CO_2 - rating

Explained

Manuel Klarmann, 2022-07-20

What is the rating good for?

- To inform consumers about the correct choice.
- A comparative rating of foods & beverages according to their climate impact:
  - **Across** categories (apple vs. beef)
  - And **within** categories (Pizza Margarita vs. Pizza Funghi)

3 elements to the rating

Where do we need to be, to reach a climate friendly society? In terms of CO_2 per day.

How do we calculate the CO_2 value of our food?

How much food do eat / need per day. And how do we measure this amount?

Climate status quo.

Food takes ⅓ of our current CO_2 budget

- Our current worldwide emissions are ca. 50 Gigatons of CO2eq
- Food is around 16 Gigatons CO2eq per year.
- That is about 2 tons CO_2eq per person and year.
- This is about 5.5 kg CO_2eq of person and day.

Food is ⅓: Crippa, M., et al. – Nature 2021 „Food systems are responsible for a third of global anthropogenic GHG emissions.“ https://www.nature.com/articles/s43016-021-00225-9
50 Gigatons: https://www.climatewatchdata.org/ghg-emissions?breakBy=regions&end_year=2019&start_year=1990
7.8 billion people: https://datacommons.org/place/Earth?category=Demographics&hl=de

Climate goal for food

We need to reduce food related emissions by more than 50% of to reach 2.0°

- Our total budget is below 1 ton CO2eq per person and year.
- That is below 2.75 kg CO_2eq per person and day.

50% reduction: „Klimabericht IPCC SR climate change and lands, Kapital 5“ and „EAT-Lancet Report“: https://eatforum.org/content/uploads/2019/07/EAT-Lancet_Commission_Summary_Report.pdf

3 elements to the rating

2.75 kg CO_2eq per person and day

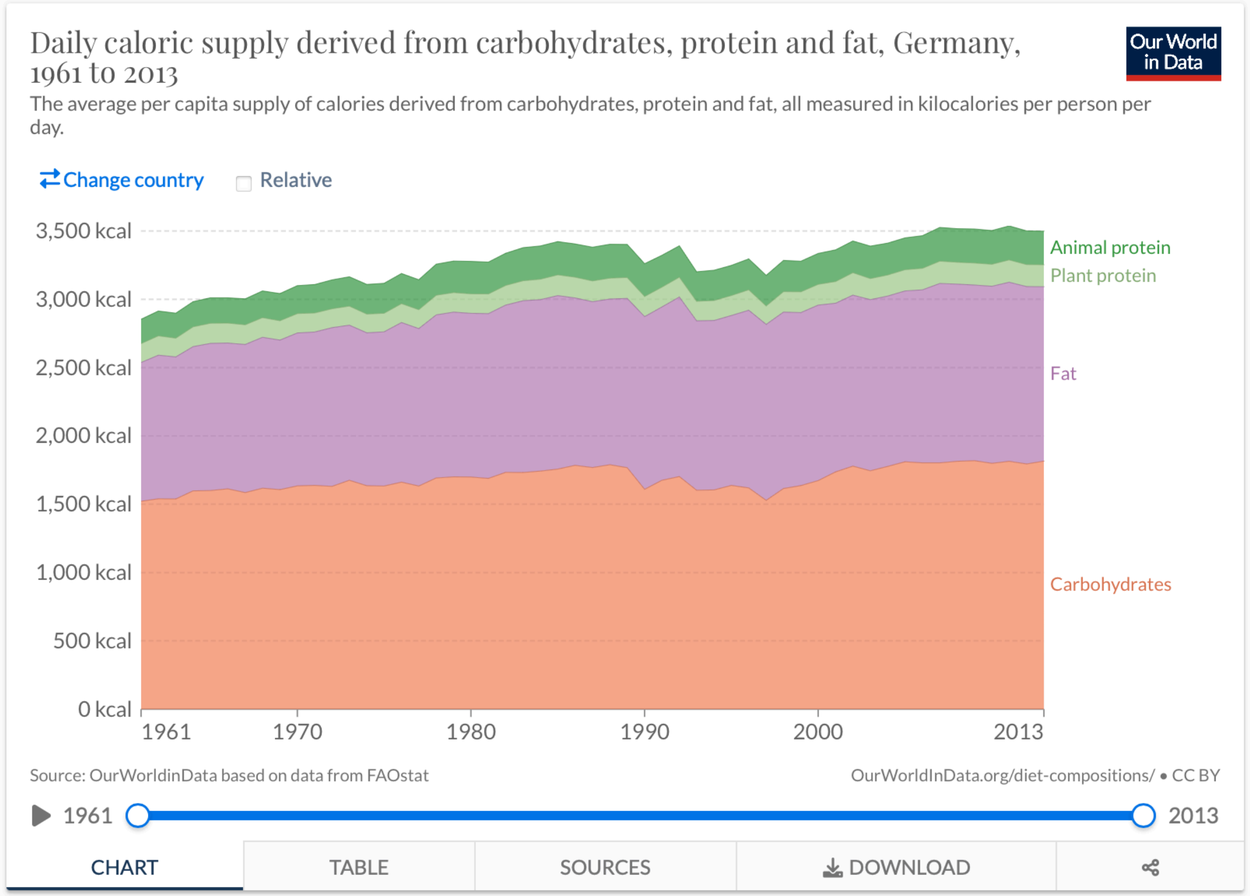
How do we calculate the CO_2 value of our food?

How much food do eat / need per day. And how do measure this amount?

What is our current food consumption?

- World: 2870 kcal per day
- Germany: 3500 kcal per day

- Also we need to drink 2.5 liter of water



purple: fats
green: proteins (animal and plant based)
orange: carbohydrate.

https://www.nationalgeographic.com/what-the-world-eats/
https://ourworldindata.org/diet-compositions <- FAOstats
EFSA Panel on Dietetic Products, Nutrition, and Allergies (2010). "Scientific Opinion on Dietary Reference Values for water". EFSA Journal. 8 (3): 1459. doi:10.2903/j.efsa.2010.1459.

What is the amount of food?

Problem: For food we cannot just isolate one aspect (like weight).

Solution
To account for the actual function of food to „fuel and fill“, we count all macronutrients towards their respective amount needed per day by a human. And use this unit, a: „daily food unit“.

Note: We deliberately do not include aspects that are about „healthy“ food (there is the nutriscore for that). We just want to know „how much“ food we need to survive.

Daily Food Unit (DFU)

