814.01/index.htm>

¹ <http://www.educ.ethz.ch/unt/um/geo/km/luftverschmutzung/index>

Chapter 1

Basics

As explained in the introduction, air is vital for humans, animals and plants. We experience this with every breath we take: Without air, there is no life.

The **atmosphere** surrounds our planet as a wafer-thin veil. As thin and vulnerable as a tomato skin, it ensures that the Earth does not become a cold desert like other planets. Over millions of years, a layer of air about a hundred kilometers thick has formed around the globe. This layer of air is increasingly being affected by air pollution. This chapter is intended to provide you with the basics to understand the relationships and conditions in the atmosphere.

The sequence of this **chapter** is as follows:

- 1) First, the **composition of air** is explained. In a further step, the **structure of the earth's atmosphere** is described.
- 2) The **greenhouse effect** has a major influence on the climate. Changes in the greenhouse climate can have massive consequences. This is explained in the second part of the chapter.
- 3) Some **terms** that are important for understanding air pollution are explained.

When working through this chapter, you should always keep the following **learning objectives** in mind:

- composition and structure of the Earth's atmosphere.
- Outline the formation of the greenhouse effect in the atmosphere.
- Explain the meaning of some important terms related to air pollution

And one more thing: You can recognize tasks by the numbers in brackets, e.g. (2.1.).



(continued on page 9)

1.1 Structure of the Earth's atmosphere

What is air? Air is a colorless, odorless gas mixture consisting of the following main components:

- 78% nitrogen (N)₂
- 21% oxygen (O)₂
- 0.9% Argon (Ar)
- 0.03% carbon dioxide (CO)₂

In addition, there is the water vapor content (gaseous H₂O). It fluctuates between 0% and 4%. The air also contains so-called **trace gases**, for example: neon, helium, krypton, xenon and hydrogen. They only occur in very small proportions.

The most important component of air is oxygen (O₂). Oxygen is needed for every combustion process. When we breathe in, oxygen is absorbed by the lungs and transported through the blood into the cells of our body, where it is used to burn nutrients (e.g. sugar). Without oxygen, life on earth would not be possible.

Let us now look at the entire atmosphere. It is divided into the following layers:

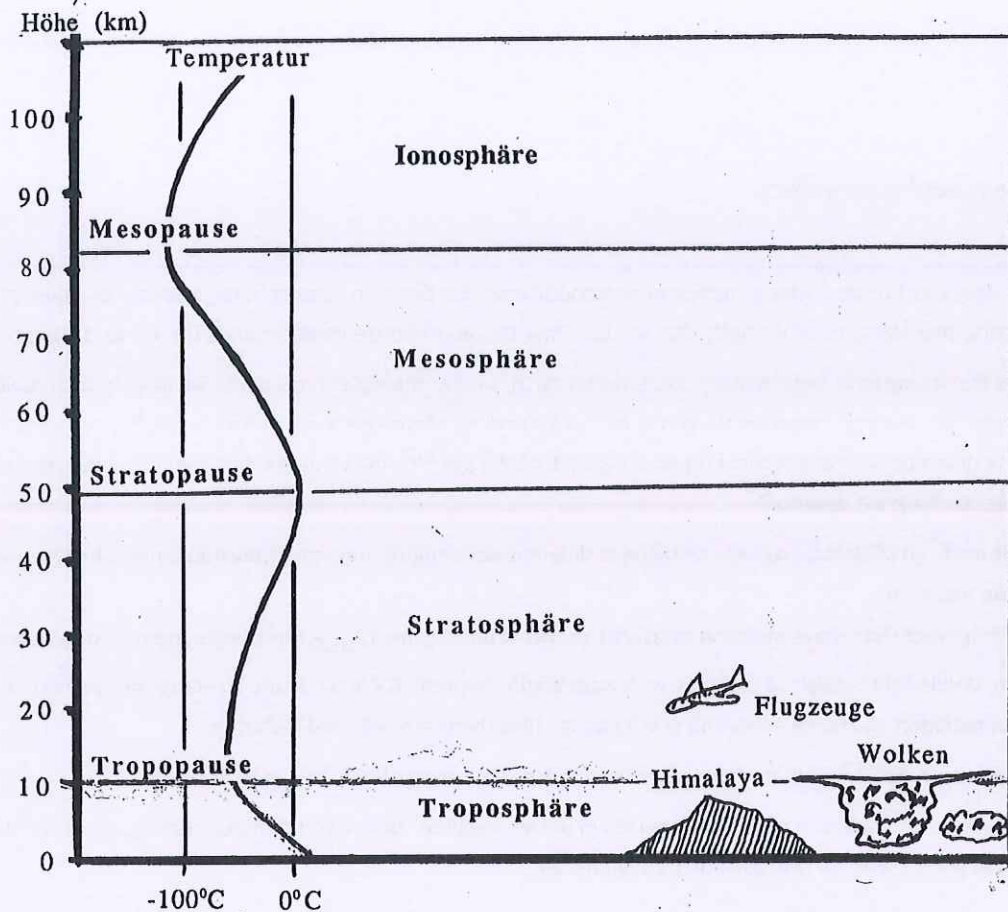


Fig.1-1: The structure of the atmosphere (after Häckel 1985, 40).

The **tropopause** at an altitude of around 10 km separates the **troposphere** from the **stratosphere**. The **stratopause** is located at an altitude of around 50 km and forms the boundary between the stratosphere and the **mesosphere**. Finally, the **mesopause** is located at an altitude of around 80 km and forms the transition from the mesosphere to the **thermosphere**.

As you can clearly see in the illustration, the temperature does not simply decrease steadily with altitude. In the troposphere, the temperature decreases by about 6°C per 1000 m altitude. Weather events take place in this layer, which is why it is also known as **the weather layer**. The huge source clouds of thunderstorms reach up to the tropopause, the upper boundary of the troposphere.

Up to the stratopause, the upper boundary of the stratosphere, the temperature rises and then falls again in the mesosphere. The warming of the air within the stratosphere is due to the influence of the **ozone layer**: The ozone has the property of filtering out dangerous, carcinogenic **ultraviolet** radiation, or UV radiation for short. The ozone layer therefore forms a vital protective shield around the earth. By absorbing the UV radiation in the ozone layer, it is partly converted into heat. This causes a rise in temperature in the upper part of the stratosphere.

The decrease in **air pressure** is also not linear with increasing altitude. At sea level, the normal pressure is around 1000 hPa (hectopascals), at an altitude of 5 km it is half that, namely 500 hPa, and at an altitude of 10 km, at the tropopause, it is still around 250 hPa. This decrease in air pressure is **exponential**.

A01On a hot summer's day, the temperature in Zurich (450 m above sea level) is +30°C. You are lucky and win a balloon ride. It will reach an altitude of around 4000 m above sea level. Why does the balloon pilot advise you to take a warm sweater with you? What temperature should you expect up there?

:°C

So much for the structure of the Earth's atmosphere. The next section explains the function and effect of the greenhouse effect.

1.2 The greenhouse effect

Life can only exist under certain temperature conditions. Earth's thin atmosphere prevents our planet from becoming a cold desert, like Mars, or a hot hell, like Venus. Only the greenhouse effect makes life on Earth possible.

The sun is the driving force behind many processes on earth, such as the water cycle or the weather. It also provides the energy necessary for life. But you know that the sun is around 150 million kilometers away. The amount of solar energy that reaches the upper limit of our planet's atmosphere is permanently **1.4 kWh per m²**. This value is called **the solar constant**. How is energy transported over such a great distance?

Sunlight is made up of electromagnetic radiation of different wavelengths. A rough distinction is made between **long-wave and short-wave radiation**.

The wavelengths of short-wave radiation measure less than 4 μm (1 μm = 1/1000 mm), while those of long-wave radiation measure over 4 μm. Visible light consists of radiation with wavelengths between 0.4 and 0.8 μm. The range below this (< 0.4 μm) is called **ultraviolet radiation**, the range above this (> 0.8 μm) is called thermal or **infrared radiation**.

Only short-wave radiation plays an important role in transporting energy from the sun to the earth.

What happens to the radiation after it is immersed in the atmosphere? Before you continue reading, examine the following drawing. It shows you the path of the radiation through the air.

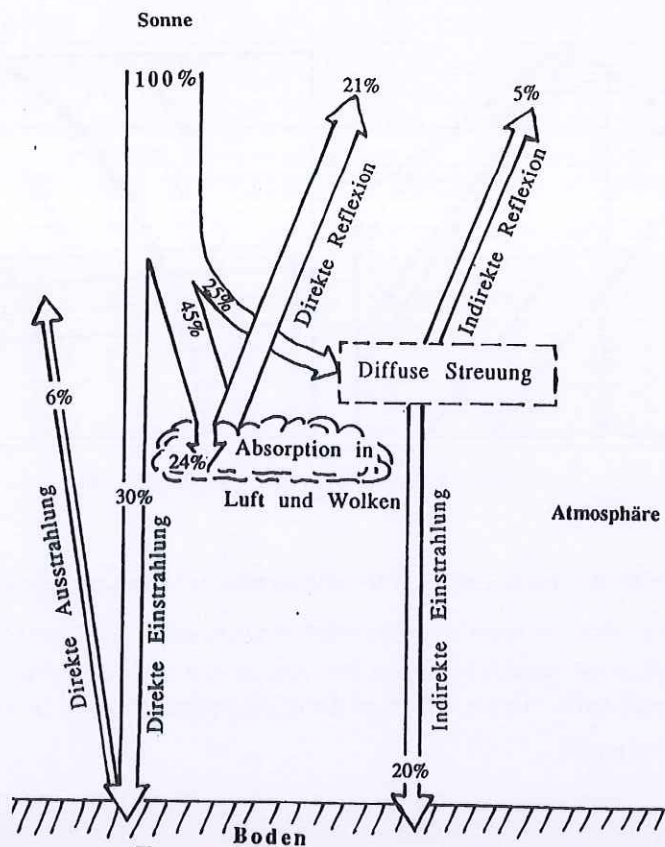


Fig.1-2: Radiation conditions in the atmosphere (Seydlitz 1982, 56).

Of the **100%** of the short-wave radiation arriving from the sun, **21%** is reflected back into space by the clouds. **30%** reaches the ground directly, with **6%** being reflected back into space. **25%** of the incoming short-wave radiation is scattered by the air and water molecules in the atmosphere. This results in so-called diffuse light. **20%** reaches the earth's surface as indirect radiation; **5%** is emitted into space as indirect reflection. **24%** is absorbed in the air and clouds and converted into heat.

The short-wave radiation that remains on the earth's surface (**44%**) is absorbed by it and converted into heat, i.e. the earth's surface heats up and emits long-wave radiation. Some of this radiation remains trapped in the atmosphere because air has a similar effect on this radiation as the glass of a greenhouse: in a greenhouse, the short-wave radiation coming from the sun penetrates the glass pane, is then absorbed by the greenhouse floor and converted into heat. The floor then emits long-wave (infrared or thermal) radiation. This is not transmitted to the outside by the glass of the greenhouse roof, but is reflected, i.e. retained in the greenhouse. As the soil continues to produce and radiate heat by absorbing short-wave radiation and this remains trapped in the greenhouse, the inside of the greenhouse heats up continuously.

