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LEUPHANA UNIVERSITY OF LÜNEBURG

Steinbeis Innovation Center Logistics and Sustainability

“CARBON AND WATER FOOTPRINT” LEARNING MODULE

NOTES FOR TRAINEES/STUDENTS

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“CARBON FOOTPRINT CALCULATION IN ACCORDANCE WITH DIN EN 16258” LEARNING MODULE

DIN EN 16258 contains templates for the calculation of energy consumption and greenhouse gas emissions of transport services. Such a European standard for the measurement of environmental pollution is a logical consequence of European aims to reduce CO_2 output. A closer consideration of the contents of DIN EN 16258 reveals its complexity and highlights the associated challenges for transport and logistics companies. But what does DIN EN 16258 actually include, and what does this standard mean for the transport and logistics sector and for your company?

Tasks to complete individually

Before you start to carry out your own carbon footprint calculations in accordance with DIN EN 16258, you will need to gain a basic working knowledge of certain terms and abbreviations.

TASKS:

1. Read through the text “Calculating greenhouse gases with DIN EN 16258 and the DSLV Guide” *(see Material 1)*.
2. Formulate a brief definition for each of the following terms. *(see Material 2)*.

CALCULATING GREENHOUSE GASES WITH DIN EN 16258 AND THE DSLV GUIDE

MATERIAL 1

Since 2013, DIN EN 16258 has formed the European foundation for the standardised calculation and declaration of energy consumption and greenhouse gas emissions within the scope of transport services. However, individual EU countries are free to decide the extent to which this standard is enshrined in law. Transport and logistics services providers in Germany, for example, are not yet mandatorily required to measure and publish their energy consumption and the greenhouse gas emissions caused. Nevertheless, they may seek certification voluntarily. By way of contrast, transport services which are offered in France or which have their starting point or destination in the country must be declared in accordance with this standard.

What are the reasons for taking a detailed look at DIN EN 16258?
Firstly, there is a basic management principle that states: "If you can't measure it, you can't control it." If you are offering transport and logistics services, you should know how many greenhouse gases (GHG) you are producing and how you are performing in this regard as compared with your competitors. According to the Kyoto Protocol, the six different greenhouse gases are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and carbon dioxide (CO_2). In the interest of better comparability, these emissions are expressed in the form of so-called CO_2 equivalents (CO_2e).
Secondly, transport and logistics processes are often conducted right across Europe or internationally rather than merely on a domestic level within one country. This may mean that you are obliged to declare the energy consumption and greenhouse gas emissions of your transport and logistics services, as is the case in France for example. So a standardised and comparable system for the calculation of energy consumption and greenhouse gas emissions (at least) across Europe is useful, don't you think?

What is in DIN EN 16258?
In a nutshell, DIN EN 16258 includes specific terminology and basic principles for the calculation of the carbon footprint of transport routes. It lists, for example, the uniform average values (emission factors) which are necessary in order to carry out comparative calculations. DIN EN 16258 takes account of the whole of the transport chain, regardless of whether a company deploys its own vehicles or uses vehicles belonging to sub-contractors. Transhipment processes, office usages, and the manufacture, maintenance, and disposal of vehicles and transport infrastructures are not covered. Loss of refrigerants, which is a factor in temperature-controlled transportation, is also not included in the calculation.

How are energy consumption and greenhouse gas emissions calculated in accordance with DIN EN 16258?
Depending on the individual case, calculation of energy consumption and greenhouse gas emissions in accordance with DIN EN 16258 can be a highly complex matter. In order to make it easier to work with the standard, the German Association of Shipping and Logistics Providers (DSLV) has drawn up a guide containing tips for its application. This guide also includes sample calculations, and these will be addressed below.

Prior to any calculation, consideration should be given to exactly WHAT is to be calculated. A distinction is drawn in this regard between direct and indirect emission. Every instance of transportation of goods or persons generates direct greenhouse gases. The extent of the emission depends on the type of vehicle, the load weight, the transport distance, and fuel consumption. Indirect emissions, on the other hand, have already been produced via such processes as the generation of electricity and manufacture of fuel. Such procedures also require energy and therefore release greenhouse gases. When considering emissions created by logistics services, therefore, a differentiation is made between the following three process sections:

Figure: Process sections for the calculation of GHG emissions from transport services in accordance with DIN EN 16258

The tank-to-wheel (TTW) section can comprise various legs of the route which may be distributed across different modes of transport. In this case, energy consumption and greenhouse gas emissions will need to be calculated per leg of the route and then aggregated. The overall result (WTW) is also informed by empty trips performed by the mode of transport prior to or after the transportation of goods.

The basic consumption data for the modes of transport also has an important part to play.
A fundamental distinction is drawn between the following two approaches towards the calculation of consumption data:

1. The consumption-based method
2. The distance-based method

In the case of the consumption-based method, the amount of greenhouse gas emissions (G in kg CO_2e) is calculated by multiplying the specific energy consumption (E in MJ) with an energy-specific emission factor (g in kg CO_2e/l). The energy consumption originally measured (F in kg) is converted beforehand with the help of strictly defined energy factors (e in MJ/l) and stated using the energy measurement unit megajoule (MJ). DIN EN 16258 lists the following three possible ways of determining the necessary consumption data:

1. Energy consumption for a specific trip has been measured and is available in detail. In reality, however, this seldom occurs.
2. Vehicle or route-specific average values (e.g. for one year) are available via the so-called Vehicle Operation System (VOS) for the tour forming the object of consideration.
3. Average fleet values are available.

By way of contrast, the distance-based method does not involve calculating energy consumption and greenhouse gas emissions on the basis of measurement of fuel consumption. The distance-based method determines energy consumption and greenhouse gas emissions by means of the weight of the shipment (W in t) and the distances covered (D in km) or the tonne kilometres (tkm = weight x distance). These values are then multiplied by consumption and emission factors per vehicle kilometre or tonne kilometre in order ultimately to identify the energy consumption and greenhouse gas emissions. The necessary consumption and emission factors are available from official databases (e.g. HBEFA, TREMOD, TREMOVE) or from freely accessible research tools (such as EcoTransIT World). These are then designated as "default values". This approach is particularly useful in cases where the sub-contractors that have been engaged are unable or unwilling to disclose their levels of fuel consumption.

The following figure summarises the calculation variants once more:

CONSUMPTION-BASED METHOD			DISTANCE-BASED METHOD
The following data relating to fuel consumption is available:			No data relating to fuel consumption is available.
Individual measurement for specific transport on a route or leg	Specific values from the transport service provider for a route or type of vehicle	Average fleet values of the transport service provider (e.g. relating to a period of one year)	Use of weight and distance in conjunction with stipulated values from databases ("default values") as a replacement for consumption values

Figure: Approaches towards the calculation of energy consumption and greenhouse gas emissions in accordance with DIN EN 16258

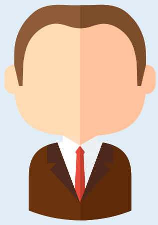
The preference expressed in DIN EN 16258 is for the consumption-based method to be used. This is because more precise results are delivered.

