# Cow´s milk & plant-based alternatives

***A life cycle assessment***

**for *interested parties***

**Developed within the project**

LCA meets EfS

www.lca-meets-efs.net

gefördert durch
DBU
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www.dbu.de

**Dear pupils, trainees, students, colleagues and interested parties,**

With this handout we would like to introduce you to the LCA learning offer on the topic of "Cow's milk and its plant-based alternatives".

With the 2030 Agenda, sustainable development is being increasingly focused on and expanded to include new concepts and strategies. Processes in everyday life, technology and industry are to be transformed toward sustainable practice. Evaluating this, however, is not an easy task. In recent decades, however, techniques have been developed for this purpose, which, when they include all relevant impacts of a process or product in the consideration, are referred to as Life Cycle Assessment (LCA). Central to the transformation in terms of sustainable development of our world today is chemistry and the sciences and economic sectors associated with and based on it. Chemistry also needs to become more sustainable; this is being done through the concept of Green Chemistry (also Sustainable Chemistry). Since Agenda 21 already outlined how important education is for the sustainable development of our society, a change in thinking is also taking place in chemistry and a new area in chemistry-related education is increasingly being implemented in many countries: Green Chemistry Education (GCE).

GCE includes knowledge of a changed view of chemistry, for example in the field of chemical synthesis and production in research and industry. Closely related to this are also competencies in the environmentally sound, legally compliant and safety-related treatment of chemicals and chemical production processes. So far, however, assessment strategies in the context of sustainable chemistry, such as LCA, have hardly been the subject of GCE. The aim of the project is the development and implementation of a digital learning environment on assessment strategies and methods for the handling of chemicals and chemical-related processes. This concerns both the LCA and integrated methods, such as the $CO_2$ or water footprint.

A website www.lca-meets-efs.net introduces the topic at different levels. It introduces central concepts and methods and explains these with examples.

In the following, we will *briefly* explain the student laboratory "*Life Cycle Assessment meets Education for Sustainability" in short LCA-meets-EfS*, the design of the student laboratory offer and safety-relevant aspects regarding behavior in the laboratory for the practical part. We would be very pleased if you would visit the student laboratory,

the project team of the student laboratory "FreiEx" at the University of *Bremen*

# I. The student laboratory "FreiEx" in the chemistry didactics of the University of Bremen

A student lab is an out-of-school learning environment that includes a pre-structured learning offer. The special feature of a student lab is the supplementation of school and extracurricular learning and the adjustment to the specific learning requirements of the students (SuS). This implies a didactic design of the learning offer.

The student lab offering is modular in design so that it can and should be flexibly adapted to different learning groups and also has a high degree of internal differentiation. The digital teaching and information elements, experiment instructions and supplementary materials are intended to challenge students to learn about topics in the sustainability debate and to be able to orient themselves in corresponding subject areas. The target groups of these student lab offerings are school and out-of-school learning groups, trainees as well as students of scientific-technical disciplines and interested parties.

# II. The LCA material for faculty and users

Based on current issues in the climate and sustainability debate, this handout on the LCA learning opportunity *"Cow's milk and plant-based alternatives"* is intended to provide an introduction to the complex topic of life cycle assessment. The material is suitable for learners from secondary level 9/10 of general and vocational schools and higher education. Of course, the offered material can/should be adapted to the individual ability and interest of each learning group, therefore the **files are** available **as Word, PowerPoint or PDF.**

**For teachers/trainers/lecturers/course instructors, the learning offer contains the following documents and materials:**

**SUBMITTALS:**

- Teacher information LCA learning opportunity *"Cow's milk and plant-based alternatives".*
- Course plan for the learning unit with suggestions for getting started, for implementation and for securing knowledge with solutions and time specifications.
- The module is suitable for group work.