Like greenhouse glass, the air in the atmosphere allows short-wave solar radiation to pass through. The infrared radiation coming from the earth's surface is partially transmitted and radiated into space. However, the rest is held back by absorption and reflection in the atmosphere. The result is an increase in the air temperature in the atmosphere. This additional warming is known as the greenhouse effect. Figure 1-3 illustrates these processes.

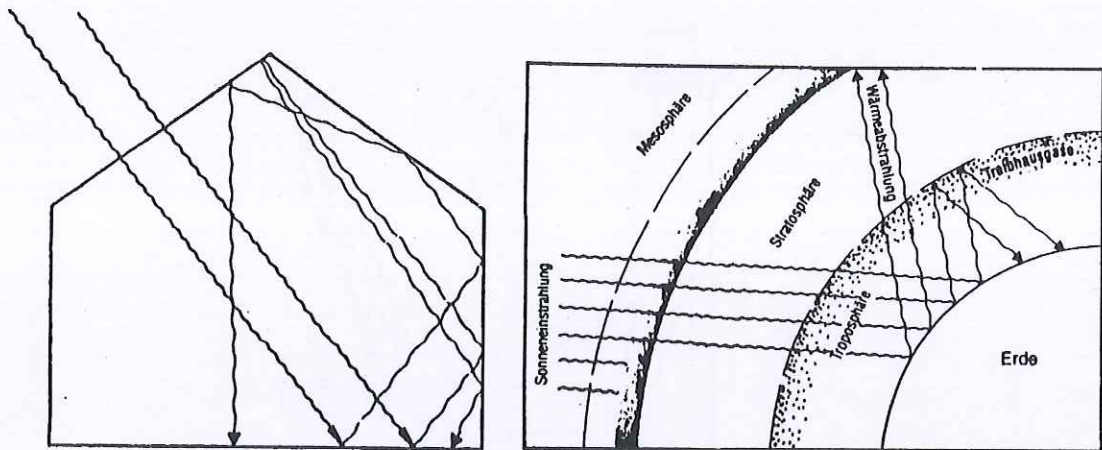


Fig.1-3: Greenhouse effect (Geiger 1989, 18).

The average air temperature on Earth today is +15°C. Without the greenhouse effect, it would be around 30°C lower.

The individual gases that make up the air retain long-wave radiation to varying degrees. They are therefore known as **greenhouse gases**, such as carbon dioxide, nitrous oxide and methane. The water content of the air also has a very large influence on the radiation balance, on the one hand in the form of fog and clouds, but especially as water vapor, i.e. as invisible, gaseous H₂O. We will return to this topic in a later chapter.

1.3 From substance to pollutant

We start with two definitions:

- **Pollutant:** Air pollutants are substances that are present in the air in concentrations that directly or indirectly affect or harm people and/or their surroundings.
- **Concentration:** Concentration is a measure of the quantity of a substance in a unit of mass, volume and/or time.

This usually requires:

- Units of mass such as tons (t), kilograms (kg), grams (g), milligrams (mg), micrograms (µg)
- Volume** units such as cubic meters (m³), cubic decimeters (dm³), cubic centimeters (cm³), liters (l)
- Time units such as year (a), day (d), hour (h), minute (min), seconds (s)

Here are some useful **conversion relationships**:

$$1 \text{ m}^3 = 1000 \text{ dm}^3 = 1'000'000 \text{ cm}^3 = 1 \times 10^6 \text{ cm}^3 = 1 \times 10^9 \text{ mm}^3$$

$$1 \text{ l} = 1 \text{ dm}^3 = \frac{1}{1000} \text{ m}^3 = 1 \times 10^{-3} \text{ m}^3$$

$$1 \text{ t} = 1000 \text{ kg} = 1'000'000 \text{ g} = 1 \times 10^6 \text{ g} = 1 \times 10^9 \text{ mg} = 1 \times 10^{12} \text{ µg}$$

$$1 \text{ a} = 365 \text{ d} = 8760 \text{ h} = 525'600 \text{ min} = 31'536'000 \text{ s}$$

Air pollutants are produced by a source, e.g. a gasoline engine, and released into the air. They spread or are dispersed by air currents. They can develop their harmful effects in their surroundings, but also at great distances from the source. In this context, you will now get to know four important terms.

- **Emission:** Emission is the transfer of pollutants from a source into the open atmosphere. For example, a car engine produces pollutants that are released into the environment via the exhaust. The exhaust gases are **emitted** into the air.
- **Transmission:** Transmission refers to the dispersion, transportation and any chemical transformation of the emitted substances in the atmosphere. In our example, the pollutants are emitted by the engine and carried away from the road by the wind. Dilution takes place in the process. Individual components can be changed by chemical reactions with air

constituents, with other pollutants or with sunlight. Transmission is primarily influenced by meteorological conditions such as wind speed, wind direction, solar radiation intensity and precipitation.

- **Deposition:** The pollutants moved by transmission are deposited on the earth's surface again over time. They are **deposited**.
- **Immission:** Immission is the impact of pollutants on humans and the environment (animals, plants, water, soil, the atmosphere and buildings or other man-made objects).

A02Correctly enter the four terms in the diagram below.

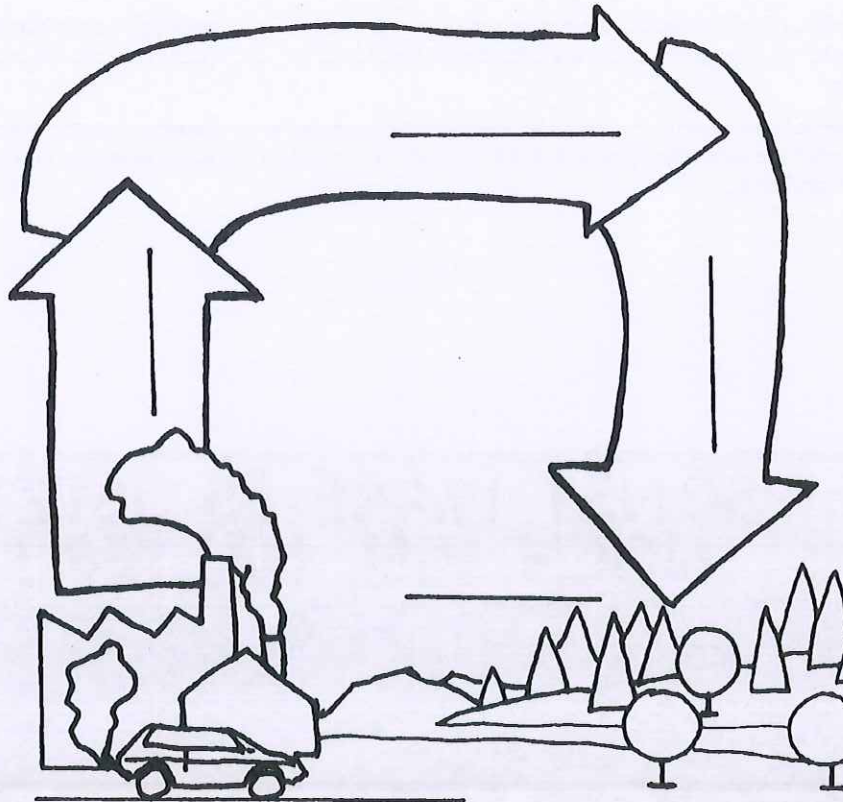


Fig.1-4: Pollutant transport (SAEFL air dossier 1991 p.17).

1.4 Summary

- The atmosphere consists of **78% nitrogen**, **21% oxygen**, **0.9% argon**, **0.03% carbon dioxide** and other **trace gases**.
- The atmosphere is divided into the **troposphere**, the **stratosphere**, the **mesosphere** and the **thermosphere**.
- The **ozone layer** is mainly located in the upper stratosphere and filters out dangerous UV radiation from sunlight.
- The sun irradiates the earth with a constant flow of electromagnetic rays of different wavelengths.
- Only just under half of the solar radiation that penetrates the atmosphere reaches the earth's surface directly or indirectly. Around a quarter is absorbed by air gases and clouds, while the remaining quarter is reflected into space.
- The earth's surface, heated by short-wave solar radiation, radiates long-wave (infrared) radiation, some of which remains trapped in the atmosphere and leads to higher temperatures. Without this greenhouse effect, life on earth would not be possible.
- A substance is released from a source (**emission**), distributed in the air (**transmission**) and possibly transformed. Finally, it is deposited (**deposition**), whereby it usually acts on contact substances at the deposition site in such a way that damage occurs (**immission**).



MASTERY

Now check independently whether you have understood the basic chapter. To do this, answer the following questions:

A03 The air pressure decreases exponentially with altitude. What is the temperature curve with increasing altitude? Describe the temperature curve in the lowest 100 km of the atmosphere.

A04 It is mainly short-wave radiation from the sun that reaches us. 30% reaches the earth's surface directly. What happens to the remaining radiation (70%)?

- in the clouds?

- in the air on the air molecules?

A05 You have learned about some important terms that play a role in the topic of air pollution. Describe in a few words what they mean:

Emission : _____

Transmission: _____

Deposition : _____

Immission: _____



ERL⁰¹

Chapter 2

Some primary pollutants

2.1 Primary pollutants and their sources

In general, the most important air pollutants can be divided into **three groups**:

- Industry and trade	Individual, mostly strong emitters (pollutant sources) with a wide variety of substance emissions that are difficult to record.
- Traffic	Both are rather weak emitters, but occur in very large numbers in populated areas.
- Domestic furnaces	The composition of their emissions is better known.

2.1.1 Carbon dioxide (CO₂) and carbon monoxide (CO)

The composition of our air is the product of an evolution that has taken several billion years. CO₂ also occurs naturally in the air. However, the CO₂ content of the atmosphere is anything but a constant. Scientific studies of gas inclusions in the Antarctic ice have shown that it is subject to large fluctuations over long periods of time. However, the fact that it has never been as high as it is today in the last 150,000 years points to an anthropogenic (= man-made) influence. Its main contribution to the greenhouse effect makes it a recurring topic of discussion.

The CO₂ content of the atmosphere is only around 1/60 of that of the oceans. As a result, the **residence time** (the average time a CO₂ molecule spends in the atmosphere) of carbon dioxide is relatively **short**. It is a characteristic of the size of a reservoir and is approx. **10 years** for CO₂ (for comparison: the residence time of nitrogen N₂ is 4 x 10⁸ years!). However, this also makes human activities very important. The unbridled **burning of fossil fuels** (this also includes flaring, i.e. burning natural gas from oil deposits) and the **clearing of tropical rainforests** lead to the accumulation of CO₂ in the atmosphere. The current **concentration** is **350 ppm** (parts per million). It has risen by around 35 ppm, i.e. 10%, since 1950! Car engines mainly emit CO (carbon monoxide), which gradually reacts with O₂ from the air to form CO₂. The seasonal fluctuation of the CO₂ concentration (approx. 7 ppm lower in summer than in winter) reflects the seasonal ups and downs in the photosynthetic activity of plants, especially in mid-latitudes (more photosynthesis in summer).

