CENTRE OF EXPERTISE

LCA GAME HANDBOOK

MNEXT
MATERIALEN
& ENERGIE
X TRANSITIE

avans hogeschool

UNIVERSITY OF APPLIED SCIENCES

Terms and Conditions:

This game was created by the Environmental Impact Assessment team from the Research Group Biobased Resources & Energy of MNEXT, part of Avans University of Applied Science, Netherlands.

- The game is available **free of charge**.
- You are **not allowed** to use the game for **commercial purposes**.
- The game is created with the **purpose of teaching** people about LCA. The game makes use of verified scientific data as much as possible and the game is set up with the most objective intentions.
- You are **allowed to make changes** to your preference regarding the concept of the game or the way you play it.
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- Please do not share the game. Do you know someone else that wants to use the game? **Please refer** them to our website. This helps us keep track of the use and impact of the game.

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About MNEXT:

MNEXT, along with SMEs, forms the bridge between innovation and society. By conducting applied research with students, lecturers, and researchers. By collaborating on educational innovation. This is how MNEXT sets the materials- and energy transition in motion. For a sustainable future.

About Biobased Resources & Energy:

The research group Biobased Resources & Energy, led by Professor Jappe de Best, aims to contribute to an accelerated realization of a more circular economy. The research focus is on the recovery of valuable building blocks and energy from low-value residual streams from industries and agriculture through biological, chemical and mechanical processes to create new circular value chains. This is done in cooperation with regional businesses, education and (inter)national (applied) universities and research institutes.

The LCA Game

Needed:

- ✓ Product life cycle cards (5)
- ✓ Environmental impact explaining cards (6)
- ✓ Empty scoring cards (11 per set, one set per group of 3-4 people)
  (Tip: plasticize these cards in case you plan on playing this game more often, it saves a lot on printing)
- ✓ Reasoning cards (12)
- ✓ Filled scoring cards (11)
- ✓ Markers (whiteboard in case you plasticized scoring cards) or pen
- ✓ A dice
- ✓ Optional: A big screen
- ✓ Read the full instructions before playing the game

Tip:

Depending on your public, time availability and goal, it could be good to give an introduction on LCA before starting the game.

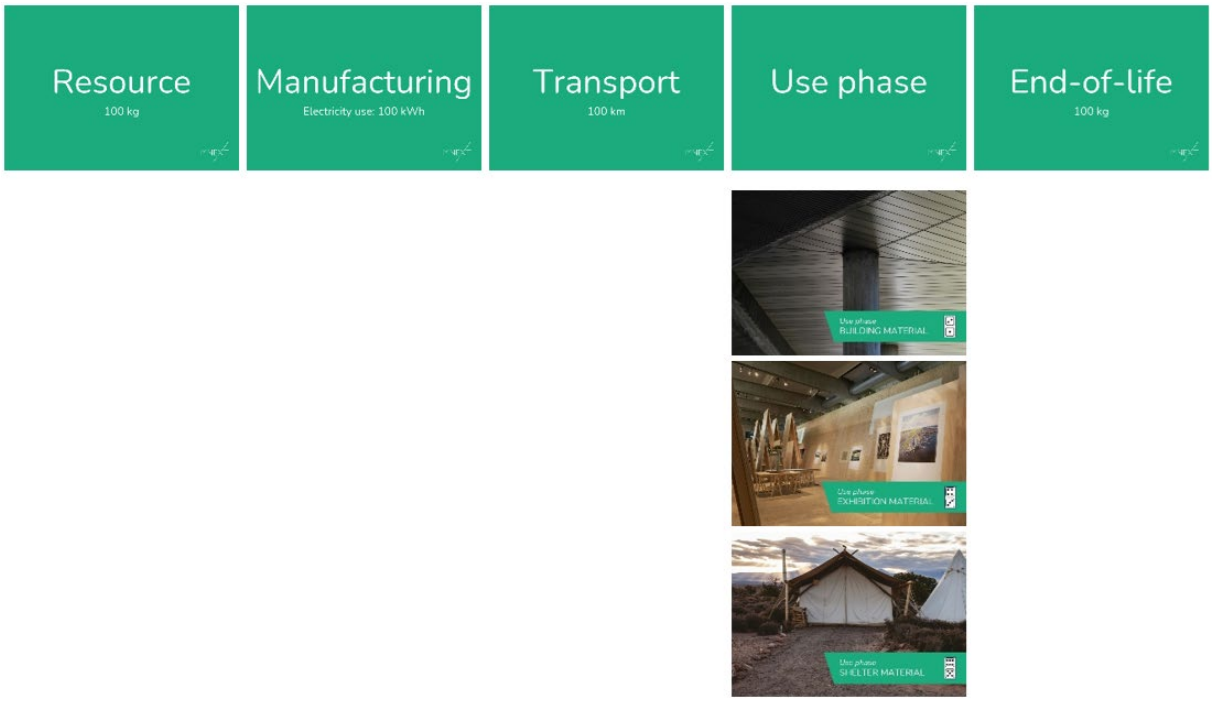
Explain to the players:

- ❖ The 6 environmental impact categories that are considered in this game. You can find an explanation of these environmental impacts on the last pages of the cards document.
  (You can mention that there are a total 18 different categories (see: https://www.rivm.nl/en/life-cycle-assessment-lca/recipe), but only 6 are considered.
- ❖ The game is created to teach the players about the basic principles and aspects of (performing) life cycle analysis.
- ❖ The game is based on reality and scientific data as much as possible. However, for educational purposes, some fictional aspects are built in.

Instructions:

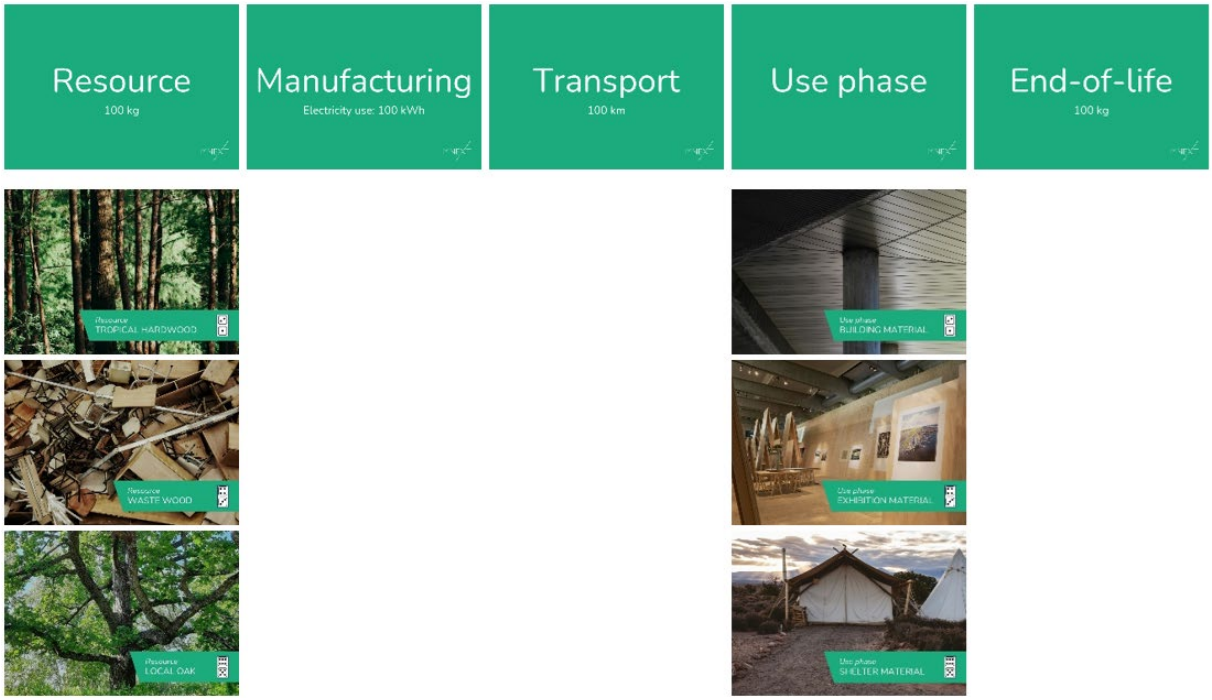
1. Layout the product life cycle in the order shown below:

2. Lay down the 3 ‘Use phase’ cards in the correct order, starting with dice numbers 1-2 at the top, 3-4 in the middle and 5-6 below. Explain that the game is about making a wooden product. The 3 product options are shown on the cards. Which product will be decided by one of the players.

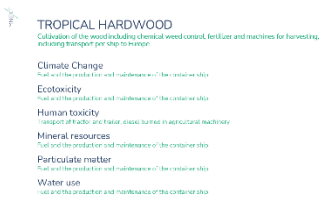


Let a player throw the dice to decide which wooden product will be made. The corresponding numbers are shown on the playing cards. For the sake of clarity, turn the ‘Use phase’ cards that were not chosen (by the dice) upside down.