The ultimate aim of stipulating the methodological approach for calculating the energy consumption and greenhouse gas emissions of transport services via DIN EN is to increase the transparency of the service and thus improve communication with customers. A further intention is for DIN EN 16258 to aid the cause of sustainable development by helping to reduce greenhouse gas emissions. Using DIN EN 16258 to calculate energy consumption and greenhouse emissions is not, therefore, an end in itself. It is a procedure that supports the transport and logistics sector in contributing towards the achievement of international aims to reduce CO_2 output.

Note: This text is based on the DSLV Guide issued in 2013. Source: DSLV Deutscher Speditions- und Logistikverband e.V. [German Association of Shipping and Logistics Providers, DSLV] (Ed.) (2013): "Berechnung von Treibhausgasemissionen in Spedition und Logistik gemäß DIN EN 16258".

MATERIAL 2

Leg	
CO_2e	
TTW or T	
WTW or W	
WTT	
F	
e	
g	
E in MJ	
G in kg	
W	
D	
Default value	
VOS	



Tasks to complete individually

You have now obtained a basic working knowledge of the terminology and abbreviations used for calculating carbon footprints in accordance with DIN EN 16258 and are in a position to understand some further calculations from other sources. The terms and abbreviations are included in the following general formulas:

Energy consumption:	$E_T = F \times e_T$	or	$E_W = F \times e_W$
Greenhouse gas emissions:	$G_T = F \times g_T$	or	$G_W = F \times g_W$

TASK:

1. Try to gain an understanding of the individual stages of the calculation process by following the examples given *(see Material 3)*.

MATERIAL 3

a) **Consumption-based calculation:**
Calculate the tank-to-wheel and the well-to-wheel energy consumption and the relevant tank-to-wheel and well-to-wheel greenhouse gas emissions for a trip from Hamburg to Karlsruhe for a lorry which uses 191 litres of diesel on the trip.

This task results in four individual calculations:
To calculate the tank-to-wheel energy consumption, consumption of diesel fuel is multiplied by the conversion factor for diesel from Germany *(see Material 4, Table 1)* >6.2 per cent admixture of biodiesel related to energy content (2011) corresponds to 6.75 per cent of biodiesel by volume.

Tank-to-wheel energy consumption
Formula: $E_T = F \times e_T$
$E_T = 139.32 \text{ l} \times 35.7 \text{ MJ/l} = 4{,}974 \text{ MJ}$

Well-to-wheel energy consumption
Formula: $E_W = F \times e_W$
$E_W = 139.32 \text{ l} \times 44.4 \text{ MJ/l} = 6{,}186 \text{ MJ}$

Tank-to-wheel greenhouse gas emissions
Formula: $G_T = F \times g_T$
$G_T = 139.32 \text{ l} \times 2.49 \text{ kg } CO_2e/\text{l} = 347 \text{ kg } CO_2e$

Well-to-wheel greenhouse gas emissions
Formula: $G_W = F \times g_W$
$G_W = 139.32 \text{ l} \times 3.15 \text{ kg } CO_2e/\text{l} = 439 \text{ kg } CO_2e$

➔ **What do these results mean?**
They clearly show that direct greenhouse gas emissions (TTW) are lower than the direct and indirect greenhouse gas emissions (WTW) put together. 476 kg CO_2e $<$ 602 kg CO_2e. This leads to the conclusion that the combustion of diesel during the trip causes far more greenhouse gas emissions than the energy provision. However, the calculation does not produce an added value until comparative data (e.g. other modes of transport, vehicle types, or drivers) are available.

b) Distance-based calculation:

A distance-based calculation may be performed if consumption data is not available (e.g. in the case of deployment of a sub-contractor). The following six points constitute the approach to be adopted when carrying out a distance-based calculation. This makes it clear just how many factors exert an impact on fuel consumption within the scope of a transport process.

1. Determination of the type of cargo (bulk goods, average goods, volume goods)
2. Identification of vehicles used by type and size
3. Selection of the specific consumption values per 1,000 km depending on the type of cargo and model or type of vehicle > E
4. Calculation of the real transport distance for the individual shipment. In the case of land-based transports (lorry, rail, inland waterway), this corresponds to the actual route covered. Special calculation provisions apply to air and maritime transport because the actual distance mostly deviates from the ideal route > D
5. Identification of the real weight of the shipment including weight of packaging or transport aids (e.g. pallets, containers) > W
6. Calculation of energy consumption for the shipment by multiplying the weight of the shipment by the transport distances and by the specific consumption values per 1,000 km (see Material 4, Table 2).
   Formula: F = W x D x E

Example:

A 40-tonne articulated lorry is transporting eight tonnes of insulation material from Hamburg to Berlin.

Identification of parameters for the calculation:

Type of cargo:	Volume goods
Class of lorry:	Articulated lorry 24–40 tonnes
Consumption data:	0.033 l/1,000 km *(see Material 4, Table 2, "Level" column > the route does not contain any significant climb)*
Transport distance:	290 km
Transport weight:	8 tonnes

Calculation of energy consumption

F [litres]= W [t] x D [km] x E [l/1,000 km] = 8 t x 290 km x 0.033 l/1,000 km = 76.56 l

➔ **Greenhouse gas emissions can therefore be calculated based on a consumption of 76.56 litres.**

TABLE 1:
FACTORS FOR THE CALCULATION OF ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

	STANDARDISED ENERGY CONSUMPTION				GREENHOUSE GAS EMISSIONS (STATED AS CO_2 EQUIVALENTS)			
	Tank-to-wheel (e_T)		Well-to-wheel (e_W)		Tank-to-wheel (g_T)		Well-to-wheel (g_W)	
	MJ/kg	MJ/l	MJ/kg	MJ/l	$kgCO_2e/kg$	$kgCO_2e/l$	$kgCO_2e/kg$	$kgCO_2e/l$
Petrol	43.2	32.2	50.5	37.7	3.25	2.42	3.86	2.88
Ethanol	26.8	21.3	65.7	52.1	0.00	0.00	1.56	1.24
Petrol E5[1)]	42.4	31.7	51.4	38.4	3.08	2.30	3.74	2.80
Petrol E10[2)]	41.5	31.1	52.2	39.1	2.90	2.18	3.62	2.72
Diesel	43.1	35.9	51.3	42.7	3.21	2.67	3.90	3.24
Biodiesel	36.8	32.8	76.9	68.5	0.00	0.00	2.16	1.92
Diesel D7[3)]	42.7	35.7	53.2	44.5	2.97	2.48	3.76	3.15
Diesel Germany[4)]	42.6	35.7	53.1	44.4	2.98	2.49	3.77	3.15
Compressed natural gas (CNG)	45.1	k.A.	50.5	k.A.	2.68	k.A.	3.07	k.A.
Liquefied petroleum gas (LPG)	46.0	25.3	51.5	28.3	3.10	1.70	3.46	1.90
Kerosene[5)]	44.1	35.3	52.5	42.0	3.18	2.54	3.88	3.10
Heavy fuel oil (HFO)[6)]	40.5	39.3	44.1	42.7	3.15	3.05	3.41	3.31
Marine diesel oil (MDO)	43.0	38.7	51.2	46.1	3.24	2.92	3.92	3.53
Marine gas oil (MGO)	43.0	38.3	51.2	45.5	3.24	2.88	3.92	3.49
Traction current [7)]	**MJ/kWh**		**MJ/kWh**		**kg/kWh**		**kg/kWh**	
Germany	3.6		11.1		0.00		0.574	
Sweden	3.6		4.0		0.00		0.004	

1) 5% ethanol by volume – 2) 10% ethanol by volume – 3) 5% biodiesel by volume – 4) 6.2% admixture of biodiesel related to energy content (2011) – corresponds to 6.75% of biodiesel by volume. – 5) Without allowing for a possible higher effect on the climate from air traffic at cruising height. – 6) HFO = heavy fuel oil (heavy oil for ships) – 7) Values are taken from the 2013 DSLV Guide, the calculations of which correspond to DIN EN 16258.