Solve all the following tasks, unless otherwise specified, on separate blank sheets of paper. This allows you to work through each chapter several times without already having your answers in front of you.

Solve all the following tasks, unless otherwise specified, on separate blank sheets of paper. This allows you to work through each chapter several times without already having your answers in front of you.

A06 (You will find Figures 2-2 and 2-3 in the appendix).

A06.1 Compare the two graphs with the titles "World population" and "Carbon dioxide content" (Fig. 2-2). Describe and explain the course of the two curves!

A06.2 Do the same for the two graphs entitled "Temperature deviation from the long-term average" and "Carbon dioxide content" (Fig. 2-3). Pay particular attention to the trend of the two curves in recent times.

2.1.2 Nitrogen oxides (NO)_x

Nitrogen (N₂) is the main component of the atmosphere (78%). The atmosphere also contains a number of gaseous nitrogen compounds, which are summarized under the term nitrogen oxides. These are of primary importance:

- Nitric oxide (NO)
- Nitrogen dioxide (NO₂) and
- Nitrous oxide (N₂O), also known as laughing gas.
- Nitrogen monoxide (NO) and nitrogen dioxide (NO)₂

NO and NO₂ are produced during high-temperature (T > 500-600 °C) **combustion processes**, especially in **road traffic** and **heating**. Between 90 and 95% of them are emitted as nitrogen monoxide (NO) and converted into the more toxic nitrogen dioxide (NO₂) in the atmosphere. In the canton of Zurich, 25,150 tons of nitrogen oxides were emitted from exhaust pipes, chimneys and jet engines in 1985. Traffic accounts for around three quarters of this figure. The catalytic converter considerably reduces nitrogen oxide emissions. Since combustion at high temperatures oxidizes some of the numerous nitrogen molecules present in the air, the problem of nitrogen oxide formation cannot be solved by changing the composition of the fuel (as with sulphur dioxide, see 2.1.3).

The concentration of NO and NO₂ **varies throughout the year**. The highest values are reached in the winter months. The lower concentrations during the summer months are due to **two effects**:

- Better dilution due to higher turbulence in the atmosphere.
- Higher conversion into secondary pollutants due to the influence of sunlight.

Nitrogen oxides are produced **naturally**, particularly by **lightning**. Electrical discharges in the air generate temperatures of up to 30,000°C; this oxidizes N₂. This process produces around 2,400 tons of nitrogen oxides in Switzerland every year. Further emissions are caused by **forest fires** (approx. 40 tons/year) and by **productive soils**. Microorganisms in these soils emit approx. 6,600 tons per year.

The **residence time** in the atmosphere is approx. **2-5 days**.

Nitrous oxide (N₂O) or laughing gas

Nitrous oxide is mentioned less frequently in the "air pollution debate" than NO and NO₂. This is probably mainly due to its completely different mode of action (see next chapter). It is produced naturally by **microbial denitrification** (i.e. reduction of NO₃⁻ to N₂) by microorganisms and by **nitrification** (i.e. oxidation of NH₄⁺ to NO₃⁻) **in soil and water**.

Nitrous oxide is emitted anthropogenically (by humans) through the **burning of biomass and fossil fuels, through land cultivation** and through **artificial nitrogen fertilizers**.

The **residence time** in the atmosphere is approx. **170 years**.

A07 Below you will find an excerpt from a newspaper article. It is from a period in the last century when the problem of air pollution was viewed somewhat differently. At the very end of the article, reference is made to the considerable reduction in nitrogen oxide pollution:

A07.1 Consider the range of concentration fluctuations from year to year? Are they rather large or small?

A07.2 Are you hopeful about the decline? What could have caused it?



Less nitrogen and yet too much

... The limit values for nitrogen dioxide, on the other hand, continue to be exceeded at the three measuring points near the city, most clearly in Opfikon, near the airport highway. An annual average value of 46 micrograms per cubic meter of air was recorded here, the limit value is 30 micrograms. In Wallisellen and Schwamendingen, these values were 36 and 38 micrograms respectively.

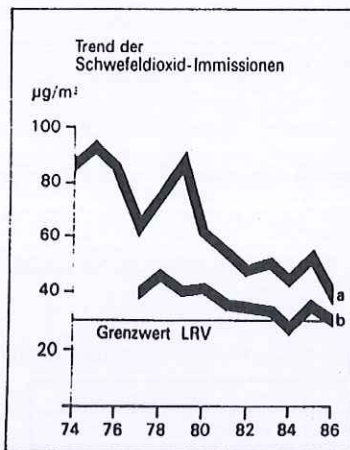
Compared to previous years, however, pollution has fallen by around a third. In 1986 and 1987, values were measured that were around 25 micrograms higher.

Tages Anzeiger, , 5.2.1991, p. 17

2.1.3 Sulphur dioxide

Sulphur dioxide is mainly produced during the **combustion of fossil fuels** (namely coal and crude oil, both of which have a highly variable sulphur content) and around 80% of it comes from **domestic and industrial furnaces**. As heating is therefore a major source, higher values are recorded in winter than in summer due to inversions and the heating period. In general, there has been a significant reduction in sulphur dioxide emissions. This shows that the measures introduced, in particular the reduction of the sulphur content in heating oil and the switch to natural gas, are producing significantly better results.

Natural emissions are mainly caused by **forest fires and volcanic eruptions**. However, these quantities are negligible compared to anthropogenic emissions.



A07.3

- List two measures that explain the decreasing trend in sulphur dioxide emissions in the graph opposite.
- Why is the sulphur dioxide problem easier to tackle than the nitrogen oxide problem?

Fig.2-5: Trend in sulphur dioxide emissions in the city of Zurich. (Air pollution control in the Canton of Zurich 1987, 22).

Jahresmittel aus kontinuierlichen Messungen in der Stadt Zürich:
 a) Messort in Zentrumsnähe (Stampfenbachstrasse 144)
 b) Messort an Peripherie, in Waldnähe (Frohburgstrasse/Winterthurerstrasse)

2.1.4 Organic compounds: VOC, CFC, methane

The collective term "organic compounds" is not used strictly in the chemical sense in air hygiene. It covers a wide range of different volatile organic compounds. Highly volatile substances are the most significant in the air.

VOC: Volatile organic compounds (VOCs)	These mainly escape when organic substances evaporate, e.g. gasoline (when refuelling) or solvents and during the incomplete combustion of petroleum products (e.g. in traffic).
CFCs: chlorofluorocarbons	They are a prominent example from current environmental discussions and are therefore specifically mentioned. These are substances that are mainly used as coolants, solvents, propellants in aerosol cans (CFCl ₃ or CF ₂ Cl ₂) and for foaming foam plastic and are re-released into the atmosphere sooner or later.
CH ₄ : Methane	Methane, also a hydrocarbon, should be mentioned here in particular, as its concentration in the atmosphere has doubled in the last 200 years. At the same time, methane is a highly effective greenhouse gas, far more effective than e.g. carbon dioxide (CO ₂). In Switzerland, around a quarter of all emissions of this substance come from natural sources. Worldwide, agriculture and land use in the tropics are the main contributors to its emissions. Microbial processes in swamps, rice fields and grasslands (activity of methane bacteria in swamp gas and biogas) are among the sources, as are livestock farming (mainly produced in the digestive tract of ruminants) and volcanoes. At the anthropogenic level, slash-and-burn agriculture and the burning of fossil fuels are again the main causes, as methane is produced there as a result of incomplete combustion processes. More recently, methane leaks from leaking gas pipelines in Siberia have also been added to the list.

2.2 The effects of primary pollutants on humans and the environment

2.2.1 Carbon dioxide (CO₂) and carbon monoxide

The colorless and odorless gas CO₂ has no direct impact on human health in the concentrations found today. However, as a **greenhouse gas**, its effects on global warming have been proven. From a global perspective, its significance is of paramount importance!

Carbon monoxide CO combines with hemoglobin and thus prevents the oxygen transport of the blood. For this reason, the idea in Fig. 2-6 cannot be described as particularly good!

The atmosphere is a reservoir for C-substances. The following table shows how many of these substances are deposited and where:

Atmosphere	Lithosphere	Hydrosphere	
700	70'005'000	40'000	in gigatons
1	100'000	approx. 60	as ratios

Fig. 2.5.1: C-substance storage in different environments

2.2.2 Nitrogen oxides (NO)_x

a) Nitrogen monoxide (NO) and nitrogen dioxide (NO)₂

Even slightly elevated levels of nitric oxide (especially NO₂) can trigger the following effects in humans:



Fig. 2-6: "Cat-Plus" model (UMWELT VERKEHR 1991, 37).

- Disease of the respiratory tract (transformation of the bronchial walls, weakening of the infection defense cells, higher risk of bronchitis)
 - dysfunction of the lungs (constriction of the bronchial tubes makes breathing difficult and can lead to asthma or exacerbate asthma).

The **environment** suffers because

- Nitrogen oxides cause a variety of damage to plants, especially in the case of combined effects (**synergy effects**)
 - nitrogen oxides contribute to acid rain (see next chapter)
- nitrogen oxides are precursors of summer smog
- Nitrogen is a nutrient that is used in many artificial fertilizers. Increased nitrogen content in the air leads to "fertilization" of the plants via **dry and wet deposition** (deposition directly from the air or with the help of

rain). Depending on the soil type and plant cover, this can lead to disturbances in soil chemistry and nutrient balance.

b) Nitrous oxide (N₂O) or laughing gas

In addition to its direct contribution to the greenhouse effect in the troposphere (section 1.2.), N₂O also has an indirect effect in the stratosphere. Through a series of chemical reactions, an increase in N₂O causes a reduction in the ozone content in the upper stratosphere, which ultimately leads to increased permeability of the atmosphere for UV radiation up to the earth's surface. This ultraviolet radiation causes skin cancer or plant damage, for example.

2.2.3 Sulphur dioxide (SO₂)

Sulphur dioxide **affects human health** in a similar way to nitrogen oxides. The pungent-smelling gas affects the respiratory tract, especially in combination with dust, irritates the skin and mucous membranes and, in higher concentrations, leads to **breathing difficulties** and **chest pain**. Here too, asthmatics and children are particularly at risk.

It also leaves its mark on **the environment**. With water, SO₂ forms sulphurous acid and in the presence of atmospheric moisture, SO₂ reacts with atmospheric oxygen to form sulphuric acid. These acids (along with nitric acid HNO₃) are the main components of **acid rain**. In addition, SO₂ causes **the death of tissue** in plants by breaking down chlorophyll. Due to its aggressiveness in relation to various materials, it contributes significantly to the **decay** of numerous **historical buildings**.