**WORKING MATERIALS:**

3 worksheets per group:

- SECTION 1 FACT CHECK
- SECTION 2 DATA SHEET Endpoints compressed
- SECTION 3 FACT TABLE WITH GROUP DISCUSSION - EXPERT ROUND (argumentation table)
- 2 print templates - world map, value chain

**SUPPLEMENTAL MATERIALS:**

- DATA-SETS for calculative processing via Excel, Numbers and Sankey
- Solutions for the SECTION 3 FACT TABLE as an argumentation aid and background information on the endpoints $CO_2$ -, water footprint as well as land consumption relevant in this module.
- Compare ingredients, nutritional values and calorific values of the products considered. Output as a summary sheet or edit and add in the PADLET (via LINK or QR code). Request invitation in advance.
- Experimental instructions - if there are to be practical parts to the set
- List of data sources, media offers, further literature, order addresses

## III. The "Cow's milk and plant-based alternatives" progression plan

Sustainability is important - but rarely easy. This is especially true for the perennial issue in the climate debate: milk. How damaging to the climate is cow's milk? And are alternatives - soy, almond, oat or rice drinks - really better?

| PHASE | SUB TOPIC | MATERIAL | DURATION |
|---|---|---|---|
| **Entry** | Who drinks cow's milk and who prefers plant-based alternative products? | Survey 1 | 20 min |
| | | | |
| **Practice** | Make your own oat drink with video tutorial by Nicole Voss | experimental guide | 60 min |
| | Tasting: try different products: Determine test criteria, evaluation | Survey 2 | 30 min |
| | Find, list and compare prices from different suppliers | Research | 10 min |
| **Group work** | **Division of the 5 working groups with 4-6 participants** | | **10 min** |
| **FACT CHECK** | Livestock, growing conditions, water, land requirements | SECTION 1 | 30 min |
| | World map: Using the Excel spreadsheets, each group identifies the main producing countries and enters the data on the world map. | World Map Print Template | 30 min |
| | LCA scheme simple - as a mind map | „Value Chain“ Print Template | 30 min |
| LCA | $CO_2$ -, water footprint, land use of 1 liter of cow´s milk and its plant-based alternatives. | SECTION 2 | 30 min |
| RESULTS | Fill in fact tables, Rating in the table | SECTION 3 | 30 min |
| | | | |
| | **Group discussion / expert round / group puzzle** | | **60 min** |
| | | | |
| LCA complex | Statista:https://de.statista.com/statistik/daten/studie/1198026/umfrage/co2-fussabdruck-von-milchprodukten-eiern-und-milchalternativen-in-deutschland/ | DATA SET | 60 min |
| | Find, add and compare ingredients: Nutritional values and calorific values - what are they? https://padlet.com/asiol/ztk2b6eyzkrk0ewk | SUPPLEMENTARY INFO via Padlet | 30 min |
| | Packing tetrapack or glass bottle optional... | | 120 min |

## IV. Explanation of the material

**To get started,** the learning group should/could approach the topic "Product consideration of cow's milk & plant-based alternatives" through surveys, impulse films, videos, etc. Suggestions for appropriate research questions are noted on the progression plan. Practical activities in the laboratory/kitchen or tastings arouse curiosity and are funny. With the division into groups and the distribution of materials or delivery of links on the padlet and/or website, each group will have access to the materials and DATESET deposited there. **(Time requirement 2 double hours)**

These material folders contain the worksheets relevant for the respective group (SECTION 1 FACTS CHECK, SECTION 2 DATA SHEET, SECTION 3 FACTS TABLE for the group discussion). In addition to cow's milk, the plant-based alternatives oat drink, soy drink, almond drink and rice drink are available for selection. Very challenging is the processing of cow's milk, which should always be assigned. How many and which of the vegetable alternatives are processed depends on the individual size and interest of the learning group. Furthermore, two print templates (world map and "value chain") are included

The worksheets AB 1-3 with the two print templates are intended to guide and support the learners in developing the facts about their product. Of course, the pupils / students are free to design their analog or digital mind maps. Each group member can thus contribute his or her individual strengths - be it analytical, organizational, creative and linguistic - to the group work. Internal differentiation is possible in the school context.

**WORKING MATERIAL**

**SECTION 1 is a FACT CHECK**. A headline with research question(s) leads to the text. This contains the most important information on ingredients, husbandry/cultivation areas and husbandry/cultivation conditions of the product under consideration in a condensed form.


COW'S MILK & PLANT-BASED ALTERNATIVES

SECTION 1 FACT CHECK COW'S MILK

Conventional dairy farming is considered a climate killer. Industrial agriculture, factory farming, and feed production harm the environment. Many are therefore looking for alternatives and switching to plant-based drinks. But is this really more sustainable?