Sources: *DIN EN 16258, DSLV Guide 2013.*

TABLE 2: KEY INDICATORS FOR SPECIFIC ENERGY CONSUMPTION PER 1,000 TKM OR TEU-KM FOR LORRY TRANSPORT

	MODERATELY HILLY (AVERAGE CARRIAGEWAY GRADIENT OF 1%)			LEVEL GROUND		
	Volume goods	Average goods	Bulk cargo	Volume goods	Average goods	Bulk cargo
Freight transport	**Diesel consumption in litres/1,000 tkm**					
Lorry < 7.5 t	26.8	21.3	65.7	0.00	0.00	1.56
Lorry 7.5–12 t	42.4	31.7	51.4	3.08	2.30	3.74
Lorry 12–24 t	41.5	31.1	52.2	2.90	2.18	3.62
Articulated lorry 24–40 t	43.1	35.9	51.3	3.21	2.67	3.90
Container transport	**Diesel consumption in litres/TEU-km**					
Lorry < 7.5 t	X	X	X	X	X	X
Lorry 7.5–12 t	X	X	X	X	X	X
Lorry 12–24 t	0.24	0.26	X	0.22	0.24	X
Articulated lorry 24–40 t	0.17	0.19	0.34	0.14	0.16	0.29

Container transport for this lorry size or this container weight not applicable.

Source: *DSLV Guide 2013.*

Tasks to complete individually

You have now gained an understanding of calculations of energy consumption and greenhouse gas emissions taken from other sources and are in a position to carry out your own calculations with the assistance of *Material 4*.

TASKS:

LORRY

A 24-tonne lorry is transporting 12 tonnes of grain from Hamburg to Cologne (430 km) and has filled up with diesel from Germany.

1. Calculate energy consumption F in litres.
2. Calculate the TTW and WTW energy consumption and greenhouse gas emissions.
3. Which calculation method is being used here?

AIRCRAFT

Belly cargo weighing 0.05 tonnes is being transported from Shanghai to Frankfurt in a passenger aircraft. 117 kg of kerosene is used for this air freight shipment.

4. Calculate the TTW and WTW energy consumption and the TTW and WTW greenhouse gas emissions.

GOODS TRAIN

DIN EN 16258 does not state conversion factors for electricity because this is dependent on the respective generating plants. The fundamental principle is that a high proportion of coal-fired energy will produce high greenhouse gas emissions whereas a high proportion of electricity from renewable sources will cause low greenhouse gas emissions. The recommendation given is that the values of the energy supplier or the average values of the network or of the whole country (e.g. Germany) should be used.

An electrically powered goods train needs around 4,850 kWh of electricity for a journey from Düsseldorf to Dresden.

5. Calculate the TTW and WTW energy consumption and the TTW and WTW greenhouse gas emissions.
6. Calculate the TTW and WTW energy consumption and the TTW and WTW greenhouse gas emissions of a goods train that is travelling under the same conditions in Sweden whilst using Swedish electricity.

7) Compare the results and explain your comparison.

BIODIESEL

8. Calculate the TTW and WTW energy consumption and the amount of TTW and WTW greenhouse gas emissions for a lorry using 207.89 litres of biodiesel that is travelling from Hamburg to Karlsruhe.
9. Compare your results with those of the sample task presented and explain how and why the energy consumption and greenhouse gas emissions change.
10. Use the Internet to research the benefits and drawbacks of using biodiesel.

You have now worked your way through a number of energy consumption and greenhouse gas emission calculations and are in a position to reflect on the use of DIN EN 16258 in practice. DIN EN 16258 recommends the consumption-based method because this delivers more precise results than the distance-based method. The principle is as follows: the more precise the available data, the more substantive the greenhouse gas emissions calculated will be. But how exactly can all of this be documented, calculated, and optimised in practice?

Tasks to complete individually

TASKS:

1. Research how energy consumption is calculated at your company and how the greenhouse gas emissions of transport services are calculated *(see Note 1)*.
2. Present the advantages and disadvantages that arise or could arise for your company as a result of the application of DIN EN 16258 *(see Note 2)*.
3. Explore the benefits and drawbacks of the application of DIN EN 16258 with your colleagues if you can.

TIPS FOR RESEARCH

NOTE 1

The following key questions may assist you in your research:

- Is data recorded and evaluated at your company?
- If the answer is no, why is this data not recorded?
- If the answer is yes, which IT system is used to capture the data?
- Does DIN EN 16258 serve as a basis for calculation at your company?
- Are consumption-based or distance-based, calculations carried out?
- If consumption-based calculations are used, which approach is adopted (individual, fleet-based, route-based, or vehicle-based)?
- Why is data recorded in this way at your company? What reasons are there as to why data is good or only of moderate quality?

TIPS FOR UNDERTAKING YOUR ASSESSMENT

NOTE 2

The following key questions may assist you in considering your views:

- Does the calculation lead to costs, and if so which costs are incurred?
- How time-consuming is this approach and why?
- Is all necessary information available?
- What benefit does standardised calculation offer for your company, your customers, your staff, your competitors, Germany's climate targets, or subsequent generations?

"THE NATURAL QUARTETS" LEARNING MODULE

The transport of people or goods produces greenhouse gases directly and indirectly (e.g. in the form of carbon dioxide). Direct emissions are created during the actual transport itself and are dependent on the respective means of transport, the weight of the load, the transport distance, and consumption of fuel. However, the production of electricity and fuels, the manufacture of vehicles, and the energy needed for road building all cause indirect greenhouse gas emissions. Your consumption of water does not merely comprise your morning shower and coffee. As well as this visible water, "invisible" water also exists. This is referred to as "virtual water". "Virtual water" is necessary to produce the goods that we use or consume on a daily basis.

In order to be able to interpret and change such ecological impacts caused by personal and company actions, you need to begin by making these effects measurable. The concepts of the carbon and water footprint make it possible for you to compare products and actions by portraying their greenhouse gas emissions and water consumption in a clear way. Within the scope of this learning module, you will use a game entitled "The Natural Quartets" to reflect upon the ecological impacts caused by personal and company actions.