„Sättigungsindex“

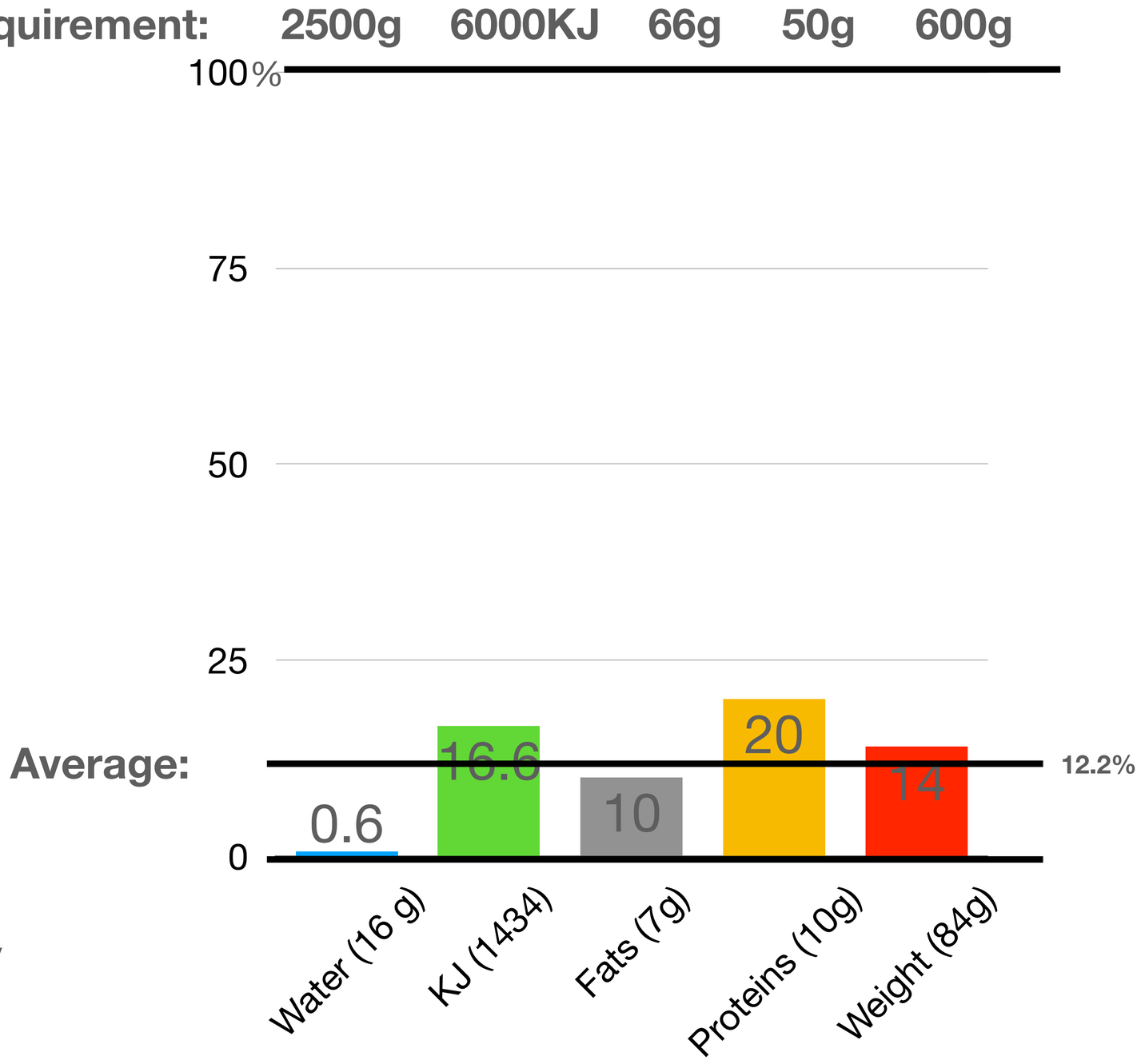
$$\frac{\frac{g\ Proteine}{50\ g} + \frac{g\ Fette}{66\ g} + \frac{kJ\ Energie\ (ohne\ Proteine\ und\ Fette)}{6000\ kJ} + \frac{g\ Wasser}{2500\ g} + \frac{g\ Trockengewicht\ (ohne\ Wasseranteil)}{600\ g}}{5}$$

Daily Food Unit

Example

- 100g whole-grain cereals:

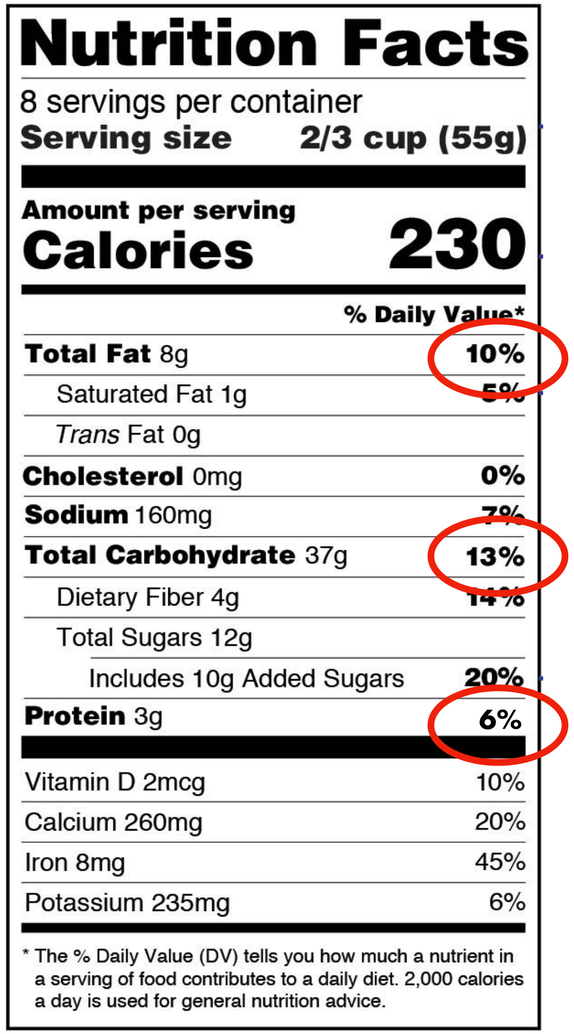
  10g proteins
  7g fats
  1434 KJ
  16 g water
  84g dry-weight



12.2% of your day

Were does this method come from?

The values are printed already on the package.



Nutrition Facts

8 servings per container

Serving size **2/3 cup (55g)**

Amount per serving

Calories **230**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	**6%**
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