Fact Check COW'S MILK

In terms of nutrients, cow's milk is superior to its plant-based competitors. It provides the body with vitamins A and B, as well as minerals such as phosphorus and zinc. Apart from that, its high calcium content speaks for itself. Health reasons for avoiding cow's milk: Intolerances such as lactose intolerance lead to undesirable reactions in those affected, for example abdominal pain.

Ethical aspects of partly questionable livestock farming: Like humans, cows only produce milk when they have had offspring. However, the calf is usually separated from its mother shortly after delivery, so that the milk is available for human consumption. If a cow's milk production declines, the next step is usually to the slaughterhouse.

Worldwide, around 270 million cows produce around 700 million tons of milk per year. The U.S. and India are the largest producers, with Germany currently in fourth place. With appropriate feeding of high-protein grass silage and concentrated feed, a Holstein high-performance cow produces up to 10,000 liters of milk annually. An "organic cow" does not reach these milk quantities.

INPUT

Grass silage 14,4 kg dry mass
Hay 1 kg dry mass
Concentrate 0,4 kg
Water 100 Liters

OUTPUT

24 liters of milk daily
3-4 calves
76 liters manure
10 kg crap / mist
Methane, $CO_2$

One liter of fresh whole milk with a fat content of 3.5% costs between 0.79 and 1.39 euros in stores. Raw milk - i.e. milk that has not been treated - directly from the farm costs 1.00 euro per liter.

As for their eco-balance....

- On average, 623 liters of water are needed to produce one liter of cow's milk.
- In addition, 3.2 kg of $CO_2$ is emitted...
- ...and 8.9 m² of land is needed.

Compare the tables in the DATA SHEET (SECTION 2). These values come from studies by the Water Footprint Network, the Öko-Institut and Statista. Other sources include the work of Mekonnen & Hoekstra (2010) and Poore & Nemecek (2018).

TASKS:

Gather more information on dairy farming and milk utilization to complete tasks 1-4.

1. In which country is milk produced? What is the production volume in tons? Uses the world map.
2. Describes livestock management. Are concentrates and roughage fed or is grazing preferred. What is the medical care situation?
3. Who exports cow's milk? Describes the world trade.
4. How is cow's milk produced? Outlines the technical process.

The learners can/should **supplement the results from SECTION 1 with their own research** and prepare them for the concluding group discussion. In the small paragraph "As far as their life cycle assessment is concerned..." exemplary formulation aids for the comparative observations are given, which at the same time establish a connection to **SECTION 2 DATA SHEET.**

**SECTION 2 is a DATA SHEET**. The information necessary to carry out a simple LCA analysis (area, water and $CO_2$ requirements or releases) is already harmonized and prepared in tabular and graphical form. Thus, even without knowledge of numerical and graphical data processing via Numbers or Excel, learning groups can make comparative observations for the five products to be discussed in this offer with regard to the focused endpoints and formulate LCA-relevant statements.


COW'S MILK & PLANT-BASED ALTERNATIVES

SECTION 2 DATA SHEET (Characteristics of water consumption, $CO_2$ footprint and land use)

Water consumption of cow's milk and plant-based drinks compared 2018

In terms of water consumption, plant-based drinks achieve a better eco-balance than cow's milk. While around 623 liters of water were consumed for one liter of cow's milk in 2018, the water consumption for the production of soy drink was only 28 liters.

| | Water Consumption in kg/L |
|---|---|
| Cow's Milk | 623 |
| Soy Drink | 28 |
| Oat Drink | 48 |
| Almond Drink | 371 |
| Rice Drink | 270 |

$CO_2$ emissions of cow's milk and plant-based drinks in comparison 2018

In terms of $CO_2$ emissions, plant-based milk achieves a better eco-balance than cow's milk. While around 3.2 kilograms of carbon dioxide were emitted in 2018 for one liter of cow's milk, $CO_2$ emissions in the production of almond drink were 0.7 kilograms.

| | $CO_2$ -Emissions in kg/L |
|---|---|
| Cow's Milk | 3.2 |
| Soy Drink | 1 |
| Oat Drink | 0.9 |
| Almond Drink | 0.7 |
| Rice Drink | 1.2 |

Land consumption of cow's milk and plant-based alternatives in comparison 2018

In terms of land consumption, plant-based milk achieves a better eco-balance than cow's milk. While around 8.9 square meters were required for one liter of cow's milk in 2018, the land required for the production of soy drink was only 0.7 square meters.

| | Land Use in m²/year |
|---|---|
| Cow's Milk | 8.9 |
| Soy Drink | 0.7 |
| Oat Drink | 0.8 |
| Almond Drink | 0.6 |
| Rice Drink | 0.3 |

TASK: Create an overview chart for the 5 products and discuss their life cycle assessments. The reference value should be one liter of cow's milk or plant-based drink.