Tasks to complete in pairs or groups

TASKS:

Before the game:

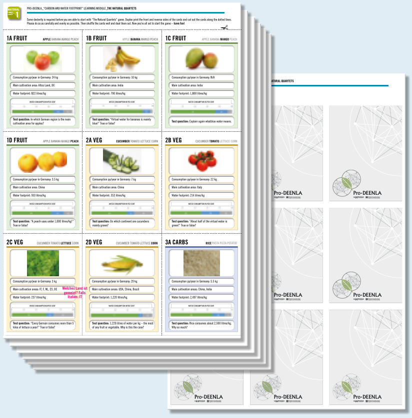
1. Work together to cut out the cards used in "The Natural Quartets" and shuffle them thoroughly (see Material 1).
2. Read through the instructions for the game and resolve any queries together with your colleagues (see Note 1).
3. Determine how much time you have to play and opt for one of the versions of the game.

During the game:

4. You can play the game "The Natural Quartets" with up to five colleagues. Use the Internet to research any questions that may arise during the game.

PLAYING CARDS

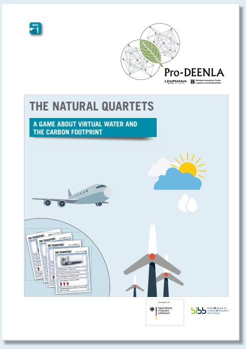
> see Annex for template to cut out



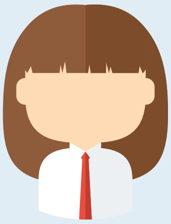
Please duplex print front and reverse sides of all six sheets at a scale of 1:1 and cut out.

INSTRUCTIONS

> see Annex



Please read through carefully before starting with the game.



Tasks to complete individually

Once you have played the game "The Natural Quartets", document the approach you took.

TASKS:

After the game:

1. Work individually to note down the terms you have learned. Illustrate these using examples from the quartets game and add instances from your everyday life.
2. Create a personal encyclopedia in which you record relevant terms relating to the concepts of the carbon and water footprint. Illustrate these using examples from the quartets game and add instances from your everyday life *(see Note 2)*.

NOTE 2

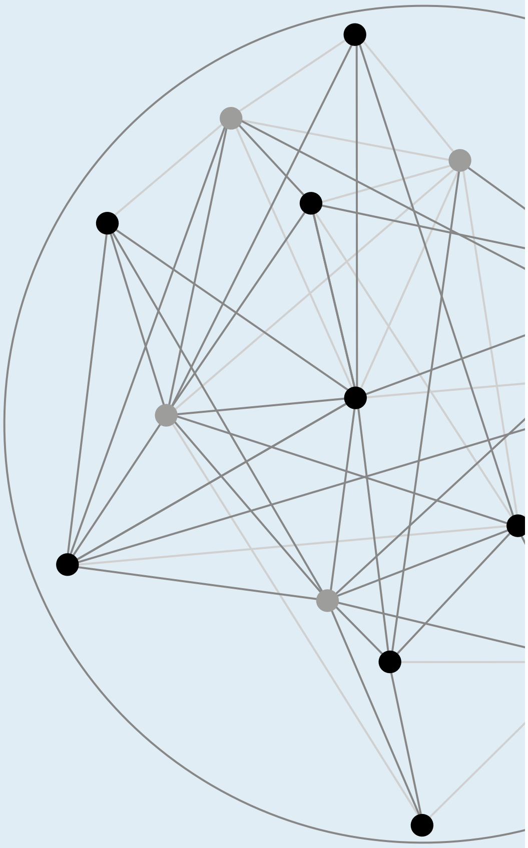
TIPS FOR DOCUMENTATION

Documentation can take place in the form of a encyclopedia. If you have already created one in the "Carbon footprint calculation in accordance with DIN EN 16258" learning module, you can use this as a basis and add the missing terms.

The following questions may assist you in the creation of the encyclopedia:

- Should the encyclopedia be sorted alphabetically or thematically?
- Should the encyclopedia be recorded electronically or written by hand?
- Should pictures be integrated into the encyclopedia?
- Which terms are relevant for consideration in the encyclopedia?
- Which examples should be used to explain the terms?

It is a good idea to use a computer to create the encyclopedia so that it can be supplemented and corrected at a later date.



IMPRINT

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Some dexterity is required before you are able to start with "The Natural Quartets" game. Duplex print the front and reverse sides of the cards and cut out the cards along the dotted lines. Please do so as carefully and evenly as possible. Then shuffle the cards well and deal them out. Now you're all set to start the game – **have fun!**

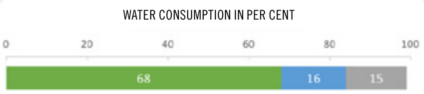
1A FRUIT

APPLE BANANA MANGO PEACH

Consumption pp/year in Germany: 24 kg

Main cultivation area: Altes Land, DE

Water footprint: 822 litres/kg



Test question: In which German region is the main cultivation area for apples?

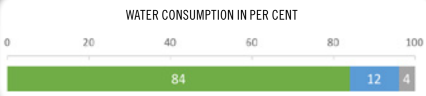
1B FRUIT

APPLE **BANANA** MANGO PEACH

Consumption pp/year in Germany: 10 kg

Main cultivation area: India

Water footprint: 790 litres/kg



Test question: "Virtual water for bananas is mainly blue!" True or false?

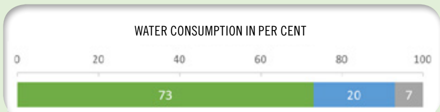
1C FRUIT

APPLE BANANA **MANGO** PEACH

Consumption pp/year in Germany: N/A

Main cultivation area: India

Water footprint: 1,800 litres/kg



Test question: Explain again whatblue water means.

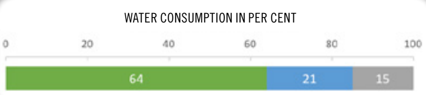
1D FRUIT

APPLE BANANA MANGO **PEACH**

Consumption pp/year in Germany: 3.5 kg

Main cultivation area: China

Water footprint: 910 litres/kg



Test question: "A peach uses under 1,000 litres/kg!" True or false?

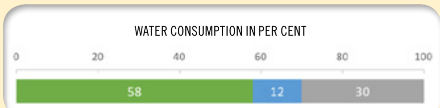
2A VEG

CUCUMBER TOMATO LETTUCE CORN

Consumption pp/year in Germany: 7 kg

Main cultivation area: China

Water footprint: 353 litres/kg



Test question: On which continent are cucumbers mainly grown?

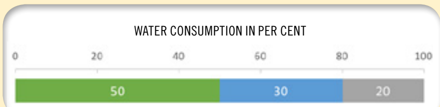
2B VEG

CUCUMBER **TOMATO** LETTUCE CORN

Consumption pp/year in Germany: 22 kg

Main cultivation area: Italy

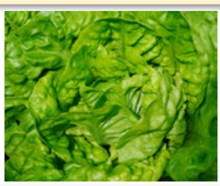
Water footprint: 214 litres/kg



Test question: "About half of the virtual water is green!" True or false?