***(Percentage of water and weight is missing in this example.)**

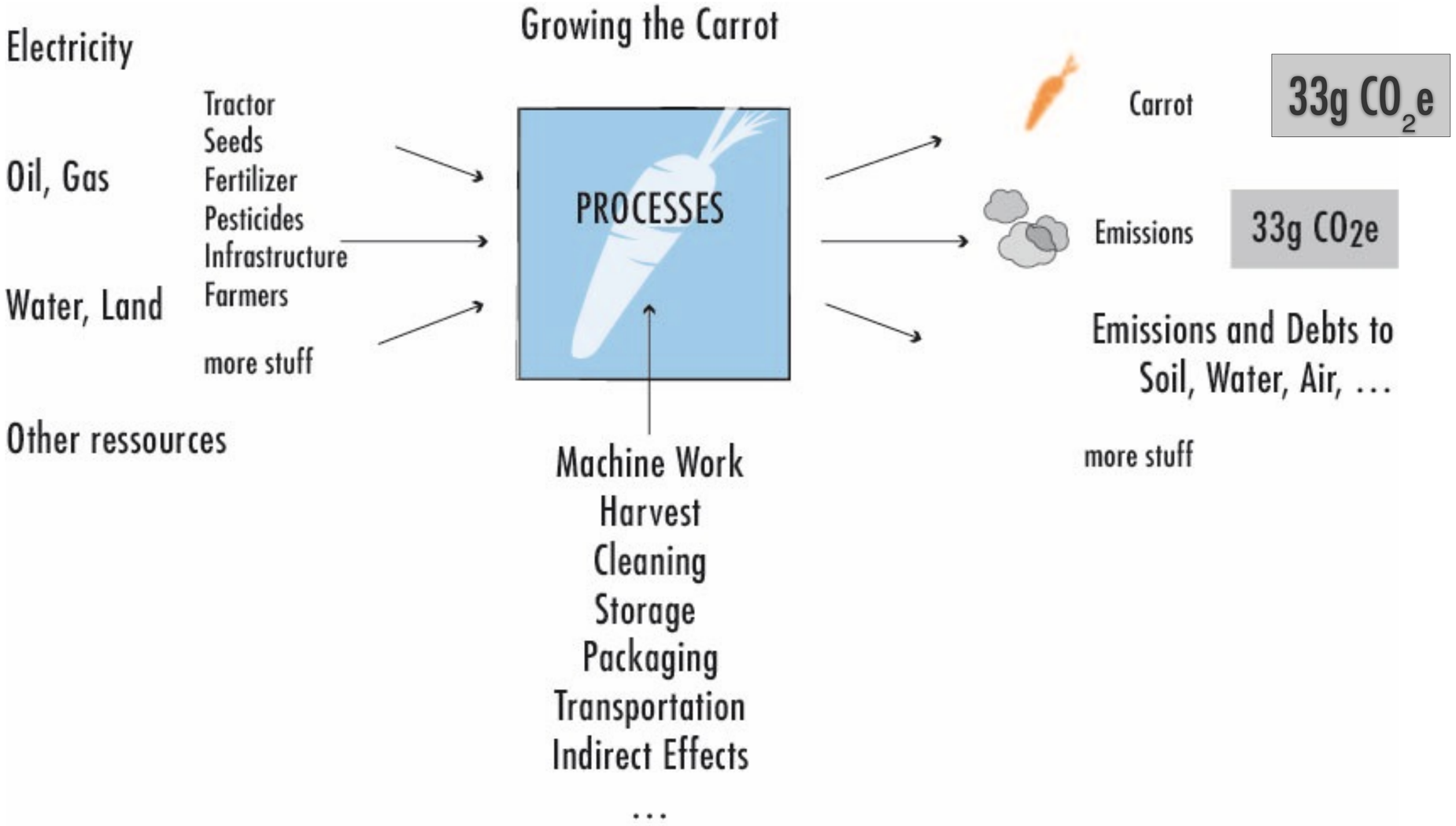
3 elements to the rating

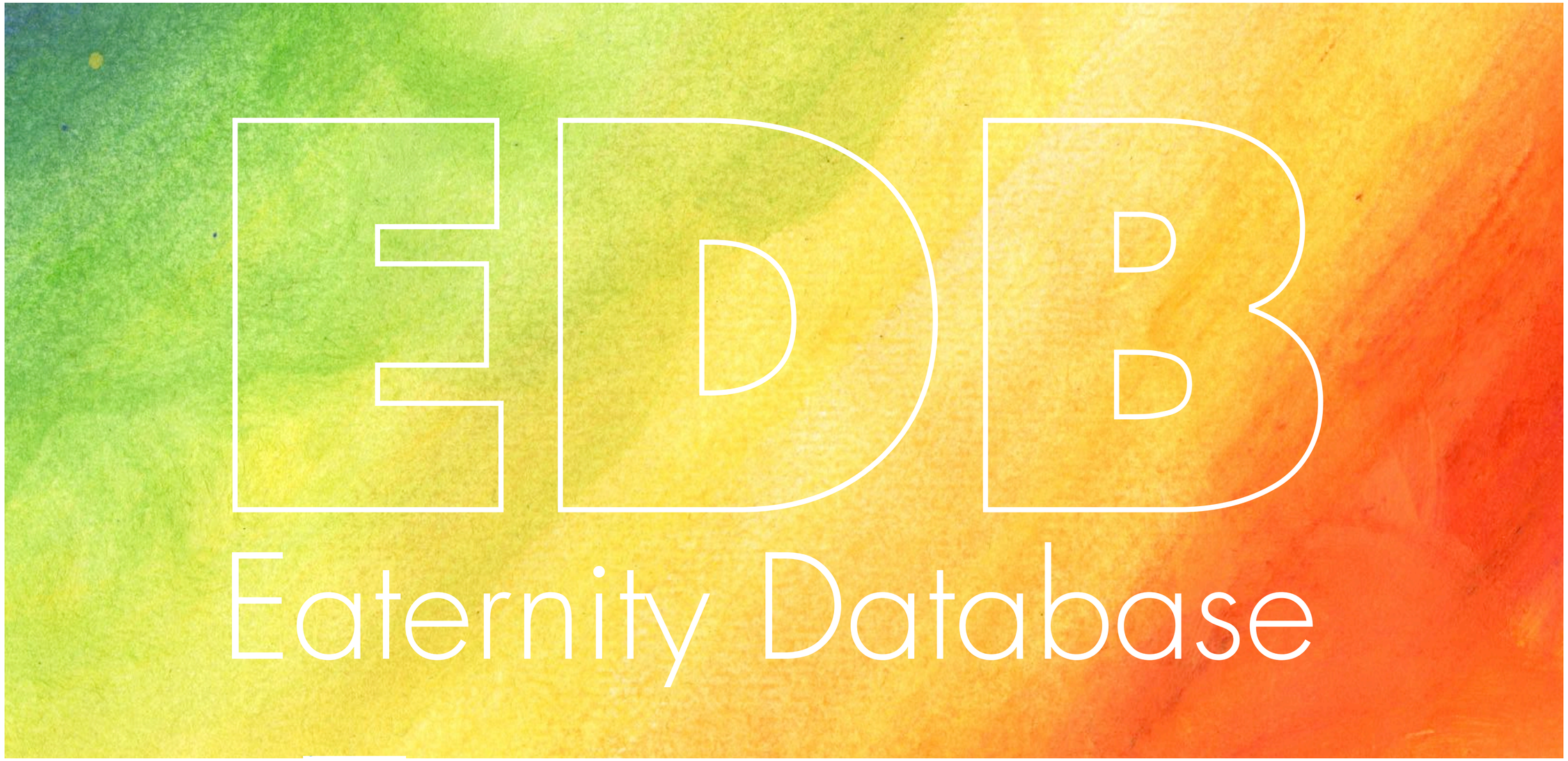
2.75 kg CO_2eq per person and day

How do we calculate the CO_2 value of our food?

Approx. marcronutrients requirement
average adult per day:
proteins: 50g
fats: 66g
energy (incl. carbohydrates): 2000 kcal
water: 2.5 liter
=
1 DFU

LCA


Growing the Carrot
Electricity
Oil, Gas
Water, Land
Other ressources
Tractor
Seeds
Fertilizer
Pesticides
Infrastructure
Farmers
more stuff
PROCESSES
Machine Work
Harvest
Cleaning
Storage
Packaging
Transportation
Indirect Effects
...
Carrot
33g CO_2e
Emissions
33g CO_2e
Emissions and Debts to
Soil, Water, Air, ...
more stuff


EDB
Eaternity Database

Transportdienstleistung Seeschiff

Versandort: 14.51978004632611 / 76.81640625

Klasse: Dry

Zusammenfassung: 7.479,79 km

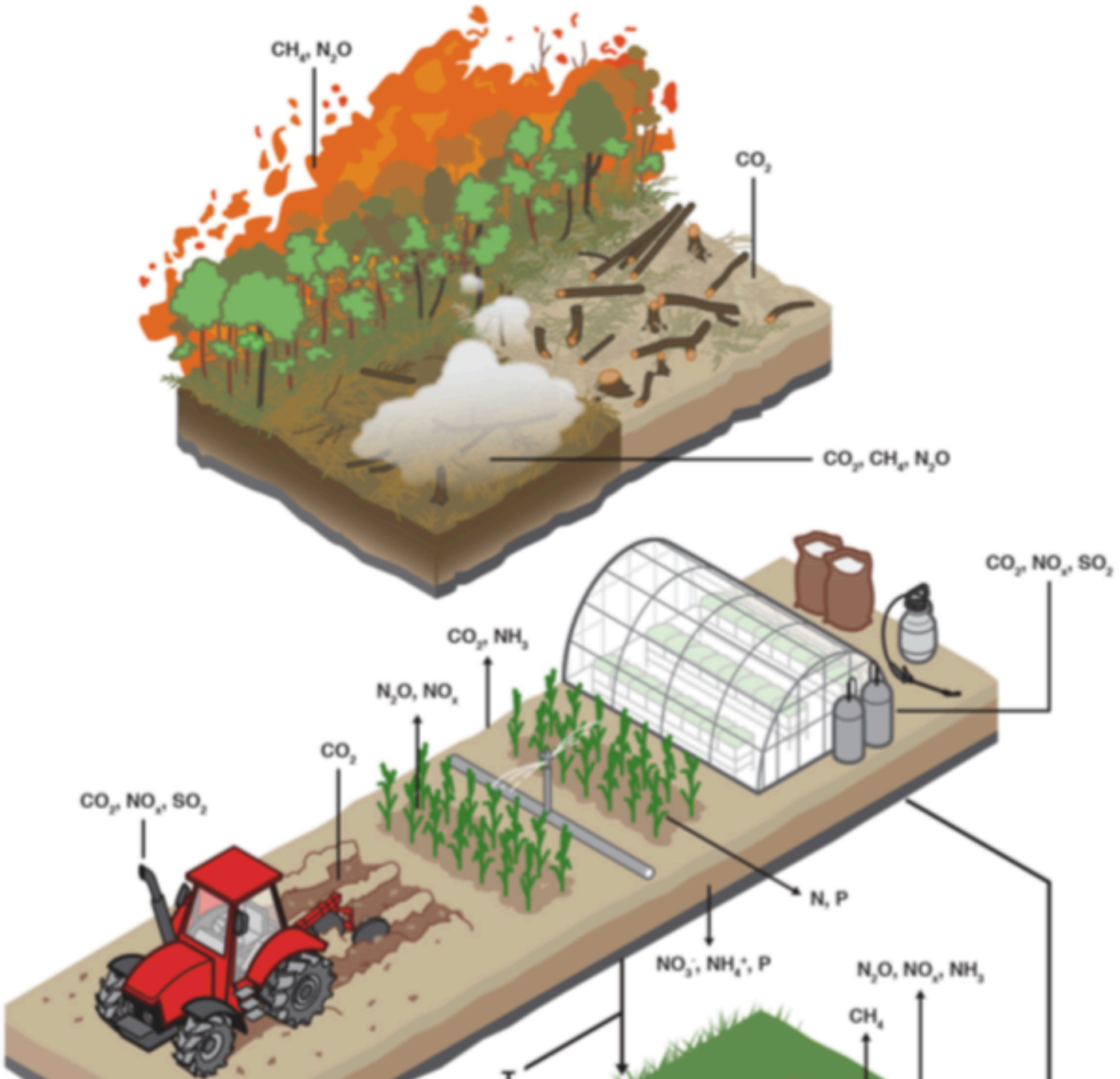
Export als KML-Datei (Google Earth)