An example: https://www.facebook.com/quarks.de/photos/pcb.3991417920643/10161364234300564

These values come from studies by the Water Footprint Network, the Öko-Institut, FAOSTAT and Statista.

consumption and possible recycling of leftovers. The required data were obtained from the databases ecoinvent, simapro, ESU-Sense as well as faostat and Statista/Destatis. The aim is to harmonize the relevant data in such a way that they can be successfully converted and graphically processed by learning groups in order to obtain a basis for the evaluation and discussion of the LCA endpoints considered here.

The **DATA-SET** (as Excel file format) **is part of the supplementary material** and should/can be provided for learning groups either to learn the use of calculation programs or who have already mastered them. Therefore, the final task formulated on the SECTION 2 DATA SHEET is to be understood as optional, which implies a further processing of the data and the new graphical preparation.
The integration of Excel into the iPad program Numbers is quite simple by copy/paste. For beginners, a joint test run may be helpful.

The third **SECTION 3** forms the basis for the final presentation and group discussion. On this sheet, facts about the evaluation criteria "animal welfare, ecological & economic, health reasons" are recorded in tabular form.

COW'S MILK & PLANT-BASED ALTERNATIVES

SECTION 3 FACTS TABLE WITH GROUP DISCUSSION - EXPERT ROUND TABLE

Cow's Milk substitutes: What the plant-based alternatives can do

In some German refrigerators, plant-based milk alternatives have now displaced classic cow's milk. In any case, cow's milk is ahead in terms of price. While it is sometimes offered for as little as 78 cents, consumers often think twice about whether they really need the almond drink for around 2 euros. Obviously, cow's milk consumption continues to be a subject of debate.

We want to shed some light on the subject and present some representatives of milk alternatives. From a purely legal point of view, only animal milk from cows, goats or horses is entitled to the name "milk". Most plant-based milk representatives therefore adorn themselves with the title "drink," which not infrequently causes additional confusion among consumers.

| Overview of arguments pro / contra cow's milk and plant-based alternatives | |
|---|---|
| COW'S MILK | |
| Animal Welfare | |
| Factory farming | |
| Handling calves | |
| Life expectancy | |
| Attitudes | |
| other | |
| Ecological reasons | |
| Land consumption | |
| Water consumption | |
| other | |
| Health | |
| Vitamin B12 | |
| Calcium | |
| Allergies | |
| World population, hunger | |
| Economic reasons | |
| | |
| | |
| | |

Other arguments:

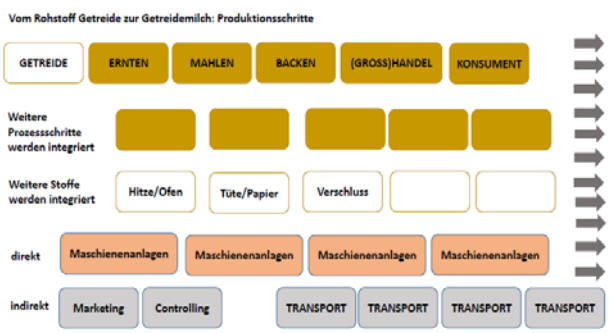
The great advantage of the vegetable alternatives is the absence of cholesterol and lactose. In terms of taste, some products are not convincing in their natural form. Manufacturers often add sugar, additives and flavorings, which quickly turns the supposedly healthy drink into a calorie bomb. In this case, it is worth taking a look at the nutritional information on the packaging. The missing calcium is now also added industrially to most milk alternatives.

With a final **presentation of the results (**via keynote, PowerPoint, padlet or as a poster) and **discussion** (as a group puzzle / panel discussion / expert round), the results from the individual group work can be communicated to the entire learning group. The argumentation aid SETION 3 can provide the pros & cons of the respective product in an expert round. (Time required: at least 2 double lessons).