2.2.4 Organic compounds: VOCs, CFCs, methane

VOC: Volatile organic compounds (VOCs)

They are very odorous and cause the typical exhaust stench. Together with nitrogen oxides, they form photochemical smog, which causes irritation of the mucous membranes and eyes in humans. They also contain carcinogenic substances such as benzene, which can cause leukemia. In the environment, they also have a damaging effect on plants and buildings and are involved in the formation of ozone in the air layer near the earth's surface.

CFCs: chlorofluorocarbons

They have become "famous" for their destructive effect on the ozone (O₃) in the stratosphere. This is why they are always mentioned in connection with the hole in the ozone layer. However, they also contribute to the artificial greenhouse effect.

CH₄ Methane:

The effects of methane on humans and the environment are diverse and complex:

In the troposphere, it interacts with OH⁻ (synergy effect) to prevent the breakdown of various pollutants (such as chlorofluoromethanes, carbon monoxide and hydrogen sulphide). Together with nitrogen oxides (NO_x), it forms ozone and is therefore involved in the greenhouse effect, plant damage, forest dieback and damage to health.

2.3. Overview and summary

(Possibly orally in plenary)

MASTERY

Now you can check for yourself whether you have read and understood chapter 2 carefully. To do this, answer the following questions:

A 08

- A08.4.1 What are the specific problems caused by air pollution from industry and commerce (waste incineration, etc.)?
- A08.4.2. Is the atmosphere a small or large C reservoir compared to the oceans and the lithosphere?
 - Give the approximate ratio between the three reservoir contents.
 - What are the consequences?
- A08.4.3 Of the substances treated, only one is worth mentioning, for which around a quarter of emissions come from natural sources. Which one is it and which sources (worldwide) contribute to it?
- A08.4.4. Hans, the committed leader of the youth nature conservation group, has been trying for a long time to cultivate a rough pasture behind the house. Fertilizer of any kind is absolutely taboo on this small piece of land. He wants to increase biodiversity by adding plants that only thrive on nutrient-poor soil. Unfortunately, even after a few years, success is slow to come. Think about why this might be the case.

Now it's up to you to decide whether you want to read certain passages again.



Source: http://www.toonpool.com/cartoons/Klimaei_48173

Chapter 3

Effects of air pollution

3.1.2 Possible effects of the artificial greenhouse effect

By increasing the concentration of greenhouse gases in the atmosphere, the natural greenhouse effect is amplified. In order to determine the direct impact of the artificial greenhouse effect, mathematical models are now available - the so-called **General Circulation Models (GCM)**. These models describe the dynamic processes within the climate system and the complex interactions between the various components. However, these models are **simplifications** of natural processes. The predicted climate changes are therefore subject to **uncertainty**.

Temperature increase

When estimating the temperature increase resulting from the artificial greenhouse effect, a doubling of CO₂ compared to the pre-industrial value of 280 ppm is generally assumed. Figure 4-7 shows, based on the year 1765, the course of the average temperature increase (average curve, best estimate) in the case of an **uninfluenced development of emissions** (business-as-usual scenario). In this scenario, it is assumed that no measures will be taken in the future to reduce and control emissions of individual greenhouse gases. A temperature increase of around **0.3 °C per decade** is expected over the next century. Such an increase in temperature would be unprecedented in the last 10,000 years! In 2025, the average global temperature is therefore likely to be around **1 °C** above today's value (+15 °C). By the year 2100, the temperature on Earth would rise by around **3 °C**.

A09

A09.1. According to Figure 4-7, what is the uncertainty range of the expected temperature increase up to the year 2100?

A09.2. How do you explain the wide variation between the three estimated temperature rises?

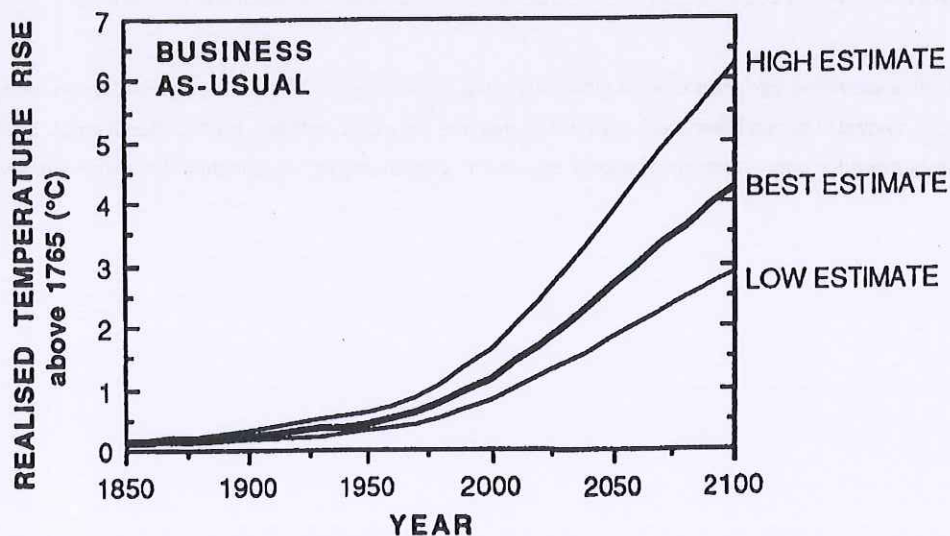


Fig.4-7: Model simulation of the average global temperature increase from 1850 to 2100 (Houghton et al. 1990, xxii). The calculations from 1850 - 1990 are based on the observed increase in the concentration of greenhouse gases in the atmosphere. The prediction of the temperature increase from 1990 - 2100 is based on the business-as-usual scenario.
best estimate = estimated mean temperature rise
low estimate = low estimate

high estimate = high estimate

At present, no reliable predictions can be made about the **regional distribution of temperature changes**. However, it is assumed that land areas are warming faster than the oceans. A greater change in the mean annual temperature is expected in the higher latitudes than in the equatorial regions. In winter, the temperature rise in the higher latitudes is even expected to be 50 - 100% greater than the global average. For Switzerland, the model calculations result in an increase in the average summer temperature of 0 - 6 °C and the average winter temperature of 4 - 8 °C.

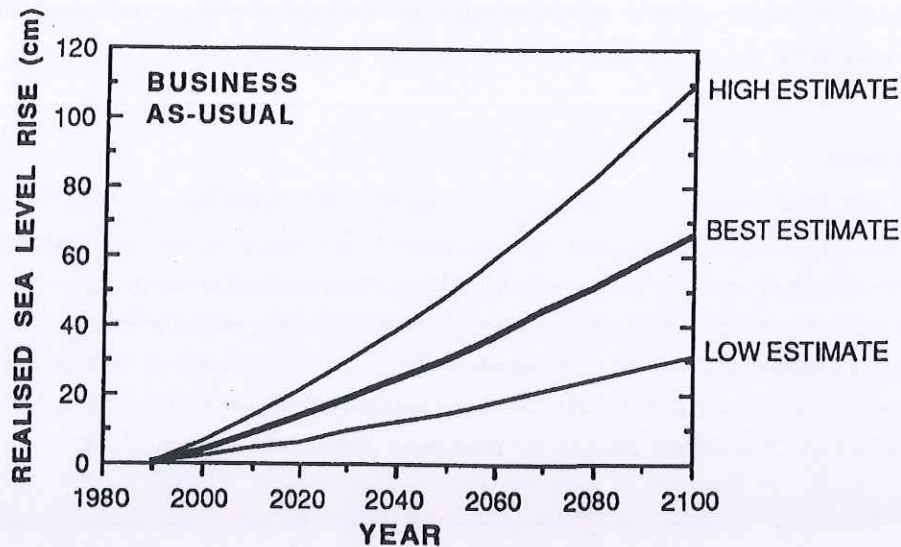


Fig.4-8: Projected sea level rise assuming the business-as-usual scenario. (Houghton et al. 1990, xxx)
best estimate = estimated mean temperature rise
low estimate = low estimate
high estimate = high estimate

Possible consequences of an increase in temperature

Due to global warming, **sea levels** will rise as a result of the thermal expansion of the oceans and the melting of ice masses. Assuming the business-as-usual scenario, a sea level rise of **20 cm** is forecast for the year 2030 and approx. **65 cm** for the year 2100 (see above: Figure 4-8, middle curve, best estimate). The uncertainty range here is 30 - 100 cm (low and high estimate curves). Regional differences are also to be expected here. A sea level rise of one meter would threaten a whole series of countries (e.g. Egypt, Bangladesh).

Problems would also arise in **agriculture**. With global warming in the range of 1.5 - 4.5 °C, the vegetation zones are likely to shift meridionally by **several hundred kilometers**. This will change the growing conditions for traditional crops. Such changes are likely to be particularly serious for poor countries with large population growth and for regions that already have unfavorable climatic conditions.



http://www.toonpool.com/cartoons/Emission_68322#img9

Chapter 4

Measures against air pollution

Research into processes in the atmosphere makes an important contribution to understanding air pollution. If we do not know where the pollutants come from, how they are formed and how they work, we cannot take targeted measures to combat air pollution.

The sequence of the chapter looks like this:

- 1 First, you will learn about the legal foundations that form the basis for air pollution control regulations.
- 2 In the second part, you will be presented with some concrete measures to reduce air pollution.
3. at the end, measures are shown that you can take personally to make a contribution to keeping the air clean.

Keep the following learning objectives in mind:

- At the end of the chapter, you can explain what legal means can be used to reduce or prevent air pollution.
- You can name some important measures against air pollution. You are also able to represent these to a third party.
- You show how you could behave in a less air-damaging way in the future.

4.1 The legal basis

4.1.1 The necessity of the law

The diverse effects of air pollution threaten people and their environment in many different ways. The realization that something must be done about this has grown. It is therefore necessary to **take measures** to reduce the harmful effects in a relatively short time or even to avoid them forever. The first step is therefore to establish regulations. In a second step, these must be enforced.

The appropriate instrument for this approach in Switzerland is the **constitution**, consisting of various **laws** and **ordinances**. These documents define the rights and obligations of citizens and the state. For example, a measure can be **enforced** by means of a legal basis. What exactly does that mean?

Here is an example:

According to the law, a corresponding measure must apply to everyone. If someone refuses to comply with it, they can be forced to do so by the state. The law authorizes the state to do so.

The Federal Constitution contains basic rights and duties. However, the constitutional text is relatively general. The individual articles must **be regulated** in more detail, i.e. **more precisely**. This is done in the **laws**. They are always based on a constitutional article. **The people can vote** on amendments to the constitution and also on new laws. This ensures that a provision is accepted by the majority of citizens. The authorities can then rely on this majority will when enforcing them.

Often, however, not all details are regulated in the laws. **Specific values and details** are therefore often laid down in so-called **ordinances**.

A10

A10.1 What is the legal basis?

A10.2 What are they used for in terms of air pollution?

A10.3 Who decides on the adoption or rejection of constitutional and legislative amendments?