Route Transport service 2 Schließen

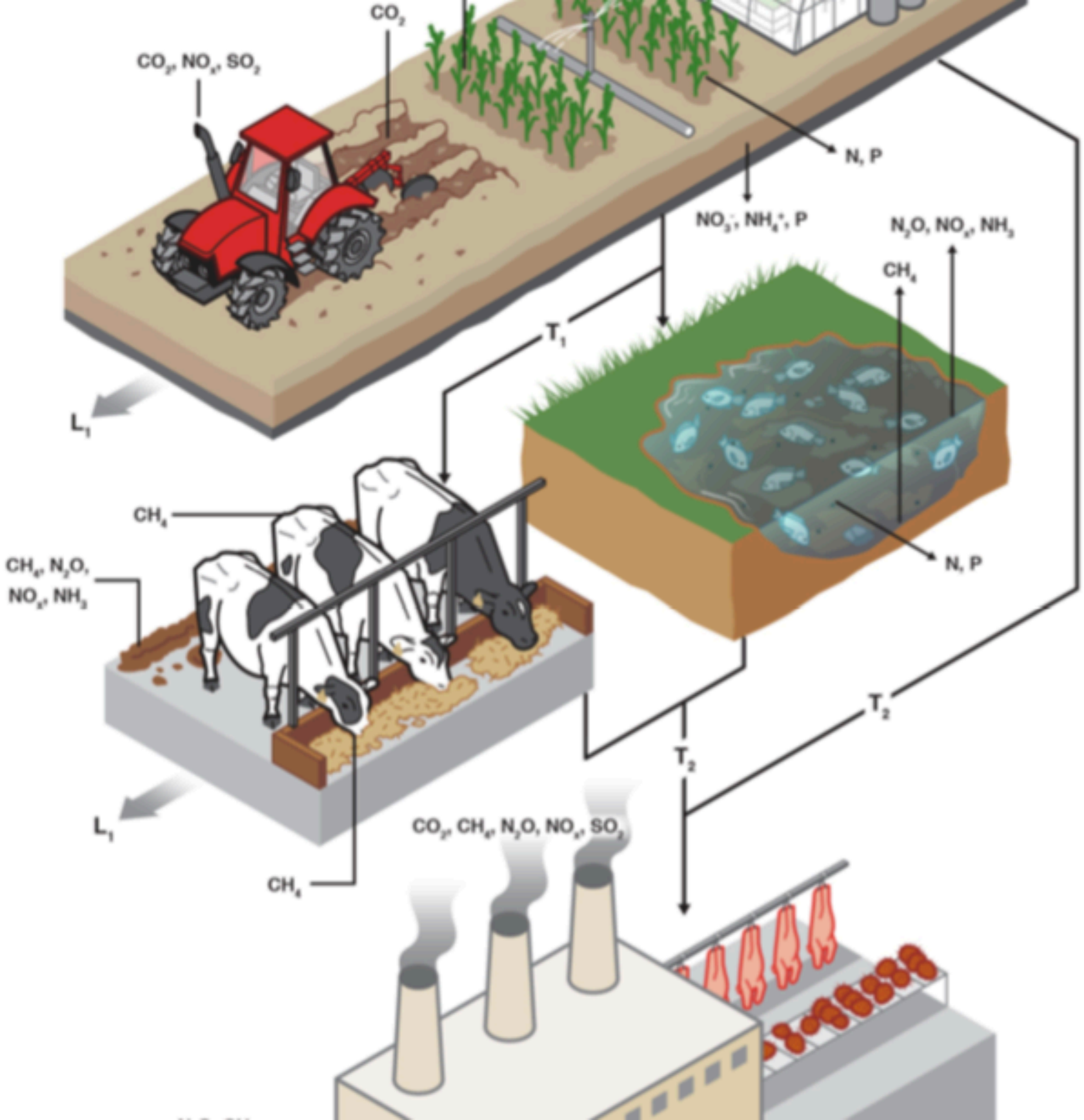
Länderspezifische Distanzen in [km]

India: 525,61

International: 8.475,36



Included	Excluded
Land Use Change	
• Above ground C stock change (CO_2) • Below ground C stock change (CO_2) • Forest burning (CH_4, N_2O) • Organic soil burning (CO_2, CH_4, N_2O)	• Leaching, runoff and induced non-CO_2 emissions
Crop Production	
• Seed & nursery • Inputs production • Machinery • Greenhouse & trellis infrastructure • Electricity & fuel • Fertilizer & retained crop residue (N_2O, NH_3, NO_x, NO_3^-, NH_4^+, P, N) • Urea & lime (CO_2) • Flooded rice (CH_4) • Residue burning (CH_4, N_2O, NH_3, NO_x) • Cultivation of drained organic soils (CO_2, N_2O) • Drying / grading • Irrigation water consumption — Land use: seed; fallow; arable and permanent crops	• Soil emissions (CH_4) • Organic fertilizer application (CH_4) • N fixation emissions • C sequestration in crop residue • Runoff (N) • Residue burning indirect emissions (N_2O) • Human labour



(N_2O, NH_3, NO_x, NO_3^-, NH_4^+, P, N)
- Urea & lime (CO_2)
- Flooded rice (CH_4)
- Residue burning (CH_4, N_2O, NH_3, NO_x)
- Cultivation of drained organic soils (CO_2, N_2O)
- Drying / grading
- Irrigation water consumption

—

Land use: seed; fallow; arable and permanent crops

- Runoff (N)
- Residue burning indirect emissions (N_2O)
- Human labour

Livestock/Aquaculture

- Pasture management (same as for food/feed)
- Feed processing
- Housing energy use
- Enteric fermentation (CH_4)
- Manure management (N_2O, NO_x, NH_3, CH_4)
- Aquaculture ponds (N, P, N_2O, NO_x, NH_3, CH_4)
- Drinking & service water