A **print template "World Map"** can/should be populated with the determined production countries and data (as .pdf). These data can either be taken from the **DATA-SET**, which are listed on the basis of the production quantities determined by faostat according to production countries for the year 2018 or have been determined after free research (e.g. via Wikipedia).

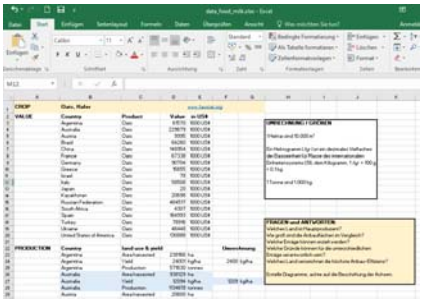
The **print template "Value chain"** (also as .pdf) contains prepared buttons with starting material, possible work steps up to the customer.

A "value chain" for raw material, water, energy and material flow analysis as well as the process-relevant parameters "energy demand, fresh & waste water flows, aggregates, yields, disposal, transport, emissions" are to be presented in production flow diagrams. The end-of-life analysis of the packaging is to be added as an expandable/optional option.



**ADDITIONAL MATERIAL**

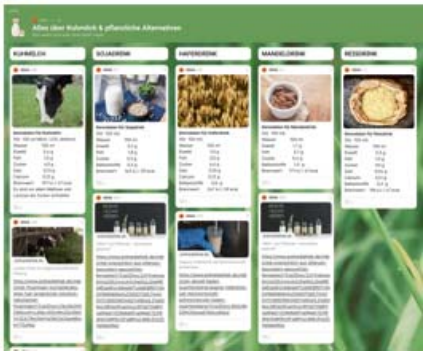
The **DATA-SET** is available as an Excel file as .xlsx. Via copy/paste the integration into the iOS application NUMBERS via iPAD is possible.



**Information on ingredients and nutritional values of** the products considered in this LCA offer is available as a printout and in digital form.

The link to the padlet :
https://padlet.com/ASiol/ztk2b6eyzkrk0ewk

There is also a QR code for this.



As a **practical offer, the experimental instructions for the production of oat drinks** with video instructions were developed by Nicole Voss as part of her bachelor thesis.

## V. LCA relevant terms

In this LCA set, the endpoints of land use, $CO_2$ footprint, and water use are used:

**Endpoint land use:** The consideration of yields or generated yields per hectare provides information about the effectiveness of a producing country. In this complex set "Cow's Milk & Plant Alternatives", a distinction should be made between the growing conditions in the up to 10 growing countries considered. Learners will identify which country has authoritative production figures and should be able to explain why. Soil quality, local climatic and geological conditions are decisive for the level of crop yields. But irrigation, fertilization and crop protection measures, as well as the use of GMOs, also have a significant impact on yield performance. These cause overfertilization and acidification of the soil used for agriculture, right through to the loss of biodiversity, for example through the clearing of tropical rainforests. Food production also competes with other forms of land use such as agricultural energy production, conservation of natural areas or settlement.

**Endpoint $CO_2$ footprint:** If the amount of a certain substance emitted into the air, for example, is known and what effect this substance has in the environment, its climate potential can be calculated. For example, we know that carbon dioxide ($CO_2$) and methane ($CH_4$) contribute to climate change - but to different degrees. The climate change potential of methane ($CH_4$) is about 24 times more pronounced than that of carbon dioxide. These differences are taken into account in the form of substance-specific damage factors.

The principle is shown below using a simple example: Life cycle inventory

| |
|---|
| $CO_2$ , fossil→ 1.00 kg $CH_4$ , fossil→ 1.00 kg |
| $CO_2$ , fossil→ **1** $CH_4$ , fossil→ **24 Damage factors in relation to climate change** |
| Determination of the climate change potential in terms of $CO_2$ |
| 1.00 kg $CO_2$ , fossil x damage factor 1 = 1.0 kg $CO_2$ equivalents |
| 1.00 kg $CH_4$ , fossil x damage factor 24 = 24.0 kg $CO_2$ equivalents ∑ = 25.00 kg $CO_2$ equivalents |

More extensive evaluations are usually carried out using appropriate software in which, for example, the damage factors for various impact categories are stored. In the "cow's milk & plant alternatives" set, cow's milk performs significantly worse than the plant alternatives. However, rice also provides quite high emission data. In both cases, the release of methane is responsible.