2C VEG

CUCUMBER TOMATO **LETTUCE** CORN

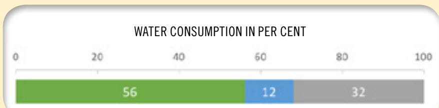


Consumption pp/year in Germany: 3 kg

Main cultivation areas: IT, F, NL, ES, DE

Welches Land ist gemeint? Falls Italien: IT

Water footprint: 237 litres/kg



Test question: "Every German consumes more than 5 kilos of lettuce a year!" True or false?

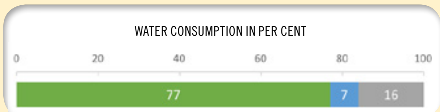
2D VEG

CUCUMBER TOMATO LETTUCE **CORN**

Consumption pp/year in Germany: 20 kg

Main cultivation areas: USA, China, Brazil

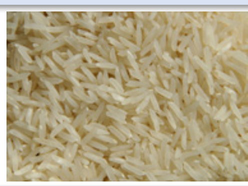
Water footprint: 1,220 litres/kg



Test question: 1,220 litres of water per kg – the most of any fruit or vegetable. Why is this the case?

3A CARBS

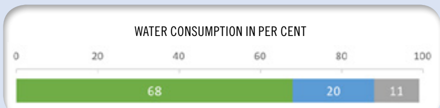
RICE PASTA PIZZA POTATOE



Consumption pp/year in Germany: 5.5 kg

Main cultivation areas: China, India

Water footprint: 2,497 litres/kg



Test question: Rice consumes about 2,500 litres/kg. Why so much?

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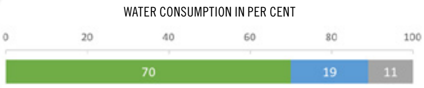
3B CARBS

RICE **PASTA** PIZZA POTATOE

Consumption pp/year in Germany: 5.5 kg

Country of origin: Italy

Water footprint: 1,849 litres/kg



Test question: "About half of the virtual water is green!" True or false?

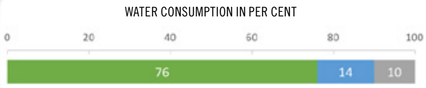
3C CARBS

RICE PASTA **PIZZA** POTATOE

Consumption pp/year in Germany: 10 (frozen)

Country of origin: Italy

Water footprint: 1,259 litres/kg



Test question: How many frozen pizzas does a German eat per year? (+/-3 pizzas)

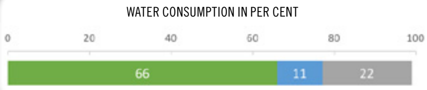
3D CARBS

RICE PASTA PIZZA **POTATOE**

Consumption pp/year in Germany: 65 kg

Main cultivation areas: China, USA, Germany

Water footprint: 287 litres/kg



Test question: "Potatoes consume more grey than blue water!" True or false?

4A MEAT

BEEF PORK GOAT CHICKEN

Consumption pp/year in Germany: 9 kg

Slaughter weight under intensive fattening conditions after: 3 years

Water footprint: 15,415 litres/kg

Test question: Over 15,000 l/kg – any ideas as to why it's so much?

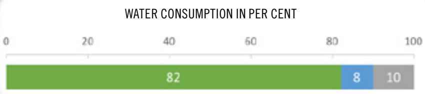
4B MEAT

BEEF **PORK** GOAT CHICKEN

Consumption pp/year in Germany: 31 kg

Slaughter weight under intensive fattening conditions after: 10 months

Water footprint: 5,988 litres/kg



Test question: "Germans eat about 15 kilos of pork a year!" True or false?

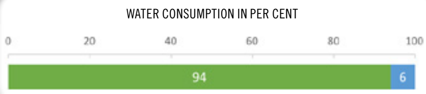
4C MEAT

BEEF PORK **GOAT** CHICKEN

Consumption pp/year in Germany: < 1 kg

Water footprint approx. 1% of the global animal production

Water footprint: 5,521 litres/kg



Test question: 0% grey – any ideas as to why this is the case?

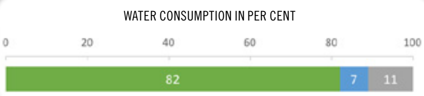
4D MEAT

BEEF PORK GOAT **CHICKEN**

Consumption pp/year in Germany: 12 kg

Slaughter weight under intensive fattening conditions after: 10 weeks

Water footprint: 4,325 litres/kg



Test question: Compared to beef "just" 4,325 l/kg – any ideas as to why this is the case?

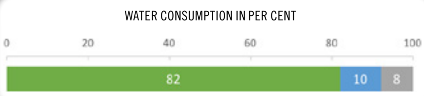
5A DRINKS

TEA MILK WINE COFFEE

Consumption pp/year in DE: 26 litres

Country of origin: India

Water footprint: 27 litres/250 ml tea



Test question: How many litres of tea does a German drink annually? (+/- 5 litres)

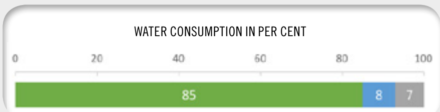
5B DRINKS

TEA **MILK** WINE COFFEE

Consumption pp/year in DE: 92 litres

Country of origin: Germany

Water footprint: 255 litres/250 ml milk



Test question: Explain why the water footprint is 1,000 times higher than the milk consumption.

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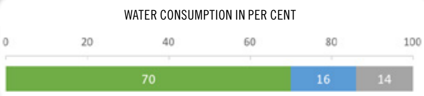
5C DRINKS

TEA MILK **WINE** COFFEE

Consumption pp/year in DE: 20 litres

Region of origin: Europe (F, DE, ES, IT)

Water footprint: 27 litres/250 ml wine



Test question: Why does wine require 70 per cent green water?

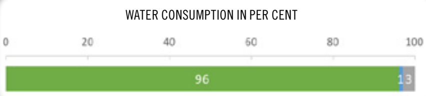
5D DRINKS

TEA MILK WINE **COFFEE**

Consumption pp/year in DE: 148 litres

Region of origin: Africa, Oceania, South America

Water footprint: 264 litres/250 ml coffee



Test question: “Over 1 ml of virtual water is needed to produce 1 ml of coffee!” True or false?

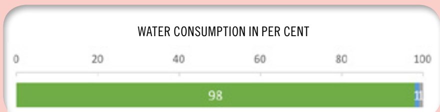
6A LIFE

CHOCOLATE LEATHER T-SHIRT MICROCHIP

Consumption pp/year in DE: 11.5 kg

Region of origin: South America

Water footprint: 17,196 litres/kg



Test question: How much chocolate does a German eat per year? (+/- 4 kg)

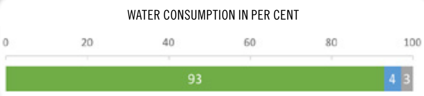
6B LIFE

CHOCOLATE **LEATHER** T-SHIRT MICROCHIP

Sales in Germany/per year: EUR 3 billion

Country of origin: Italy, Brazil

Water footprint: 17,093 litres/kg



Test question: “Leather uses more than 17,000 litres of water/kg!” True or false?