As you can see, the law makes statements about five different areas. We are particularly interested in chapter 1 in title 2. The law contains the following brief **summary**:

- a) The above-mentioned environmental impacts should be limited by measures at the place where they occur. Emissions should be prevented wherever possible.
- b) Emission limits must be **tightened** if the effects on the environment become harmful or a nuisance.
- c) Emissions must be limited by issuing regulations. These include, for example, **emission limit values**, building regulations, traffic regulations and others. These must be complied with.
- d) **Immission limit values** are required to assess the point at which impacts cause damage. They form the damage threshold.
- e) Installations must be **remediated** if they do not comply with the provisions of the law.

You have noticed that the law mentions limit values. However, it does not mention any specific figures. In order for it to be applicable to individual cases, an ordinance is required.

A11

The law provides for measures at various levels:

Emissions are to be limited. This is done, among other things, with emission limit values. However, if the effects become harmful, the emission limit values must be tightened. The immission limit values serve as a yardstick for the harmfulness of the effects.

A11.1 Imagine the following situation:

There are increasing cases of respiratory illnesses near a factory. At first, only children and the elderly were affected. Now more and more adults between the ages of 20 and 60 are complaining of constant coughing and unbearable pain in their throats.

Think about what could be the cause of these illnesses. Then make a brief note of what the law requires to be done in this case.

4.1.3 The Ordinance on Air Pollution Control

The **Ordinance on Air Pollution Control**, or LRV for short, regulates four areas:

1. precautionary emission limitation
2. the requirements for fuels and combustibles
3. the maximum permissible air pollution (so-called immission limit values)
4. the procedure in the event of an excessive increase in immissions.

What are these four areas about?

- 1) Limit values are listed in the relevant annexes to the ordinance as a precautionary measure to limit emissions. For a wide variety of substances, the exact quantities of a substance that may be released into the air are specified there.
- 2) Fuels and combustibles must also comply with limit values. The main aim here is to keep the sulphur content low.
- 3) Immission limit values define the maximum permissible air pollution. The impact of a pollutant at one location should not exceed this value.
- 4) If the emissions exceed this limit value and no single polluter can be identified, an action plan must be drawn up. This provides for stricter emission limits. This affects all installations that emit the relevant pollutant.

The main instrument of the Ordinance on Air Pollution Control for combating air pollution is the **limit values**. They form the framework on which the measures are "hung". If they are adhered to, there is no reason to intervene. However, if they are exceeded, a whole package of measures is usually necessary.

A **limit value** is defined as the concentration of a substance that is considered **harmful** if it persists over a certain period of time.

Here is an example:

If the ozone limit value of $120 \mu\text{g}/\text{m}^3$ is exceeded for several hours on a fine summer's day, people who are sensitive to ozone suffer from eye irritation, coughing and other symptoms. According to scientific findings, a limit value is therefore the **value that does not cause any damage in the long term**.

The **emission limit value** is the maximum permissible concentration of a pollutant in the **exhaust gases** of an emission source.

According to the current state of knowledge, the **immission limit value** separates the harmless concentration range from the harmful one. It forms the **damage threshold**, so to speak.

Compliance with the limit values must be checked. This requires measurements, which are often carried out at the same location over a long period of time. Persistently exceeding the limit values triggers certain measures to combat air pollution.

A12

A12.1 What is the main instrument of the LRV?

A12.2 How is the main instrument defined?

A12.3 Consider the difference between emission and immission limits.

4.2 Measures

Specific measures are needed to comply with the limits that are often exceeded. Any action that is suitable for helping to reduce air pollution is considered a measure. Correspondingly different measures must be taken for the large number of emitters.

We deal here with the following issuer groups:

- Furnaces
- Passenger transportation
- Freight transport
- Industry and trade

a) Measures relating to furnaces:

The aim here is to reduce emissions of NO_x and SO_2 . The corresponding limit values in the Ordinance on Air Pollution Control set the target. It is achieved through the following measures:

- Use of low-sulphur fuels
- Use burners that emit less NO_x
- Saving heating energy through:
 - the insulation of buildings
 - individual, consumption-based heating cost billing. (If you consume less, you pay less!).
 - financial incentives from the state to promote alternative energies such as solar and geothermal energy.
 - Tax deductions for energy-saving investments in buildings.
 - correct maintenance and adjustment of the heating system.
 - replacing old heating systems with new, low emission, correctly dimensioned systems.

b) Measures relating to the movement of persons:

The main aim here is to encourage people to switch to lower-emission public transport. This can be achieved through various measures:

- **Increasing travel speed** on public transport, improving reliability and comfort.
- Offer **fewer parking spaces** in the city. Make the remaining parking spaces **more expensive**.
- Create additional **'Park+Ride'** facilities at train stations. Drivers can park their cars there at reasonable prices and transfer to the train.
- **levy taxes on fuel**. This will make private transportation more expensive. This is intended to provide a financial incentive to use public transport, which may be cheaper.
- In order to make cars themselves drive with lower emissions, **emissions regulations** are being **tightened**. Regular **checks** ensure compliance.

c) Measures relating to freight traffic:

As with passenger transport, the exhaust emission limits should also be complied with here. To achieve this, the technical possibilities for saving emissions must be exhausted.

- Old vehicles should be replaced as quickly as possible with lower-emission vehicles. **Regular exhaust emission checks** also ensure compliance with the regulations.
- **Avoidance of empty runs**. Switching the transportation of **goods to rail**.
- **Speed reductions** for passenger and goods vehicles should result in fewer pollutants being emitted.

d) Measures that affect industry and commerce:

The same measures apply here as for furnaces. In addition, the consumption of volatile organic compounds (VOCs) should be reduced. This can be achieved by means of the following measures:

- Increase in price or replacement of the VOC.

Reduction in the price of low-solvent products.

-capture released VOCs and feed them back into the manufacturing process.

-Install flue gas cleaner.

-waste separately and recycle it, i.e. send it for reuse. This avoids emissions that would be caused by incineration or new production of the material.

A13 List all the measures for the following groups of issuers that you have learned about.

Furnaces	Passenger transport	Freight traffic	Industry+Commercial

4.3 What can I do about air pollution?

The air pollution control targets have been set. As you have seen, regulations have been issued for this purpose. They are intended to help protect the common good and each individual. However, **voluntary measures** are better than regulations. Every individual or company should take responsibility for clean air. It is important to change your own behavior where necessary. This is all the more important as it is already clear that technical regulations and political measures alone will not be enough to achieve the clean air targets within a reasonable period of time.

Voluntary restriction is therefore more necessary than ever. **You can also help with this.** The advantage is that you can decide for yourself how to change your behavior. It is up to you which technical and other means you want to use to achieve the goal of "clean air".

The following sections briefly summarize what you can do to combat air pollution.

a) In traffic:

- The general rule is: **drive less by car and motorcycle!**
- Where there is less driving, there are also fewer exhaust fumes. You should avoid unnecessary journeys. Walk or cycle short distances. Use the streetcar and train.
- If you still need the moped or car: ride **less fast and more evenly**. Lane acceleration may seem "great", but it unnecessarily pollutes the air with additional pollutants! Switch off the engine when stationary. Use cars with catalytic converters. **Drive together:** a car with four people pollutes the air less than four cars with one person!

b) When heating (with wood, oil, gas):

- **Reduce the room temperature:** where there is less heating, there are also fewer exhaust fumes. In winter, you should only **ventilate rooms briefly, but vigorously**.

c) At school:

- Replace environmentally harmful substances in your school materials with lower-emission ones: **environmental paper** is recycled waste paper and uses less energy and raw materials in its production. This also produces fewer emissions. The same applies to other recyclable (reusable) materials. So: take part in recycling at school. As with heating, the same applies here: **Lower the room temperature and only ventilate briefly and vigorously**.

d) At home:

- If you produce **less waste**, you also produce fewer pollutants when you incinerate it! Look out for unnecessary packaging material when you go shopping.
- **Kitchen and garden waste, waste glass, waste paper, pet bottles, aluminum and scrap metal** are recyclable. They therefore do not belong in the waste bin, but at the **collection point**. **Batteries, waste oil, fluorescent lamps and solvents** must be disposed of separately. Incinerating them would produce toxic pollutants. To protect the ozone layer in the stratosphere, you should **avoid using aerosol cans with chlorofluorocarbons (CFCs) as propellants**.

A14 Max has just come home from school. The teacher has once again given them a load of white paper to work through over the weekend. But he wanted to go skiing! His parents even wanted to give him the car! He would have loved to throw the whole pile of paper in the bin. He is hot with anger. He opens the window in his overheated room. The cool air feels good. It's time for dinner. He leaves the window open and goes into the kitchen. His mother wants him to dispose of the kitchen waste. He throws them in the bin. To make matters worse, the neon lamp in the kitchen burns out! Max agrees to replace it. The burnt-out tube ends up in the garbage can. "There," he thinks, "I've earned this dinner."

It is now your job to point out Max's failings. What should he have done or not done to prevent additional pollutants being released into the air? Give your answer in short key words.

A15 Below is an excerpt from Annex 7 of the Ordinance on Air Pollution Control. The immission limit values for sulphur dioxide and ozone are indicated.

Pollutant	immissions limit	value	Statistical	definition
Sulphur dioxide	30	$\mu\text{g}/\text{m}^3$	annual	mean value
	100	$\mu\text{g}/\text{m}^3$		95% of the 1/2 h mean values of a year _ 100 $\mu\text{g}/\text{m}^3$
	100	$\mu\text{g}/\text{m}^3$	24-h	mean value ; may be exceeded no more than once per year be exceeded
Ozone	100	$\mu\text{g}/\text{m}^3$	98%	of the 1 st decade of a month _ 100 $\mu\text{g}/\text{m}^3$
	120	$\mu\text{g}/\text{m}^3$	31-h	mean value ; may be exceeded no more than once per year be exceeded

(μg = microgram; 1 μg = 0.001 mg)

What is the purpose of setting immission limit values? Give your answer in short sentences.

A16 Imagine you were responsible for traffic in your canton of residence. Measurements have shown that the immission limits have been massively exceeded recently. Your administrative department is asked by the cantonal government to propose measures to reduce the pollutants. The cantonal government is asking you to propose at least three measures for traffic that can be implemented in a relatively short space of time. Which would you propose? Explain your choice.

A17 a) Under this small letter, write down the measures you are already taking personally to ensure clean air.
b) Think about what else you could do under lowercase b).

Compare these measures with each other!

Measures from a) _____

Measures from b) _____

Chapter 5

Perhaps the climate catastrophe is just a fairy tale

Meanwhile, Ulrich Giezendanner, transport entrepreneur, SVP, has become a climate specialist and considers those warning of a climate catastrophe to be misinformed. "I know of a study that says temperatures have fallen in the last ten years, not risen." And: "Nature regulates itself. It's always been like that." (SF1, Club, 16.2.10).