The simplification made in this module only provides for the consideration of $CO_2$ as a climate-relevant greenhouse gas (GHG). However, the pages highlighted in green in the DATA-SET also allow for more detailed considerations of the environmental impacts of cow's milk, almond tree and cereal production.

**Water footprint endpoint - virtual water (water availability):** Water, especially clean drinking water, is increasingly perceived worldwide as a scarce and valuable commodity. However, water is also used in large quantities in the manufacture of products. The Water Footprint primarily takes into account only the amount of water used, with a distinction being made between

- Surface and groundwater (blue water)
- Rainwater (green water)
- polluted water (grey water)

must be distinguished. Both cow's milk and its plant-based alternatives rice and almond have high water requirements - but for different reasons!

Dairy cattle require concentrated feed for milk production, most of which consists of crushed (imported) soy. Soybean cultivation is limited by a large number of pests, weeds and powdery mildew, which can only be countered by massive use of pesticides (mainly herbicides and fungicides), which reduces soil quality and in particular increases the proportion of "gray" - i.e. polluted - water. Downstream water treatment in cultivation areas, especially in Brazil, is often inadequate or non-existent. For this reason, there has been a steady increase in genetically modified seeds of almost all crops worldwide. Monsanto's "soybean", for example, is resistant to the total herbicide glyphosate.

Rice is produced in fields in Asia that are regularly flooded. The water for this comes mainly from rain and surface waters (rivers, lakes). The boggy soil must be rich in nutrients, which results in the formation and release of methane. Almonds have a very poor $H_2$ O balance due to their high irrigation requirements in the hot main growing region of California.

**The energy inputs to** the production of cow's milk & plant alternatives involves extensive data review. This requires an appropriate alternative or comparative process to understand and evaluate

the results obtained. For this purpose, the data sets published by authors Poore and Nemecek in Science 2018 were primarily used.
The transportation of goods and the design of individual transport are currently the focus of numerous discussions on the scope and nature of sustainable transport planning and drive technology. The global trade in raw materials and goods is mainly fossil-based. The conversion of transport kilometers per ton of goods is distributed among the four transport types: airplane, freighter, rail and truck.

Information on LCA endpoints can also be found at "BASIC KNOWLEDGE→ FACTS SHEETS."

## VI. Notes and literature on the technical background

In the following you will find references, technical background and links:


- Deichsel, K. (2019) *Cow's milk vs. plant milk How sustainable are milk alternatives?* online https://www.br.de/puls/themen/leben/kuhmilch-vs-pflanzenmilch-100.html
- Krinner, J. (2019) *Milk substitutes compared: oat, almond or soy milk? How plant milk helps the environment.* With video https://www.chip.de/artikel/Der-beste-Milchersatz-Hafer-Soja-und-Mandelmilch-im-Vergleich_158119161.html
- Poore, J. & Nemecek, T. (2018) *Reducing food's environmental impacts through producers and consumers in* Science Vol. 360, 6392. https://www.science.org/doi/10.1126/science.aaq0216
- Statista https://de.statista.com/statistik/daten/studie/1179366/umfrage/co%25E2%2582%2582-emissionen-von-kuhmilch-und-pflanzlicher-milch/
- FAO https://www.fao.org/land-water/databases-and-software/crop-information/en/
- https://waterfootprint.org
- Voss, N. (2021) Bachelor thesis on the *comparison of cow's milk and oat milk - an LCA consideration with experimental instructions and video*. University of Bremen, August 2021
- U.S. Food and Drug Administration 2013 *Analytical Results from Inorganic Arsenic in Rice and Rice Products Sampling* as .pdf and http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm319870.htm
- Mekonnen, M.M. and Hoekstra, A.Y.. (2010) *The green, blue and grey water footprint of farm animals and animal products*, Value of Water Research Report Series No.48, UNESCO-IHE. Main Report Volume 1 and Appendices Volume 2 & at https://waterfootprint.org/en/water-footprint/product-water-footprint/water-footprint-crop-and-animal-products/
- Albert Swiss Foundation, retrieved 12/10/2021 https://albert-schweitzer-stiftung.de/aktuell/studie-ernaehrung-flaechenbedarf-klima
- Quarks und Co: various video contributions from the ARD media library and at https://www.facebook.com/quarks.de/photos/rpp.399241730563/10161264234100564
- www.proplanta.de
- www.wikipedia.de