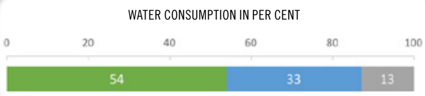
6C LIFE

CHOCOLATE LEATHER **T-SHIRT** MICROCHIP

Average possession per person: 30

Country of origin: China, India

Water footprint: 2,495 litres/T-shirt (250 g)



Test question: “A T-shirt uses less than 1,000 litres of water!” True or false?

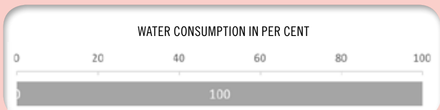
6D LIFE

CHOCOLATE LEATHER T-SHIRT **MICROCHIP**

Installed in (almost) every technical device

Market leader: Intel

Water: 16,000 litres/kg (32 l per 2 g chip)



Test question: What do you know about rare earths? You might need to do some research.

7A DIN EN 16258

E_T E_W G_T G_W

T = Tank-to-wheel

E = Energy consumption in MJ (megajoule)

E_T = Energy consumption x Energy factor

Example: Freiburg → Hanover / lorry / 186 litres diesel

$E_T = F \times e_T$

= 186 l x 35.9 MJ/l = 6,677 MJ

Test question: “Tank to wheel (E_T) shows energy consumption for the trip.” True or false?

7B DIN EN 16258

E_T **E_W** G_T G_W

W = Well-to-wheel

E = Energy consumption in MJ (megajoule)

E_W = Energy consumption x Energy factor

Example: Freiburg → Hanover / lorry / 186 litres diesel

$E_W = F \times e_W$

= 186 l x 42.7.0 MJ/l = 7,942 MJ

Test question: What does well to wheel mean?

7C DIN EN 16258

E_T E_W **G_T** G_W

T = Tank-to-wheel

G = Greenhouse gas emissions in kg

G_T = Energy consumption x Emission factor

Example: Freiburg → Hanover / lorry / 186 litres diesel

$G_T = F \times e_T$

= 186 l x 2.67 kg CO_2 e/l = 497 kg

Test question: What does the "F" stand for in the calculation formula ($G_T = F \times g_T$)?

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7D DIN EN 16258

E_T E_W G_T $\mathbf{G_W}$

W = Well-to-wheel

G = Greenhouse gas emissions in kg

G_W = Energy consumption x Emission factor

Example: Freiburg → Hanover / lorry / 186 litres diesel

$G_W = F \times g_W$

$= 186\ l \times 3.24\ kg\ CO_2\ e/l = 603\ CO_2 e$

Test question: What does G_W means?

8A HOLIDAY

MALLORCA MEXICO RÜGEN BALCONY

Aeroplane/14 days/3 people

87 kg CO_2 per person/day

Carbon footprint: 1,222 kg CO_2 per person

Outward and return travel:	925 kg
Accommodation:	148 kg
Food and drink:	91 kg
Activities at the destination:	58 kg

Test question: Do outward and return travel together exceed 1,000 kg CO_2?

8B HOLIDAY

MALLORCA **MEXICO** RÜGEN BALCONY

Aeroplane/14 days/2 people

515 kg CO_2 per person/day

Carbon footprint: 7,218 kg CO_2 per person

Outward and return travel:	6.361 kg
Accommodation:	487 kg
Food and drink:	205 kg
Activities at the destination:	165 kg

Test question: Estimate the carbon footprint in kg. (+/- 1,000 kg)

8C HOLIDAY

MALLORCA MEXICO **RÜGEN** BALCONY

Car/14 days/4 people

18 kg CO_2 per person/day

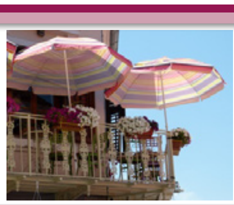
Carbon footprint: 258 kg CO_2 per person

Outward and return travel:	80 kg
Accommodation:	52 kg
Food and drink:	56 kg
Activities at the destination:	70 kg

Test question: The carbon footprint per person is under 300 kg. True or false?

8D HOLIDAY

MALLORCA MEXICO RÜGEN **BALCONY**



At home/14 days/4 people

4 kg CO_2 per person/day

Carbon footprint: 59 kg CO_2 per person

Outward and return travel:	0 kg
Accommodation:	17 kg
Food and drink:	9 kg
Activities at the destination:	33 kg

Test question: "Only 20 kg CO_2 are produced per person." True or false?

9A AIR ROUTE

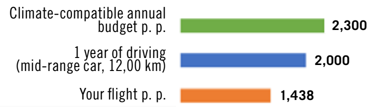
1 2 3 4

Hamburg – New York

Carbon footprint per person: 1,438 kg CO_2

Compensation value: EUR 34

CO_2 emissions in kg



Test question: Is the climate-compatible annual budget of one person exceeded?

9B AIR ROUTE

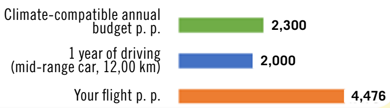
1 **2** 3 4

Frankfurt a.M.–Bangkok – Melbourne

Carbon footprint per person: 4,476 kg CO_2

Compensation value: EUR 104

CO_2 emissions in kg



Test question: "The flight uses almost twice the climate-compatible annual budget." True or false?

9C AIR ROUTE

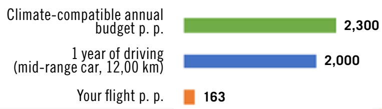
1 2 **3** 4

Bremen – London

Carbon footprint per person: 163 kg CO_2

Compensation value: EUR 5

CO_2 emissions in kg



Test question: "The carbon footprint per person is below 200 kg." True or false?

9D AIR ROUTE

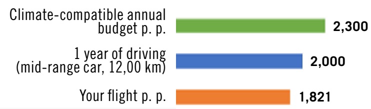
1 2 3 **4**

Berlin – Chengdu

Carbon footprint per person: 1,821 kg CO_2

Compensation value: EUR 42

CO_2 emissions in kg



Test question: In which country is the city of Chengdu located?

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10A TRANSPORT

WATER AIR RAIL ROAD

Route: Hamburg – St. Petersburg

22 tonnes of chemicals over 1,658.87 km

Carbon footprint: 421 kg CO_2e (TTW)

Carbon footprint: 463 kg CO_2e (WTW)

Test question: What does TTW mean? (Perhaps other players can help?)

10B TRANSPORT

WATER **AIR** RAIL ROAD

Route: Hamburg – St. Petersburg

22 tonnes of chemicals over 1,543.89 km

Carbon footprint: 24,946 kg CO_2e (TTW)

Carbon footprint: 30,448 kg CO_2e (WTW)

Test question: "The WTW carbon footprint is 10,000 kg CO_2e." True or false?

10C TRANSPORT

WATER AIR **RAIL** ROAD

Route: Hamburg – St. Petersburg

22 tonnes of chemicals over 2,742.53 km

Carbon footprint: 0.0 kg CO_2e (TTW)

Carbon footprint: 1,660 kg CO_2e (WTW)

Test question: Why is the TTW carbon footprint 0 kg CO_2e?