—

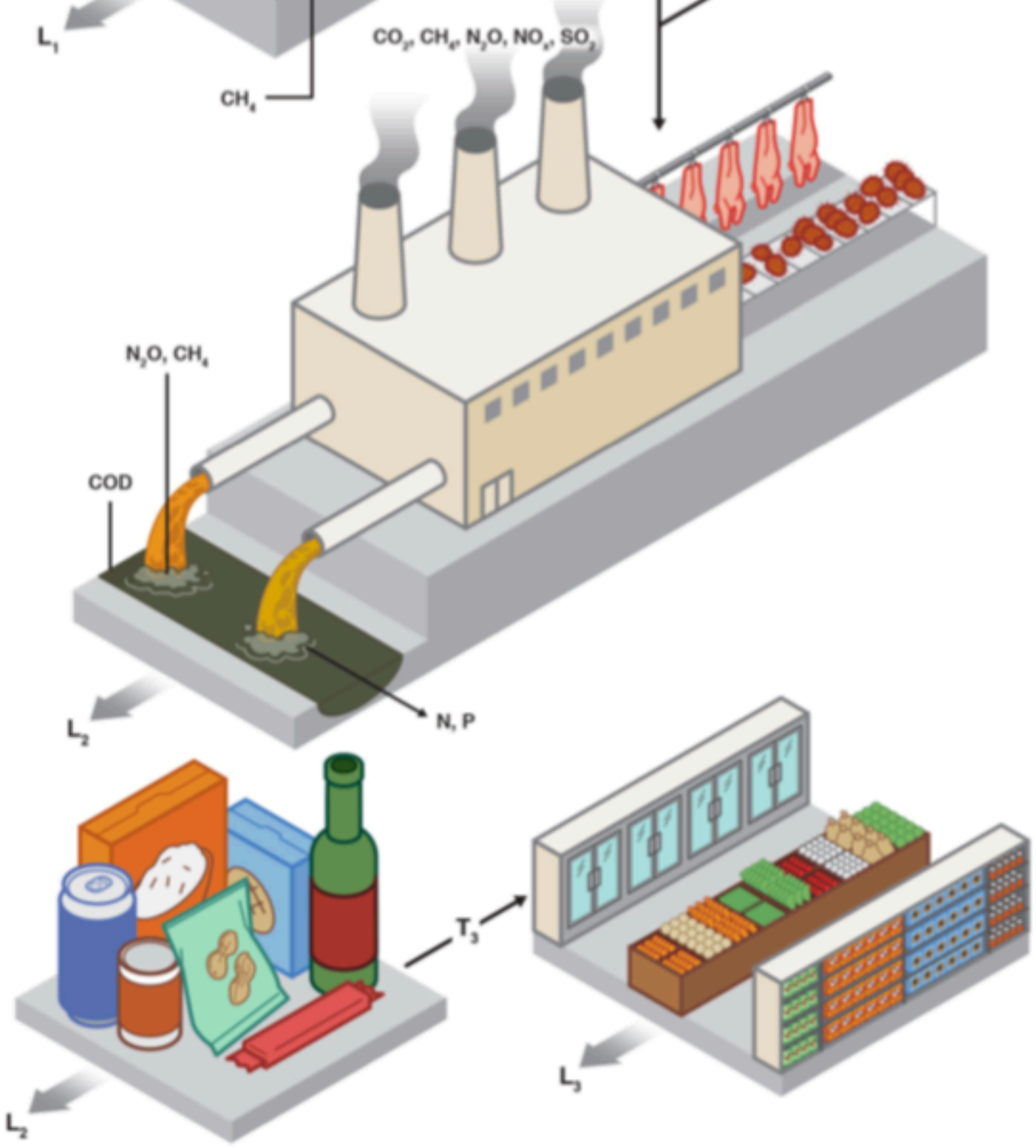
Land use: permanent pasture; temporary pasture; aquaculture ponds

- Infrastructure
- Pasture residue (emissions or burning)
- Pasture N fixation emissions
- Pasture runoff (N)
- Manure management (P)
- Human labour

Processing

- Energy (CO_2, NO_x, SO_2)
- Wood burning (CH_4, N_2O, NO_x, SO_2)
- Wastewater (CH_4, N_2O, P, N, COD)
- Incineration (CH_4, N_2O, NO_x, SO_2)
- Processing water consumption

- Miscellaneous inputs
- Human labour
- Infrastructure
- Land use



Processing

- Energy (CO_2, NO_x, SO_2)
- Wood burning (CH_4, N_2O, NO_x, SO_2)
- Wastewater (CH_4, N_2O, P, N, COD)
- Incineration (CH_4, N_2O, NO_x, SO_2)
- Processing water consumption
- Miscellaneous inputs
- Human labour
- Infrastructure
- Land use

Packaging

- Materials
- Material transport
- End of life disposal
- Human labour
- Infrastructure
- Land & water use

Retail

- Energy use
- Human labour
- Infrastructure
- Land & water use

Losses

L_1 - Storage and transport

L_2 - Processing and packaging

L_3 - Wholesale and retail

Transport (CO_2, NO_x, SO_2)

T_1 - Feed

T_2 - Food

T_3 - Processed food

together

2.75 kg CO_2eq per person and day

Scope 3 life cycle assessment analysis.
kg CO_2eq per product

Approx. marcronutrients requirement
average adult per day:
proteins: 50g
fats: 66g
energy (incl. carbohydrates): 2000 kcal
water: 2.5 liter
=
1 DFU

Example

100g whole-grain cereals

Amount

- 10g proteins
  7g fats
  1434 KJ
  16 g water
  84g dry-weight

LCA

- Land use change (20%)
  Fertilizers (60%)
  Machinery (2%)
  Transport (5%)
  …

12.2% of your day

85g CO_2eq

together

2.75 kg CO_2eq per person and day

0.085 kg CO2eq / 0.12 = **0.71 kg CO2eq**

Scope 3 life cycle assessment analysis. **kg CO_2eq per product**

0.085 kg CO_2 eq

Approx. marcronutrients requirement
average adult per day:
proteins: 50g
fats: 66g
energy (incl. carbohydrates): 2000 kcal
water: 2.5 liter
=
1 DFU

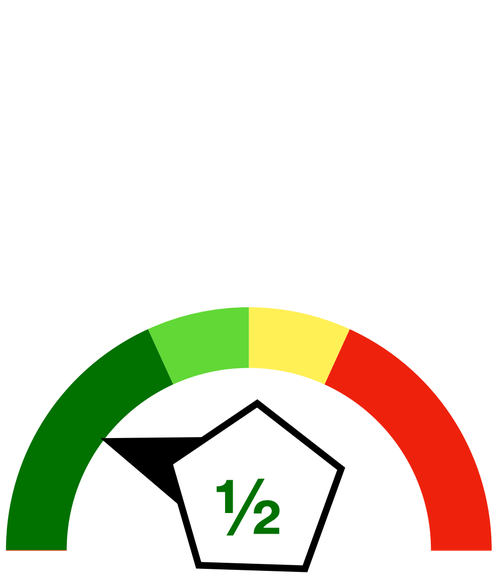
0.12 DFU

74% better (2.75-0.71)/2.75

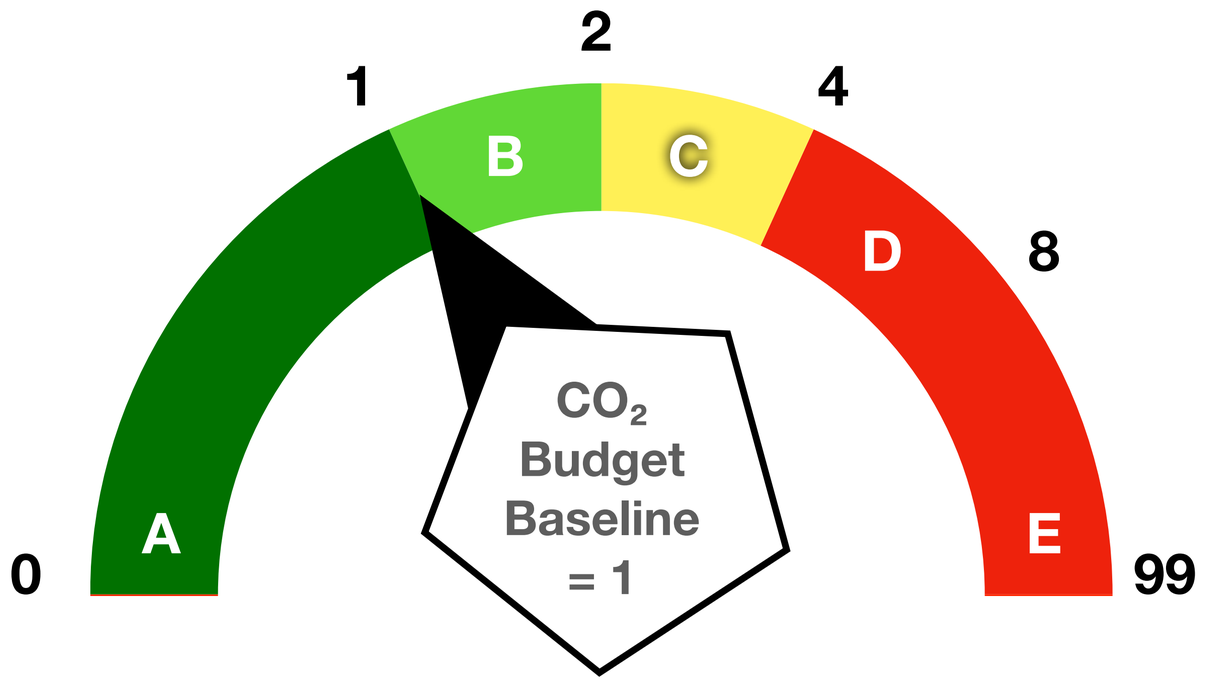
Example Rating Communication

We eat and drink 1 DFU per day.

„2750 g CO_2 / 1 DFU“ is hence the ratio below we which would call food climatefriendly.



50% better than budget baseline



5 times worse than the budget baseline

Joghurt vs. Milk vs. Butter

Except processing and transport, they are actually all the same!