In the meantime, stakeholders around the world have formed against "the climate catastrophe fairy tale". A few errors in a report by the IPCC (Intergovernmental Panel on Climate Change), which runs to several thousand pages, are now causing a lot of "sniping". In Switzerland, *Avenir Suisse* economist Hans Rentsch, who is anything but independent, rails on the TV channel: "The IPCC is a kind of climate bible that publishes a gospel. Its compendium of knowledge is the Bible. The skeptics are denigrated, they don't understand anything about the subject." (SF1, Club, 16.2.10). The "climate deniers" demand an apology from Al Gore for the published errors. In the NYT of February 27, 2010, Al Gore takes a stand.

You will answer a few questions about this statement. You formulate the answers on a **separate sheet of paper in complete sentences**:

A18

- A18.1Al Gore is a kind of symbolic figure in the fight against global warming. He works on behalf of climate protection institutions and earns his money by claiming that a climate catastrophe could be imminent. Nevertheless, he claims that he would be relieved if his warnings turned out to be wrong. a) Do you believe him? b) Why (not)?
- A18.2With which sentence does Al Gore apologize for errors in the IPCC report? Quote the wording in writing.
- A18.3Does the apology make sense to you? (Answer only YES or NO)
- A18.4Al Gore picks apart the arguments of the "climate deniers". What does he say? (keywords suffice).
- A18.5Explain your understanding of the following terms: Market triumphalism / regulatory reform / market fundamentalists.
- A18.6Al Gore names two reasons why the climate summit in Copenhagen was not more successful. Which ones? (complete sentences)
- A18.7How could the NZZ graphic be made differently so that the changes can be seen at a glance? Make a sketch of an effective alternative.

Text

We can't wish climate change away

Al Gore², *New York Times*, 02/27/2010

It would be an enormous relief if the recent attacks on the science of global warming actually indicated that we are not facing an unimaginable catastrophe. This would give us the opportunity to dispense with preventative measures to protect human civilization as we know it. Of course, a few problems would remain. We would still have to deal with the national security risks of our growing dependence on a global oil market, of dwindling reserves in unstable regions of the world. And then there would be the economic risks of sending hundreds of billions of dollars a year abroad in return for the oil. Also, we would still be chasing China in a race that is independent of the climate catastrophe debate. This race is about "intelligent power grids", so-called smart grids, fast trains, solar energy, wind energy, geothermal energy and other renewable energy sources. This race is about the most important sources of new jobs in the 21st century. But still: a huge burden would be lifted from us. We would not have to worry about our grandchildren one day looking back on us as a generation that criminally, selfishly and carelessly ignored clear warnings when we held their future destiny in our hands. We could rejoice, along with the critics of climate change, that they persevered and have now proved that all the major national academies of science made a big mistake.

² Al Gore, the Vice President from 1993 to 2001, is the founder of the Alliance for Climate Protection and the author of the book "Our Choice: A Plan to Solve the Climate Crisis." As an entrepreneur, he is an investor in alternative energy companies.

For my part, I would really like the climate crisis to be an illusion. But unfortunately, the danger we face is real. Nor can it be wiped away just because at least two errors have been found in the thousands of pages of painstaking scientific work produced over the last 22 years by an intergovernmental panel of experts on climate change (IPCC). The fact is that the crisis is still worsening because we continue to pump 90 million tons of pollutants into the atmosphere every day as if it were a garbage pit.

It is true that the expert group published and used an erroneous overestimate of the melt rate of debris-covered glaciers in the Himalayas and equally true that the Dutch government provided information about the Netherlands that was later found to be inaccurate. In addition, email messages stolen from the University of East Anglia in the UK show that scientists, covered by an onslaught of hostile job creation requests from climate skeptics, may not have adequately followed the requirements of the UK Freedom of Information Act.

But a scientific enterprise is never completely free from error. Importantly, the overwhelming consensus on global warming remains unchanged. It is also worth noting that the panel of scientists - relying in good faith on the most up-to-date information - have probably even underestimated the extent of sea level rise this century, the rate at which the Arctic ice cap is disappearing and the rate at which some of the major glaciers in Antarctica and Greenland are melting and their ice masses are collapsing into the sea.

However, as these and other effects of global warming are spread around the world, they are difficult to identify and interpret in a specific location. For example, January was unusually cold in much of the United States. But from a global perspective, it was the second hottest January since surface temperatures were first measured 130 years ago.

Likewise, the last decade was the warmest decade since records have been kept. Despite this, climate deniers claim that there has been no warming in the last ten years.

This month's heavy snowfall has become fodder for ridicule from those who claim that global warming is a myth, but scientists have long pointed out that warmer global temperatures have increased the rate of evaporation from the oceans. This means that at higher temperatures, more moisture is released from the oceans into the atmosphere. This leads to higher levels of rain and snow in certain regions, such as the northeastern United States. Just as it is important not to miss the forest for the trees, we should not lose sight of the global climate because of a snowstorm.

Here is a list of what scientists have discovered about our climate:

- The pollutants produced by humans trap the sun's heat in the atmosphere, causing atmospheric temperatures to rise.
- These pollutants - especially carbon dioxide - are increasing in parallel with the increase in the burning of coal, oil, natural gas and forests. Temperatures are rising.
- Almost all of the Earth's ice-covered areas are melting and the seas are rising.
- Hurricanes are expected to become stronger and more destructive, although their number is likely to decrease.
- The periods of drought are becoming longer and longer and the drought is penetrating deeper into many regions of the mid-continent. On the other hand, the number and severity of floods is increasing.
- The predictability of seasonal rainfall and temperatures is becoming more difficult, which poses a serious threat to agriculture.
- The extinction of animal and plant species is accelerating to a dangerous level.

Despite impressive efforts by many business people, hundreds of millions of individuals and families around the world, by numerous national, regional and local governments, our civilization is failing miserably to reduce emissions. On the contrary, emissions continue to increase.

And despite President Obama's efforts at the Copenhagen summit in December, world leaders have failed to do more than "take note" of the need to act.

Because the world relied on the leadership of the United States, the failure of the Senate to pass legislation to limit US emissions before the Copenhagen meeting was a fatal sign. It also meant that the result fell far short of the necessary minimum and that a sensible solution was prevented.

In Washington, political paralysis is making itself painfully felt. It has so far prevented the Senate from adopting the necessary measures - and not just on climate and energy policy. The necessary legislation is also lacking for the reform of the healthcare system, the reform of financial supervision and a number of other pressing issues.

This state of affairs comes at a painful cost. China, now the world's largest and fastest growing source of the pollution that is causing global warming, signaled early last year that it would join an effective treaty if the United States, for its part, passed an effective law. The Senate failed to follow the House of Representatives and forced the President to go to Copenhagen without a new law in hand. Naturally, the Chinese were reluctant. But because the two biggest polluters refused to act, they paralyzed the world community.

However, some analysts say that the failure in Copenhagen was more the result of a design flaw. The trading of emissions certificates³ (cap-and-trade approach) is too unwieldy and difficult to implement. Furthermore, these critics believe that the financial crisis that began in 2008 has shaken global confidence in market-based solutions.

³ The basic idea for emissions trading was presented in 1968 by the Canadian economist J. H. Dales in his book *Pollution, Property and Prices* (...). Dales proposed setting up a market for pollution rights in order to limit water pollution from industrial wastewater. The revolutionary novelty of this idea was that politicians could directly set a concrete upper limit on total emissions as an environmental target.

To achieve this, an upper limit for certain emissions (e.g. [carbon dioxide](#), [sulphur dioxide](#), [nitrogen oxide](#)) within a specific area (regional, national, international) and a specific period (e.g. calendar year) must first be set politically. Then (...) so-called environmental certificates are issued, which entitle the holder to emit a certain amount. If, for example, an upper limit of 100 million tons of carbon dioxide is set for a certain region within a year, certificates are issued that entitle the holder to emit a total of 100 million tons of carbon dioxide. This cap can be gradually reduced in subsequent years. As these certificates are freely tradable, the [price](#) of

But there are two major problems with this criticism:

- Firstly, there is no immediately recognizable alternative that could be implemented politically. It is difficult to imagine a globally harmonized carbon tax or coordinated multilateral regulation. A policy that allows the flexibility of a global market - supplemented by regulation and cost-neutral tax policy measures - is the option that has by far the best chance of success. The fact that it is extremely difficult does not mean that we should simply abandon the idea.
- Second, we should be under no illusions about the difficulty and time required to convince the rest of the world to adopt an entirely new approach. Further delays mean that we would create conditions that make the large and destructive consequences inevitable - long before their terrible manifestations such as the displacement of hundreds of millions of climate refugees, civil unrest, chaos, collapse of governments in many developing countries, major crop failures and the spread of deadly diseases.

It is important to point out that the United States is not alone in its inaction. Global policy paralysis has so far affected not only climate policy, but also trade and other pressing issues that would require internationally coordinated action.

The reasons for this are primarily economic in nature. The globalization of the economy, combined with the outsourcing of jobs from the industrialized countries, has simultaneously heightened fears of further job losses in the industrialized world and is generating increasing expectations in the emerging markets. The result? Heightened opposition to any restrictions on the use of carbon-based fuels, which remain our main source of energy - in both developed and developing countries.

The clear victory of democratic capitalism over communism in the 1990s led to a worldwide philosophical dominance of free-market ideas and the illusion of a unipolar world. It also led to a hybrid "bubble" of market fundamentalism in the United States. Opponents of regulatory restrictions were emboldened in their aggressive attempt to shift the boundary between the sphere of democracy and the market sphere. Markets would solve most problems more efficiently, they argued. Laws and regulations were interventions in market processes and would also carry the smell of the discredited state opponent that had just been defeated.

This period of market triumphalism coincided with the confirmation by scientists that earlier fears about global warming had been grossly underestimated. But the political context in which the climate debate took shape was strongly determined by the views of market fundamentalists who opposed any existing constraints. They scoffed at admonitions that global constraints were needed to stop dangerous atmospheric pollution and thus global warming.

Over the years, as the science became clearer, some industries and companies whose business depended on unrestrained pollution of the atmosphere became more and more entrenched. Their representatives fought the mildest regulations as ferociously as the tobacco companies fought any restriction on the marketing of cigarettes for four decades after science had confirmed the link between cigarette smoking and lung and heart disease.

At the same time, changes in the US political system - including the displacement of newspapers and magazines by television as the most important medium of communication - gave strong advantages to the wealthy advocates of the unbridled market. Proponents of legal and regulatory reform have been weakened to the same extent. Some of the new media employ outright showmen, disguised as political thinkers, who disguise hatred and discord as entertainment. As times past have proven, this is a potent poison to the veins of the body politic. These people attach the label "socialist" to any proposal against exploitative behavior and thus seek to block any reform.

From a governance perspective, the stakes are high. It is about whether we retain the ability to use the power of the law as an instrument of human (democratic) problem-solving.

After all that has been said and little that has been done, the truth about the climate crisis - as uncomfortable as ever - must be clearly stated. The road to success is still open but we will have to do all we can. It starts with the possibility of the US passing legislation to regulate taxes on atmospheric pollution. The House of Representatives, with the support of some Republicans, has already passed a bill that takes the first steps to curb greenhouse gas emissions.