10D TRANSPORT

WATER AIR RAIL **ROAD**

Route: Hamburg – St. Petersburg

22 tonnes of chemicals over 1,991.97 km

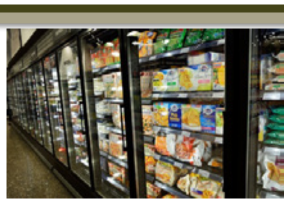
Carbon footprint: 2,643 kg CO_2e (TTW)

Carbon footprint: 3,298 kg CO_2e (WTW)

Test question: What does WTW mean? (Perhaps other players can help?)

11A FOOD

FROZEN REGIONAL SEASONAL ORGANIC



Person: male / aged 18–29 / 80 kg / mixed diet

Average CO_2 emissions for food: 1.75 tonnes

Women generally consume less

Carbon footprint per year: 2.40 tonnes

Test question: "Given the same conditions, women consume exactly the same as men." True or false?

11B FOOD

FROZEN **REGIONAL** SEASONAL ORGANIC

Person: male / aged 18–29 / 80 kg / mixed diet

Average CO_2 emissions for food: 1.75 tonnes

More exercise = higher consumption = 2.27 tonnes

Carbon footprint per year: 1.93 tonnes

Test question: Does the level of carbon emission change if the person does lots of exercise?

11C FOOD

FROZEN REGIONAL **SEASONAL** ORGANIC

Person: male / aged 18–29 / 80 kg / mixed diet

Average CO_2 emissions for food: 1.75 tonnes

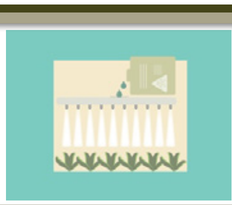
Grown without additional artificial heating

Carbon footprint per year: 1.93 tonnes

Test question: "Products do not need any additional artificial heating whilst growing." True or false?

11D FOOD

FROZEN REGIONAL SEASONAL **ORGANIC**



Person: male / aged 18–29 / 80 kg / little exercise

Average CO_2 emissions for food: 1.75 tonnes

1.20 tonnes in the case of a vegan diet

Carbon footprint per year: 2.00 tonnes

Test question: Do people on a vegan diet use more or less CO_2 than others?

12A SHORT-HAUL TRIP

FLIGHT RAIL CAR BUS

Route: Berlin – Frankfurt

Distance: 433 km Time: 1:30 hours

Costs: from EUR 33

Carbon footprint: 81.2 kg (not including RFI factor)

Test question: "Is the carbon footprint lower than that produced by a car?" (Perhaps the others can help?)

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12B SHORT-HAUL TRIP
FLIGHT **RAIL** CAR BUS

Route: Berlin – Frankfurt

Distance: 510 km Time: 4:19 hours

Costs: from EUR 29

Carbon footprint: 26 kg

Test question: Name three ways of reducing our carbon footprint in everyday life.

12C SHORT-HAUL TRIP
FLIGHT RAIL **CAR** BUS

Route: Berlin – Frankfurt

Distance: 543 km Time: 05:04 hours

Costs: from EUR 45

Carbon footprint: 94.2 kg

Test question: "The carbon footprint exceeds 100 kg." True or false?

12D SHORT-HAUL TRIP
FLIGHT RAIL CAR **BUS**

Route: Berlin – Frankfurt

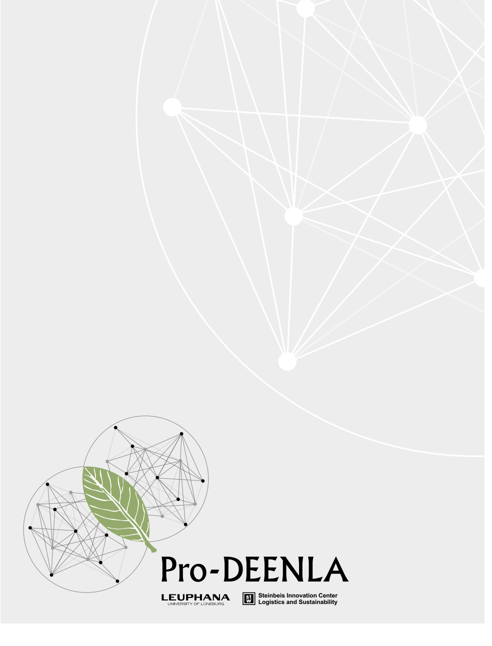
Distance: 543 km Time: 09:50 hours

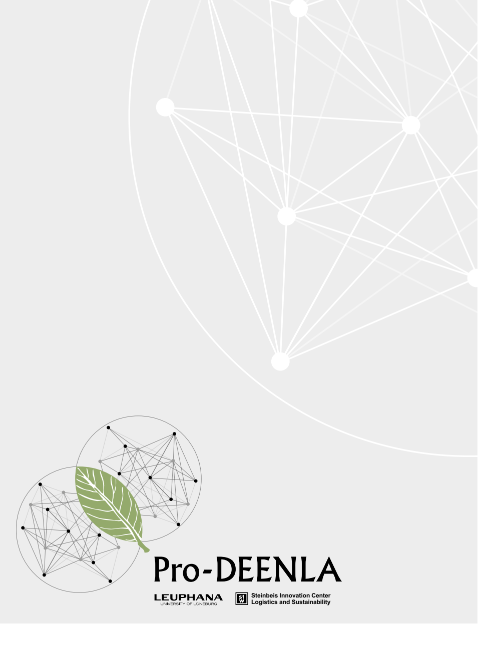
Costs: from EUR 10

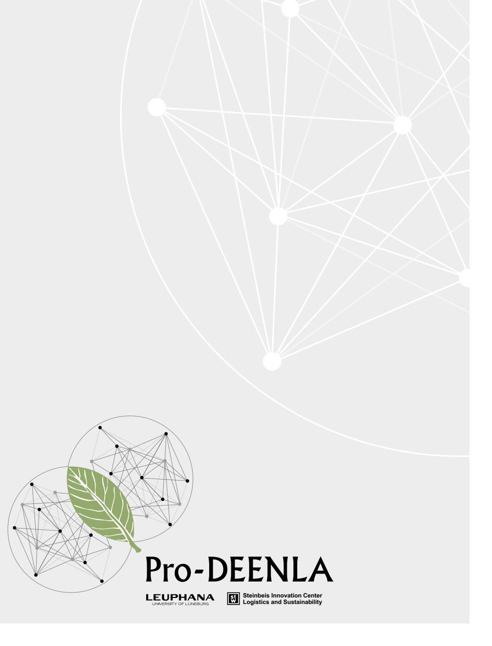
Carbon footprint: 19.2 kg

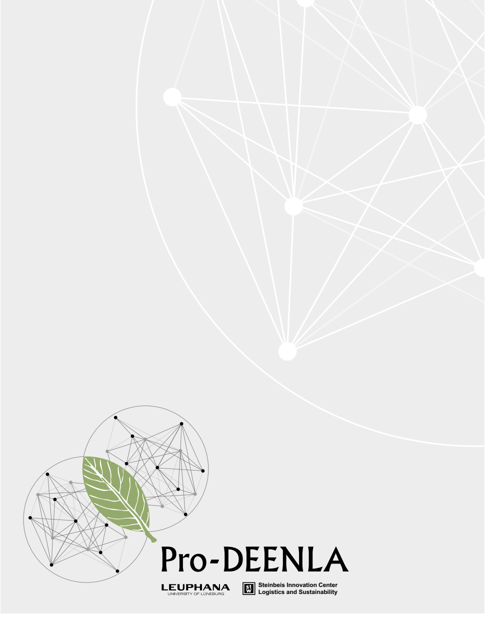
Test question: How great is the carbon footprint? (+/- 10 kg)