1000 g	**1 l**	**56 g**
Joghurt	Milk	Butter
		
2,0 kg CO_2	1,9 kg CO_2	1,8 kg CO_2
		

The rating is similar.
And also accounts for efficiencies in transporting less.

Beef vs. Beef Soup

Except processing and transport, they are actually the same!

1 liter

Beef Stew

100 g CO_2

5 g

Minced Beef

50 g CO_2

The rating is now similar. Still better for the stew.

https://www.amazon.de/Knorr-Kraftbouillon-vielseitig-anwendbare-Rinderbrühe/dp/B00LBC0A8S
5 gram beef, per 1 Liter of soup - 2600/(1258/2)/(1+1/2.5)

Not so obvious, but same effect: Avocado vs. Tomato

In this case the nutrients are almost the same.

250 g

Avocado

- 5g proteins
  38g fats
  1674 KJ
  183 g water
  67g dry-weight

250 g CO_2

17.8% of your day

1 kg

Tomato

- 9g proteins
  2g fats
  753 KJ
  950 g water
  50g dry-weight

250 g CO_2

15.2% of your day

Better eat avocado next time?

(457/489)/(2750/3100)
(505/2000)/(2750/3100)
((5/50)+(38/66)+(((1674)-5*17-38*37)/6000)+(183/2500)+(67/600))/5 = 17.8%
((9/50)+(2/66)+(((753)-9*17-2*37)/6000)+(950/2500)+(50/600))/5 = 15.2%

Bottled water vs Tap Water

1 l

Bottled water

284 g CO_2

1 l

Tap water

0.5 g CO_2

Bottled water won’t save the climate. It causes 80% more emissions than were we need to get.

Rapeseed oil vs. Salad

Rapeseed oil is the most efficient source of fat on this planet.

1 kg

Rapeseed oil

2 kg CO_2

1 kg

Lettuce

250 g CO_2

This looks much better.

(209/105)/(2750/3100)
(502/2078)/(2750/3100)

Soy bean proteins

Soy beans are the most efficient source of proteins on this planet.

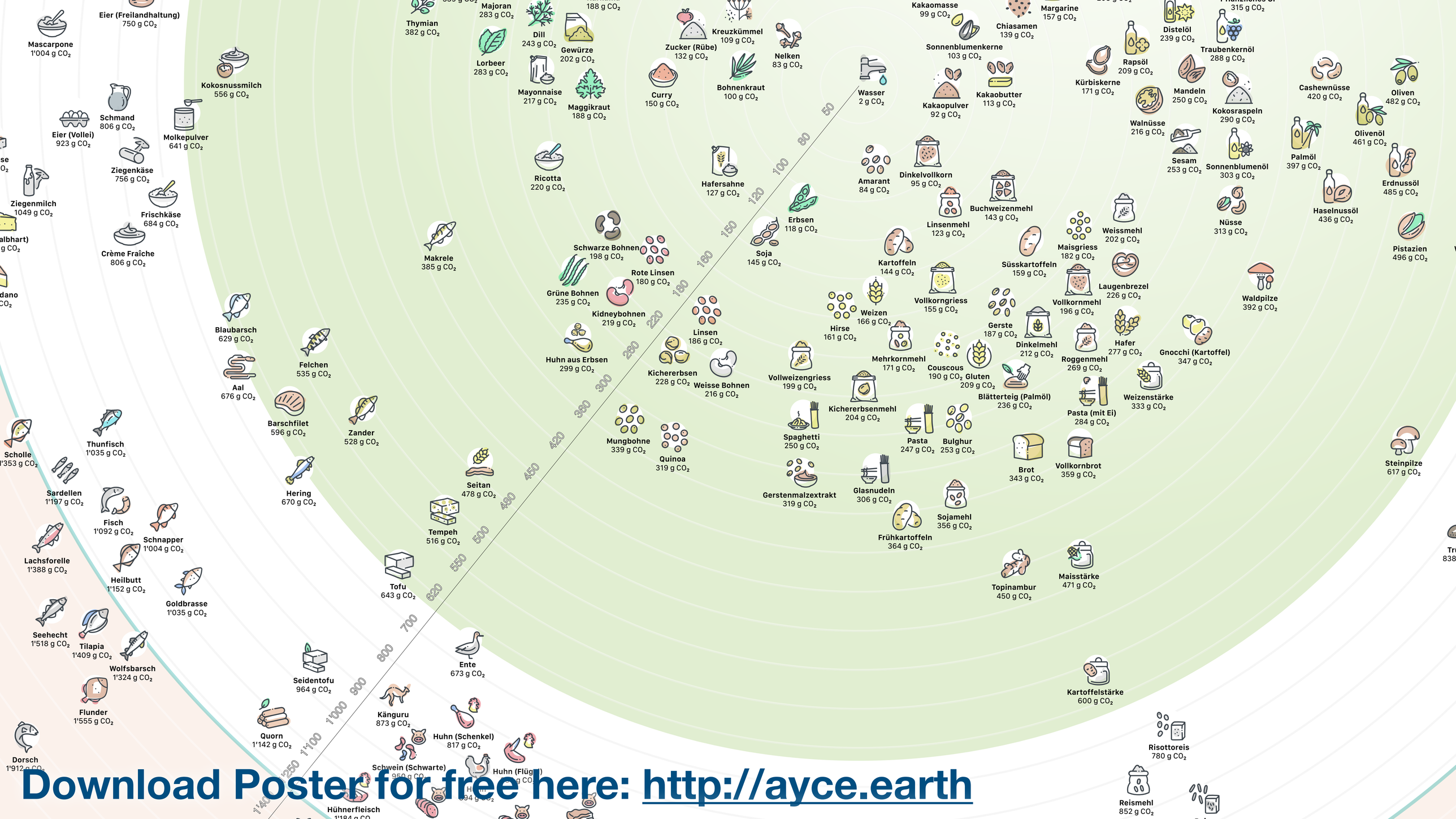
1 kg

soy bean proteins

7.56 kg CO_2

Great that we have them!

7560/(20/1.6)/(1258/2)



Download Poster for free here: http://ayce.earth

Appendix

„Daily Food Unit“ as a functional unit

PRO

- Better to apply:
  - Across categories: No false outliers (beef stew),
  - Within categories: all foods are comparable (tomato vs avocado)
- More meaningful: Captures more of what food actually is. Sets the right goals for this planet.

CON

- More complex: Harder to explain and understand (like IPCC GWP100)
- Not established: There is no scientific publication on the DFU.

The last point is IMO the only issue. But this can be solved!
Science didn’t give us a CO_2 label either.

Related Work:

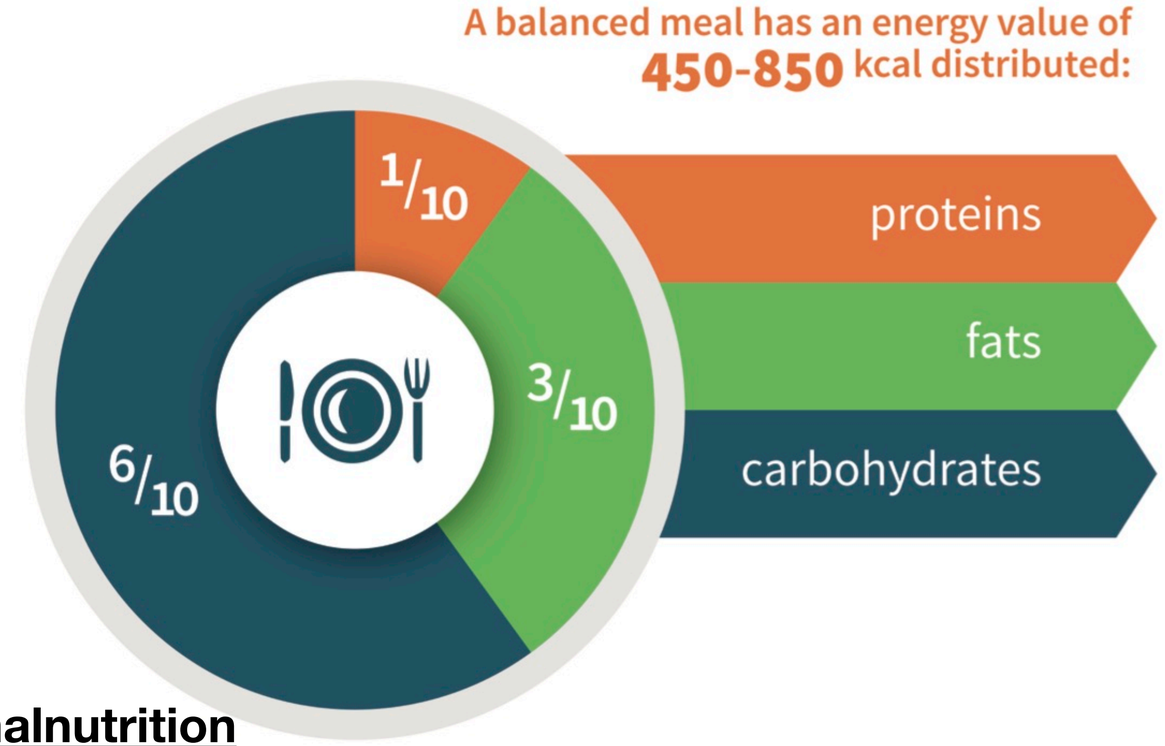
- Nutrient Density Unit (NDU)
- Nutrient Rich Food (NRF 9.3 …)
- PEF category rules (for diary) allow for a functional unit based on nutrients (no conflict!)
- FAO (integration of environment and nutrition in LCA of food items: opportunities and challenges)
- Smetana S. - researches: novel foods to replace proteins.
- Bo Weidma: (nutrition in the life cycle of food, functional impact?)