This week, Senators John Kerry, Lindsey Graham and Joe Lieberman will introduce a bill on emissions trading (cap-and-trade legislation), which I hope will be an effective measure against carbon dioxide emissions and create an incentive for the rapid development of low-carbon energy sources. We intend to overcome an existential threat. Winston Churchill is commonly quoted as saying: "Sometimes doing your best is not enough. Sometimes you must do what is necessary." Now is the time! People's representatives must do what is necessary and the public must demand that they do so - or they must be replaced.

these certificates is determined by demand. Emissions that are made without emission rights are subject to a penalty. This is also referred to as *cap and trade*.

Klimawandel – eine Umfrage bei US-Amerikanern

Gibt es eine Klimaerwärmung?



Ja	71%	57%
Nein	10%	20%
Weiss nicht	19%	23%

Ist die Erwärmung allenfalls durch den Menschen oder die Natur bedingt?



Mensch	57%	47%
Natur	33%	36%
beides	5%	6%
Weitere Antworten	5%	11%

Wie sehr sind Sie über die Erwärmung besorgt?



Sehr besorgt	17%	12%
ein wenig	46%	38%
nicht sehr	24%	27%
überhaupt nicht	13%	23%

Quelle: Umfrage bei 1001 Erwachsenen, 2009, Yale University/George Mason University

Source: NZZ am Sonntag from 7. 3. 2010

Closing words

Congratulations! You've reached the end of the master program and have become a bit of an expert on air pollution. You will certainly now look at the complex problem of air pollution with different eyes. You are now able to critically assess the air information disseminated daily by the mass media and to act in a more "air-friendly" way yourself. Pass on your knowledge and explain the connections to interested friends and neighbors.

Unfortunately, problems such as the greenhouse effect, the hole in the ozone layer, forest dieback and smog alerts cannot be solved overnight. However, thanks to the understanding of processes that you have gained by working through this guidance program, you know the causes and effects of the processes. With this understanding, air pollution can at least be slowed down and targeted changes to our way of life can be tackled.



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http://www.toonpool.com/cartoons/Knuts%20Scholle_67383#img9

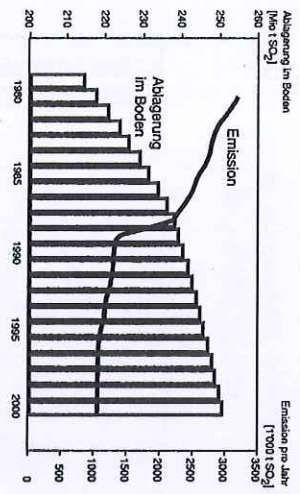


Abb. 8: Zusammenhang zwischen Verminderung der Schwefeldioxid-Emission und der Ablagerung dieses Gases bzw. seiner Folgeprodukte im Boden
 Prognose für die Bundesrepublik Deutschland (Teufel, 1991)
 Entwürflich zeigt sich hier, dass trotz markanter Emissionsverminderung die Bodenschmutzung weiter ansteigt, weil der Abbau der Schwefelverbindungen im Boden sehr langsam erfolgt.

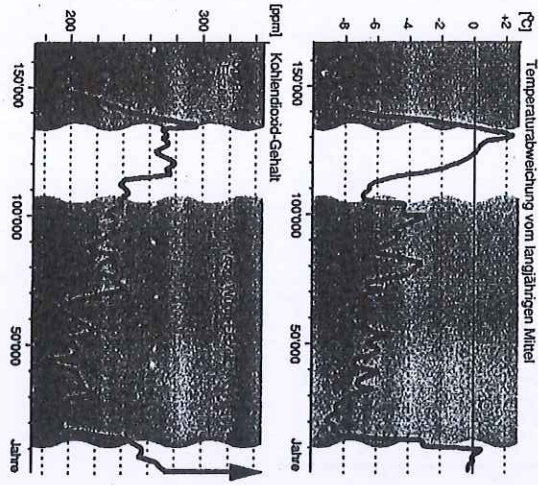


Abb. 9: Verlauf der Temperatur und des Kohlendioxid-Gehalts der Erdatmosphäre während der letzten 150'000 Jahre
 Werte bis 1960 aus Analysen von Gaseinschlüssen im Eis der Antarktis bis zu einer Tiefe von etwa 2000 m, später Dreikesslungen (Fouhthun, 1989; ETH, 1991)

Fig. 2-2

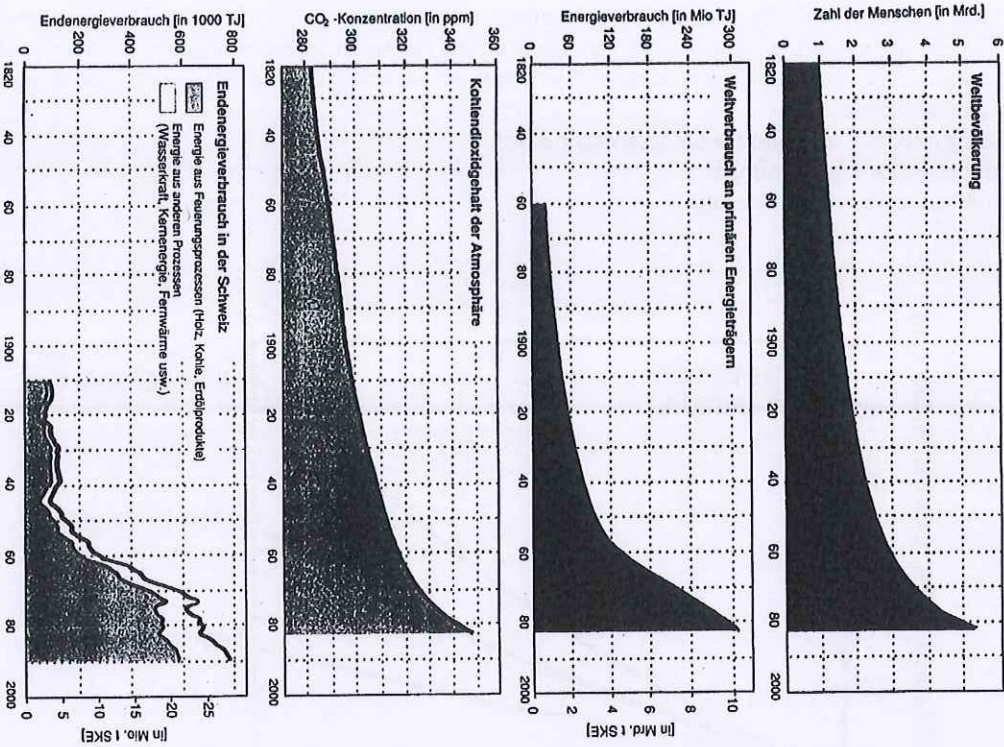


Abb. 10: Zeitliche Entwicklung umweltrelevanter Grössen
 Die zunehmend schnellere Entwicklung der Bevölkerungszahl und des Energieverbrauchs sind Ursachen für den zunehmenden Schadstoffgehalt der Luft auf unserer Erde. Dazu trägt auch die Schweiz ihren Teil bei.
 (Baumbach 1990; Energiestatistik 1990)

Fig. 2-3

Appendix: Charts 4-7 and 4-8

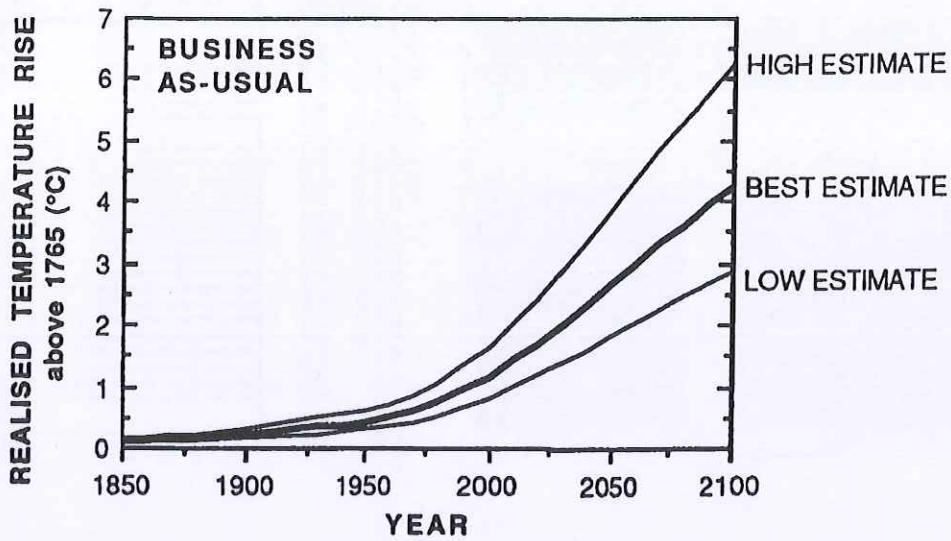


Fig.4-7: Model simulation of the average global temperature increase from 1850 - 2100 (Houghton et al. 1990, xxii). The calculations from 1850 - 1990 are based on the observed increase in the concentration of greenhouse gases in the atmosphere. The prediction of the temperature increase from 1990 - 2100 is based on the business-as-usual scenario.
 best estimate = estimated mean temperature rise
 low estimate = low estimate
 high estimate = high estimate

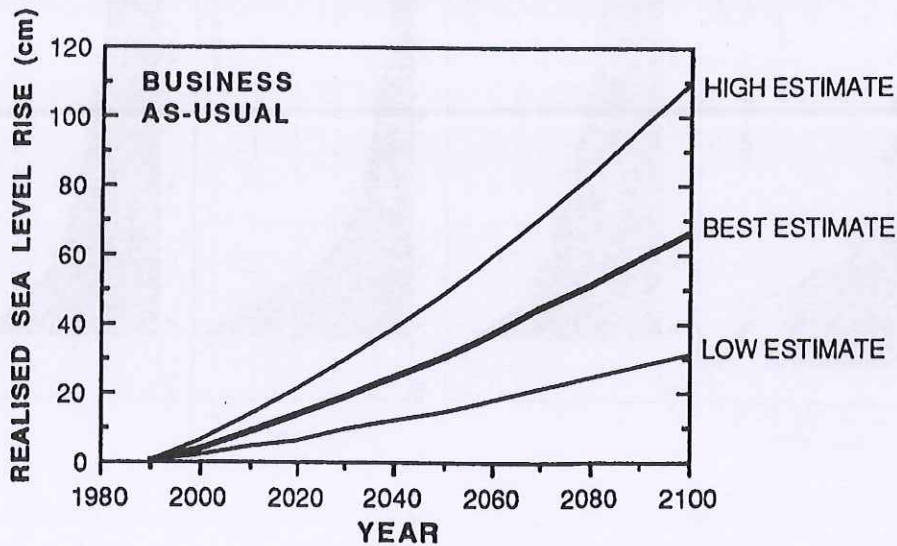


Fig.4-8: Projected sea level rise assuming the business-as-usual scenario. (Houghton et al. 1990, xxx)
 best estimate = estimated mean temperature rise
 low estimate = low estimate
 high estimate = high estimate