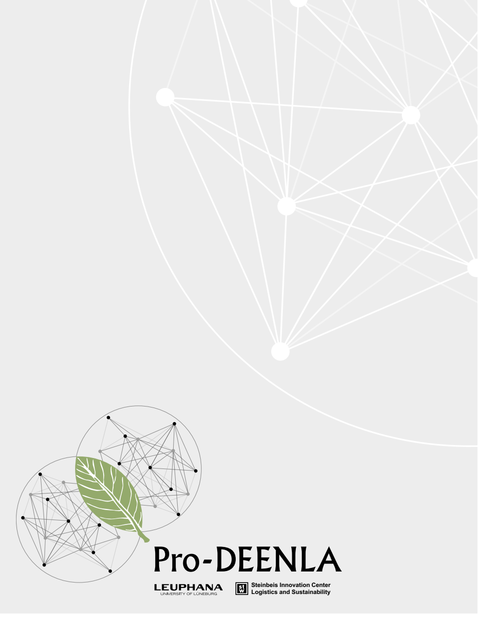
Please use this **reverse side** for all cards.

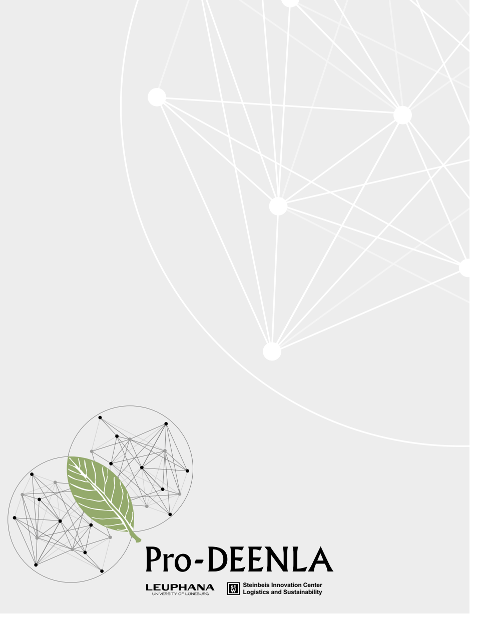












NOTE 1

Pro-DEENLA

LEUPHANA UNIVERSITY OF LÜNEBURG

Steinbeis Innovation Center Logistics and Sustainability

THE NATURAL QUARTETS

A GAME ABOUT VIRTUAL WATER AND THE CARBON FOOTPRINT

SPONSORED BY THE

Federal Ministry of Education and Research

Federal Institute for Vocational Education and Training

WHAT IS IT ABOUT?

Briefly, this game centres on the ecological impacts caused by your personal and company actions. The consumption of water and the CO_2 emissions that result from the manufacture and delivery of a product can, for example, be represented and measured in the form of a virtual water and carbon footprint.

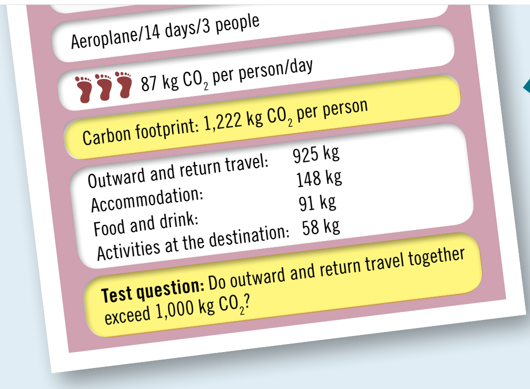
Any transport of people or goods produces greenhouse gases directly and indirectly, in the form of carbon dioxide, for example. Direct emissions are created during the actual transport itself and are dependent on the means of transport used, the load, the distance and consumption of fuel. However, the production of electricity and fuels, the manufacture of vehicles and the energy used for road building all cause indirect greenhouse gas emissions. The total amount of direct and indirect greenhouse gas emissions (GHG) is expressed via so-called CO_2 equivalents.

Our consumption of water does not merely comprise our morning shower and the coffee we prepare. It consists of much more than water that is actually visible. Virtual water is also necessary in order to produce the goods that we use or consume on a daily basis. Virtual water is the term deployed to describe the quantity of water used to make a product. A distinction is drawn between blue, green, and grey water. Blue water refers to the ground and surface water used in production. This may, for example, be taken from rivers. Green water is rainwater, which evaporates when it comes into contact with plants and is therefore mainly of significance in agriculture. Grey water is the quantities of water that are polluted as a result of the manufacturing process.

HOW DOES IT WORK?

You will need between two and six players. Firstly, the quartets cards are shuffled. All the cards are then dealt out to the players. One player may receive more cards. This is not a problem. The player to the left of the dealer begins the game. This player looks at all of his or her cards and then asks any other player for a card that can be clearly identified as being necessary for the formation of a quartet. The top row of the card will help with the identification (e.g. 9A Air route). Each quartet comes with the letters A to D. However, a player may only request a card if he or she already holds at least one card from the quartet in question. When players are asked for a card, they must say if they hold it or not. The owner of the card now reads out what it says to the other players.

Leo: *"Anna, can you give me card 5D Coffee?"*
Anna: *"Yes. The card is in the Drinks category. Each of us drinks 148 litres of coffee per year on average. Most of this comes from Africa and Oceania. The virtual water used is mainly green, but is it true to say that less than 1 ml of virtual water is needed to produce 1 ml of coffee?"*
Leo: *"I would think that the amount is much higher."*
Anna: *"That's right! Here's your card ..."*



PLEASE NOTE!

When you read out the information, make sure that you do not give away the answer to the test question (at the bottom of the card). After a brief exchange with the player requesting the card, you will then ask the test question to him or her. If the player answers correctly, he or she is given the card and can ask for more cards. If the player does not hold the card requested, it's then his of her turn his or her turn to ask another player for cards. Once a player has collected a full quartet, these cards are laid out face-up on the table. A player who has no more cards is out of the game, and the turn then passes to the player to his or her left. The winner is the player who has collected the most complete quartets at the end of the game.

HINTS AND TACTICS

- Some of the test questions are not all that easy. Help one another and try to work out the answers together!
- Listen carefully to what the other players say. You might need some of the information you hear for your own test questions!
- Perhaps you need to return to work and don't have all that much time?
    - Before you begin the game, stipulate a time at which it will end. The winner will then be the player with the most quartets at this point.
    - Play the game using fewer quartets (e.g. eight instead of all twelve).
    - The winner is the first player to collect two quartets!

ABBREVIATIONS:

D	Germany
E	Energy consumption
e	equivalent
G	Greenhouses gases
p.P.	per person
T/F	True or false?
T	Tank-to-Wheel
W	Well-to-Wheel

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