What is necessary for a nourished society

undernutrition vs. overweight / obesity

- We should derive 5-14% of it's calories from proteins and 20-35% from fat and at least 50% from carbohydrates. Have enough vitamins and minerals.

- Approx. marcronutrients requirement average adult:
  proteins: 50g
  fats: 66g
  energy (incl. carbohydrates): 2000 kcal
  water: 2.5 liter



https://www.dge.de/wissenschaft/referenzwerte/
https://www.who.int/news-room/fact-sheets/detail/malnutrition

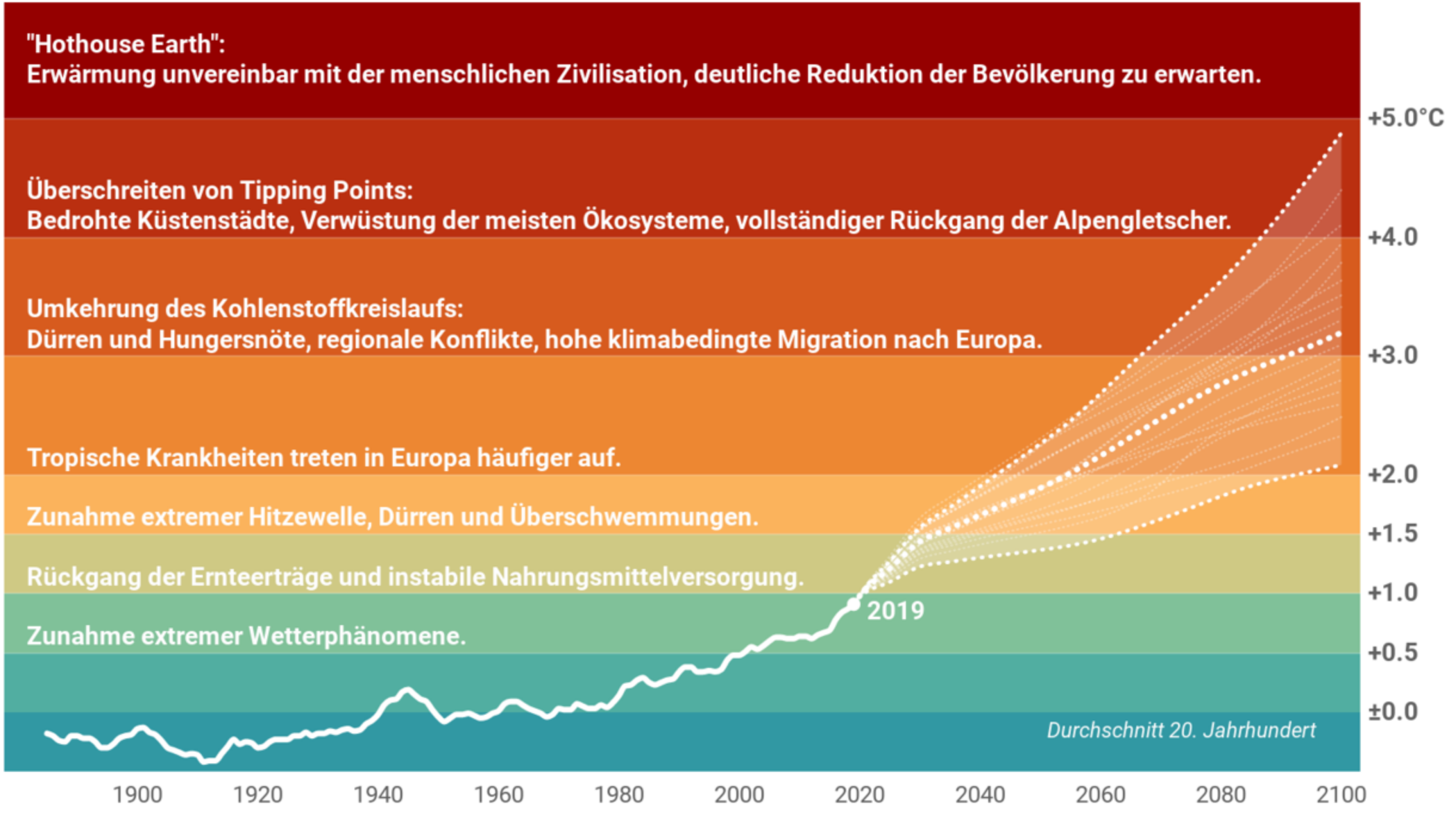
What is healthy food?

Global Burden of Disease Project: non-communicable diseases

- Cardiovascular
- Diabetes
- Cancer

Dietary risk factors	Definition	TMREL interval	TMREL value	Pos / neg
Diet high in sodium (salt)	24 h urinary sodium measured in g per day	1-5 [g]	3 [g]	negative
Diet high in processed meat	Average daily consumption of meat preserved by smoking, curing, salting, or addition of chemical preservatives	0-4 [g]	2 [g]	negative
Diet high in trans fats	Average daily intake of trans fat from all sources, mainly partially hydrogenated vegetable oils and ruminant products	0-1% of total energy	0.5% of total energy	negative
Diet high in red meat	Average daily consumption of red meat (beef, pork, lamb, and goat but excluding poultry, fish, eggs, and all processed meats)	18-27 [g]	23 [g]	negative
Diet high in sweetened beverages	Average daily consumption of beverages with ≥50kcal per 226·8 g serving, including carbonated beverages, sodas, energy drinks, and fruit drinks, but excluding 100% fruit and vegetable juices	0-5 [g]	2.5 [g]	negative
Diet low in fruits	Average daily consumption of fruits (fresh, frozen, cooked, canned, or dried, excluding fruit juices and salted or pickled fruits)	200-300 [g]	250 [g]	positive
Diet low in whole grains	Average daily consumption of whole grains (bran, germ, and endosperm in their natural proportion) from breakfast cereals, bread, rice, pasta, biscuits, muffins, tortillas, pancakes, and other sources	100-150 [g]	125 [g]	positive
Diet low in vegetables	Average daily consumption of vegetables (fresh, frozen, cooked, canned or dried vegetables including legumes but excluding salted or pickled vegetables, juices and starchy vegetables such as potatoes or corn)	340-500 [g]	420 [g]	positive
Diet low in nuts & seeds	Average daily consumption of nut and seeds	16-25 [g]	20 [g]	positive
Diet low in omega-3	Average daily intake of eicosapentaenoic acid and docosahexaenoic acid	200-300 [mg]	250 [mg]	positive
Diet low in fiber	Average daily intake of fiber from all sources, including fruits, vegetables, grains, legumes, and pulses	19-28 [g]	23 [g]	positive
Diet low in poly unsaturated fatty acids (PUFA)	Average daily intake of omega-6 fatty acids from all sources, mainly liquid vegetable oils, including soybean oil, corn oil, and safflower oil	9-13% of total energy	11% of total energy	positive
Diet low in calcium	Average daily intake of calcium from all sources, including milk, yogurt, and cheese	1-1.5 [g]	1.25 [g]	positive
Diet low in milk	Average daily consumption of milk, including non-fat, low-fat, and full-fat milk, excluding soy milk and other plant derivatives	350-520 [g]	435 [g]	positive

TMREL: Theoretical Minimum Risk Exposure Level
https://www.healthdata.org/data-visualization/gbd-compare
https://eaternity.org/assets/smart-chefs/2017-12-12_VitaScore_Documentation_web.pdf



right. based on science GmbH, inspiriert von Gregor Aisch. Vollständige Quellenangaben s. Anhang.