Glossary on global warming

2nd law of thermodynamics	Heat always flows from the warmer to the colder body
¹⁸ O	Oxygen isotope used as a measure of temperature. The ratio of the stable isotopes ¹⁸ O and ¹⁶ O in the oceans and the atmosphere is a function of temperature. Water molecules with the lighter ¹⁶ O evaporate faster than those with the heavier ¹⁸ O. A smaller ratio is found in snow and ice than in seawater. Therefore, the ratios in the ice cores reflect the temperature of the atmosphere over time.
Absorption	Absorption of electromagnetic radiation by atoms and molecules. This raises electrons to an excited state.
Aerosol	Finely dispersed droplets of a liquid in the air
excited state	high-energy state of a particle due to energy absorption
Aquifers	water-bearing layers in the soil
Svante Arrhenius	speculated whether the mean earth temperature, which he estimated at +15°C, was dependent on heat-absorbing gases such as CO ₂ .
Arctic Ocean model	If the Arctic Ocean is frozen, as it is today, it prevents the water from evaporating into the atmosphere and returning as snow. If there is then less snow to replenish the Arctic ice cap, it shrinks. This is probably the reason for the current situation. If the ice cap melts when the Earth warms up, the Arctic Ocean opens up again. This allows more radiation to be absorbed and the temperature continues to rise (= albedo/temperature feedback loop). At some point, there will be enough water for evaporation and the water will return as snow and the ice cap will expand again.
Acidosis/alkalosis	Hyperacidity or exceeding the normal blood pH value of 7.4
Blood buffer	Substances that intercept H ⁺ ions in the blood, such as HCO ₃ ⁻
Soil respiration	Cellular respiration of soil organisms
Ludwig Boltzmann	James Clerk Maxwell (1831-1879) and Ludwig Boltzmann (1844-1906) developed a theory that describes how particles move in an ideal gas: the kinetic theory of gases.
CO ₂ fumigation	Increasing the CO ₂ concentration in a gardener's greenhouse
Dodecahedron	geometric figure with 12 faces; 12-face calculator
dynamic equilibrium	= Reversible reaction with back and forth reaction
Ice cores	Cylindrical columns as a result of ice drilling
Electromagnetic radiation	Electromagnetic radiation is a form of energy transfer via electromagnetic waves.
El Niño	If the cyclical warming of the East Pacific Ocean is disrupted, this leads to significant weather changes in the USA and worldwide. This is known as El Niño. This occurs when warm water flows in from the equator towards South America and replaces the cold water of the Humboldt Current, leading to an interruption in the evaporation process.
Emission	Radiation of energy by an atom or molecule
Fourier, Jean Baptiste	was the first to speculate on the existence of a warming atmospheric effect that kept the earth warmer than it would otherwise be. He is credited with inventing the term greenhouse effect.
geothermal heat	Heat from the earth; hot springs etc.
Speed distribution	All velocities of the particles of a medium listed by size
Rock cycle	Cyclical process of rock reshaping over millions of years; mountains are formed by the collision of plates. Through weathering, components such as grains of sand, clay and limestone find their way into rivers and oceans. There they sink to the bottom, forming sediment that is absorbed by marine invertebrates and stored in their calcareous shells, which form sediment again when they die.
Equilibrium constant	Dynamic equilibrium reactions have a back and forth reaction. An equilibrium constant can be formulated for these according to the law of mass action. The equilibrium constant for the solution equilibrium of CO in water is: $K = \frac{p(\text{CO}_2)}{c(\text{CO})}$.

Global Warming	Global warming is the current warming of the earth (earth's atmosphere). Warming of the earth due to increased solar activity or greater proximity to the sun;
Urea cycle	Urea is formed in the liver of most terrestrial vertebrates in the so-called urea cycle.
Henry's constant	Equilibrium constant of the water solubility of CO ₂
Lime balance	$\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \rightleftharpoons 2\text{H}^+ + \text{CO}_3^{2-}$ $\text{H}_2\text{CO}_3 + \text{CaCO}_3 \rightleftharpoons \text{Ca}(\text{HCO}_3)_2 = \text{calcium bicarbonate}$ $\text{or } \text{H}^+ + \text{HCO}_3^- + \text{CaCO}_3 \rightleftharpoons \text{Ca}^{2+} + 2\text{HCO}_3^-$
Calcium carbonate	= Lime
Keeling, David	David Keeling built a CO ₂ measuring station on a lava field of an active volcano in Hawaii (see Mauna Loa measuring station) and initially collected measurement data until 1970, which were then published and went down in climate history as the Keeling curve.
Kirchhoff, Gustav	founded spectral analysis, formulated Kirchhoff's laws of radiation and defined the black body as an optimally absorbing and emitting entity.
Kirchhoff's law	Kirchhoff's law establishes the relationship between a blackbody radiator and a real radiator.
Kinetic energy	= kinetic energy
Kinetic gas theory	(Ideal) gases consist of moving gas particles whose properties can be calculated
small ice age	ca. 1600- 1700, ca. 1-2° colder than today
Carbonic acid	CO ₂ dissolves much better in seawater than in fresh water due to the pH of approx. 8. Among other things, the reaction to form carbonic acid occurs: CO ₂ + H ₂ O \rightleftharpoons H ₂ CO ₃ (carbonic acid) approx. 1%
Carbon cycle	cyclic transformation of carbon into its various forms (CO ₂ , CaCO ₃ , etc.) in the lithosphere
Continental drift	the plates of the earth's crust move slowly on the plastic asthenosphere
Lake Nyos	The outgassing (2.3 Mt/year) at the crater lake Lake Nyos, Cameroon, Africa killed more than 1700 people in 1986. A UNESCO artificial outgassing project provided a remedy.
LeChatelier	Established principles for dynamic equilibria according to which a disturbance of equilibrium occurs
Line spectra	Spectra of missing wavelengths in an absorption spectrum
Lithosphere	Earth's crust, uppermost layer of the earth, 75-250 km thick, consists of plates
Lithospheres/plate cycle	Subduction pushes the Earth's crust into the asthenosphere, whose material is returned to the surface by volcanic eruptions together with the "Gase. Sea-floor spreading" at the oceanic cracks causes the crust lost through subduction to be replaced by the escape of asthenosphere material. This cycle of plates and sediment is called the lithosphere/plate cycle.
Solution equilibrium	Dynamic dissolution and outgassing of gases in liquids
relative humidity	The relative humidity is the ratio of the actual vapor density to the saturation density.
Mammoth Mountain	At Horseshoe Lake, Mammoth Mountain USA, CO ₂ emissions were measured to be so high that the trees around the lake died.
Law of mass action	Law for determining the equilibrium constants in dynamic reactions
Maxwell, James Clerk	James Clerk Maxwell (1831-1879) and Ludwig Boltzmann (1844-1906) developed a theory that describes how particles move in an ideal gas: the kinetic theory of gases.
Mesosphere	Mesosphere: mixing zone, middle layer of the earth's atmosphere
Milankovich cycles	These are cyclical changes in heat on Earth caused by cyclical changes in the Earth's distance from the sun. In 1941, the Serbian astrophysicist Milutin Milankovitch provided formulas for calculating these cyclical processes, which were proven 35 years later.
medieval warm period	ca. 900 - 1350, at that time it was about 2-4° warmer than today

Non-volcanic soil outgassing	The emissions from volcanoes, which are usually given as 0.6 GT C/year, hardly correspond to reality, as only 24 of around 550 active volcanoes have been measured to date and the ground emissions around the volcanoes have hardly been taken into account. Added to this are the non-volcanic outgassing emissions, which are even higher. The measured ground emissions in southern Italy from Naples to Sicily alone amount to approx. 0.4 x 10 ⁸ tons/year in the form of CO ₂ .
Max Planck	Max Planck (1858 - 1947) revolutionized physics with his quantum theory (Nobel Prize 1918) and, among many other discoveries, established the law of radiation for black bodies.
Plate tectonics	= Continental drift
Plinian eruption	Plinian eruptions are large, explosive events that eject huge, dark clouds of ash into the stratosphere (i.e. at least 11 km high).
Northern lights	Auroras are caused by the interaction between the Earth's magnetic field and charged particles from the sun, the solar wind
Proxy data	In order to obtain climate data from the past, so-called proxy data is used. These are obtained by analyzing natural climate-dependent processes such as: Tree rings, ice cores, fossil pollen, marine sediments, corals and historical data.
Quantum leap	If exactly one quantum is absorbed, the electrons of an atom are raised to a higher-energy orbit (n=1,2,3..) (= quantum leap).
RUBISCO	Enzyme that binds CO ₂ to ribulose-1,5-diphosphate
black spotlight	A gas cloud or a star in space or an object emitting thermal radiation is referred to as a black body if its emissivity is almost 1.0
Sunspots	The surface temperature of the sun varies cyclically due to the occurrence of magnetic storms. During the course of such storms, the temperature there is about 2000°C lower, sunspots appear and the area is darker.
Solar wind	Due to the high temperature of the solar corona, the particles it contains can reach such a high speed that they escape the sun's gravitational field. The gas that escapes from the sun in this way is known as solar wind.
Saturation vapor pressure	In a closed vessel, vaporization takes place until there is an equilibrium between the number of molecules leaving the liquid and those re-entering. This state is called saturated and the vapor pressure in (mmHg) is called saturation vapor pressure.
Stefan/Boltzmann law	Stefan/Boltzmann law (<i>black body</i>): $E = \sigma T^4$
Radiation temperature	Temperature according to the Stefan/Boltzmann radiation law at which radiation is possible
Radiation spectrum	The radiation spectrum is the distribution of radiation energy over different wavelengths.
Stratosphere	2. lowest layer of the atmosphere; area of ozone formation through absorption of UV radiation (11-50 km altitude)
Subduction	continental plates pushing against each other (= subduction)
Thermosphere	top layer of the earth's atmosphere. O ₂ molecules absorb the short-wave solar radiation, which leads to an increase in temperature
Troposphere	Lowest layer of the atmosphere (0 -11 km)
John Tyndall	built the first differential spectrometer and proved Fourier's assertion that gases in the atmosphere can absorb heat.
Dwell time	The electrons remain in the excited states for a short time (typically 10 ⁻⁶ to 10 ⁻⁹) seconds.
Vibration energy	Excitation energy of a molecule at which parts of the molecule vibrate
Vukaneruption	Eruption of a volcano
Heat	Particle movement
Heat conduction	Transfer of the energy of the particles by collision
Heat radiation	IR radiation that converts into heat during absorption
Heat flow (convection)	Movement of particle quantities of different densities
Wien's displacement law	It is found that the radiation maximum shifts to lower wavelengths at higher temperatures.
Cellular respiration	Metabolic process