• Erstellt mit Datawrapper

Eat Lancet Budgets

5Gt CO_2 per year = boundary today

- Eat Lancet argues for a 72% reduction to 0.63t CO2/person/year for food to meet the planetary boundary. That is 1.73kg CO2 per day (12.1kg CO2 per week) - yet as far as I know this is only CO_2 (not Methan, etc.)

			GHG emissions	Cropland use	Water use	Nitrogen application	Phosphorus application	Biodiversity loss
Food production boundary			5.0 (4.7–5.4)	13 (11.0–15.0)	2.5 (1.0–4.0)	90 (65.0–140.0)	8 (6.0–16.0)	10 (1–80)
Baseline in 2010			5.2	12.6	1.8	131.8	17.9	100–1000
Production (2050)	Waste (2050)	Diet (2050)						
BAU	Full waste	BAU	9.8	21.1	3.0	199.5	27.5	1,043
BAU	Full waste	Dietary shift	5.0	21.1	3.0	191.4	25.5	1,270
BAU	Halve waste	BAU	9.2	18.2	2.6	171.0	23.2	684
BAU	Halve waste	Dietary shift	4.5	18.1	2.6	162.6	21.2	885
PROD	Full waste	BAU	8.9	14.8	2.2	187.3	25.5	206
PROD	Full waste	Dietary shift	4.5	14.8	2.2	179.5	24.1	351
PROD	Halve waste	BAU	8.3	12.7	1.9	160.1	21.5	50
PROD	Halve waste	Dietary shift	4.1	12.7	1.9	151.7	20.0	102
PROD+	Full waste	BAU	8.7	13.1	2.2	147.6	16.5	37
PROD+	Full waste	Dietary shift	4.4	12.8	2.1	140.8	15.4	34
PROD+	Halve waste	BAU	8.1	11.3	1.9	128.2	14.2	21
PROD+	Halve waste	Dietary shift	4.0	11.0	1.9	121.3	13.1	19

Table

Results

Only the extremes:

Kategorie	Name DE	Name EN	Name FR	g CO2 / 100g	g CO_2 / DFU	g CO_2 / kcal	Daily Food Unit	Energy [kcal]
beverages	Wasser	Water	Eau	0.04	5.00	4000.00	0.008	0.00001
vegetables & mushrooms	Batavia Salat	Batavia lettuce	Laitue de Batavia	26.18	1454.44	2.06	0.018	12.68
vegetables & mushrooms	Gurken	Cucumber	Concombres	28.18	1565.56	2.85	0.018	9.9
beverages	Mineralwasser (oh	Mineral water (non-(	Eau minérale (plate	28.40	3550.00	2840000.00	0.008	0.00001
vegetables & mushrooms	Artischocken	Artichokes	Artichauts	28.47	949.00	2.37	0.03	12
vegetables & mushrooms	Chinakohl	Chinese cabbage	Chou chinois	29.88	1494.00	2.44	0.02	12.26
vegetables & mushrooms	Pak Choi	Pak choi	Pak Choi	29.88	1660.00	2.68	0.018	11.13
vegetables & mushrooms	Rettich	Radish	Radis	31.70	1761.11	2.33	0.018	13.61
spices & condiments	Salz	Salt	Sel	32.00	941.18	3200000.00	0.034	0.00001
vegetables & mushrooms	Radicchio	Radicchio	Radicchio	35.18	1954.44	2.96	0.018	11.9
vegetables & mushrooms	Romanesco	Romanesco	Romanesco	38.65	1486.54	2.37	0.026	16.29
beverages	Mineralwasser (mit	Sparkling water	Eau minérale (gazeu	39.90	4987.50	3990000.00	0.008	0.00001
beverages	Tomatensaft	Tomato juice	Jus de tomate	40.42	2887.14	2.60	0.014	15.52
vegetables & mushrooms	Knollensellerie	Celery root	Céleri-rave	40.70	1695.83	2.00	0.024	20.4
spices & condiments	Bärlauch	Wild garlic	Ail sauvage	41.19	4381.90	2.57	0.0094	16
vegetables & mushrooms	Lauch	Leek	Poireau	41.22	1585.38	2.40	0.026	17.18
vegetables & mushrooms	Brokkoli	Broccoli	Brocoli	43.65	1558.93	2.29	0.028	19.09
vegetables & mushrooms	Stangensellerie	Celery	Branches de céleri	44.63	2028.64	4.94	0.022	9.03
vegetables & mushrooms	Pfifferlinge	Chanterelles	Chanterelles	54.73	2487.73	3.29	0.022	16.62
fruits & berries	Zitronen	Lemons	Citrons	56.06	3114.44	2.49	0.018	22.47
vegetables & mushrooms	Sauerkraut	Sauerkraut	Choucroute	57.59	3199.44	3.01	0.018	19.11
vegetables & mushrooms	Peperoni	Paprika	Piments	59.41	3228.78	1.86	0.0184	32
vegetables & mushrooms	Jalapeno	Jalapeno	Jalapeno	59.41	4950.79	3.96	0.012	15
vegetables & mushrooms	Aubergine	Aubergine	Aubergine	61.41	3070.48	3.23	0.02	19.03
fruits & berries	Sternfrucht	Starfruit	Carambole	67.34	3741.06	2.69	0.018	25
vegetables & mushrooms	Artischockenherze	Artichoke hearts	Coeurs d'artichauts	68.47	2633.46	2.74	0.026	25
diary & eggs	Molkepulver	Whey powder	Poudre de lactosér	256.29	2002.27	0.68	0.128	374.75
nuts & seeds	Nüsse	Nuts	Noix	267.79	977.34	0.45	0.274	592.34
nuts & seeds	Haselnüsse	Hazelnuts	Noisettes	270.43	965.82	0.43	0.28	632.94
diary & eggs	Eigelb	Egg yolk	Jaune d'œuf	271.26	1490.44	0.78	0.182	346.33
nuts & seeds	Sonnenblumenöl	Sunflower oil	Huile de tournesol	289.36	945.62	0.36	0.306	795.36
starches & bread	Sojamehl	Soy flour	Farine de soja	291.53	1112.71	0.74	0.262	396.48
nuts & seeds	Pflanzliches Öl	Vegetable fat	Huile végétale	301.37	984.87	0.38	0.306	795.36
starches & bread	Risottoreis	Risotto rice	Riz pour risotto	303.37	2861.98	0.85	0.106	358
nuts & seeds	Cashewkerne	Cashews	Noix de cajou	338.92	1313.64	0.58	0.258	587.56
nuts & seeds	Palmöl	Palm oil	Huile de palme	375.14	1242.19	0.48	0.302	785.8
spices & condiments	Milchschokolade	Chocolate (milk)	Chocolat au lait	377.72	2030.75	0.71	0.186	535.01
nuts & seeds	Pistazien	Pistachios	Pistaches	406.47	1551.41	0.72	0.262	566
spices & condiments	Weisse Schokolad	Chocolate (white)	Chocolat blanc	427.72	2160.20	0.76	0.198	566.06
nuts & seeds	Olivenöl	Olive oil	Huile d'olive	441.15	1441.67	0.55	0.306	795.36
nuts & seeds	Haselnussöl	Hazelnut oil	Huile de noisette	463.32	1362.71	0.51	0.34	902.84
nuts & seeds	Erdnussöl	Peanut oil	Huile d'arachide	463.32	1514.12	0.58	0.306	795.36
nuts & seeds	Walnussöl	Walnut oil	Huile de noix	578.62	1722.08	0.66	0.336	880
meat	Schweineschmalz	Lard	Lard	605.19	1811.95	0.69	0.334	874.18