3. Lay down the cards for ‘Resource’, like shown below (in which 2 of the ‘Use phase’ cards should be facing upside down by now). Let a player throw the dice to decide which wooden resource will be used for making the wooden product. Turn the alternative ‘Resource’ cards that were not thrown upside down.



4. Split the group of players into subgroups of 3 to 4 players.
Show the ‘reasoning card’ from the resource that was decided by the dice, either on a screen or provide it physically to the groups. The reasoning card shows the scope of the process (to see what is included and what is not) and per midpoint environmental impact category what the main contributor is to this effect.


TROPICAL HARDWOOD
Cultivation of the wood including chemical weed control, fertilizer and machines for harvesting, including transport per ship to Europe

Climate Change
Fuel and the production and maintenance of the container ship

Ecotoxicity
Fuel and the production and maintenance of the container ship

Human toxicity
Transport of tractor and trailer, diesel burned in agricultural machinery

Mineral resources
Fuel and the production and maintenance of the container ship

Particulate matter
Fuel and the production and maintenance of the container ship

Water use
Fuel and the production and maintenance of the container ship


WASTE WOOD
Wood originating from end-of-life products that have been used already and have no economic value left

Climate Change
It is assumed to cause burden free

Ecotoxicity
It is assumed to cause burden free

Human toxicity
It is assumed to cause burden free

Mineral resources
It is assumed to cause burden free

Particulate matter
It is assumed to cause burden free

Water use
It is assumed to cause burden free


LOCAL OAK
Planting, including seedling production and all process related to forest management (excluding site preparation, planting, tending, young growth tending, clearing, thinning) and harvesting operations. It also covers the maintenance and construction of forest roads

Climate Change
Clefting, skidding and sawing

Ecotoxicity
Skidding and gravel for natural road

Human toxicity
Gravel for natural road, clefting and skidding

Mineral resources
Gravel for natural road, clefting and skidding

Particulate matter
Clefting and skidding

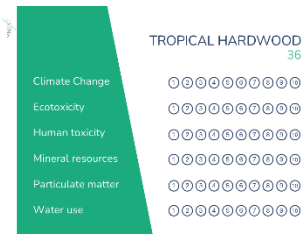
Water use
sawing and gravel for natural road

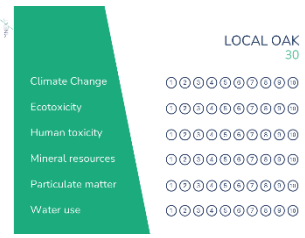
Sidenote and explanation to players:
It is sometimes not clear why certain impacts take place, even when the main contributing cause is given. This is typical for LCA. Sometimes you must deal with verified data, without any further explanation. In other occasions, there might be a broad documentation coming along with your dataset, giving more detailed information. In case it is not given, you can always search literature to try to find out what aspects could be causing these specific impacts.

Sidenote and explanation to players:
Waste wood doesn't have an impact because it is assumed to be a residual stream. In case waste wood was thrown, explain that within LCA, residues or wastes could be assumed to come without any environmental burden.

Note: The next step is **not applicable** in case waste wood was thrown, due to it having no environmental burden. In this case you go to step 5.

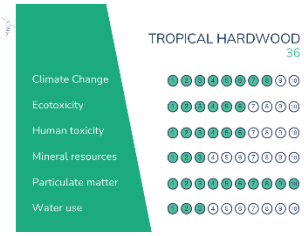
Hand out the empty scoring cards to the groups (1 per group).
Let the players discuss the division of the impact points (the number shown on the top right corner of the card) and let them divide these points over the 6 environmental impact categories. The reasoning card can be helpful to give a score to each environmental impact.

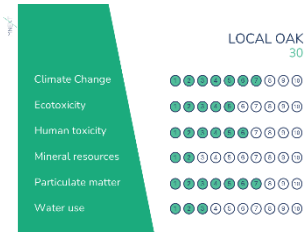




5. Discuss the scoring of the groups before showing the answers.
   - What impact did you assign the most points? Why?
   - What impact did you assign the least points? Why?
   - Did another group make any (significant) different choices? Why?

   Show the filled scoring card with the correct division of the impact points on the screen or manually tell the players the correct scoring. Compare the correct scoring with the scoring of the groups and discuss differences. Try reasoning them by using the reasoning card.





   When the discussion is finished, lay the correct scoring card on top of its corresponding playing card with the scoring visible.

   Note: Do **not show** the scoring cards of the alternatives.

6. Repeat steps 3, 4 and 5 for the remaining part of the product life cycle, except for the 'Use phase'. The use phase application in this game is assumed to cause no impact during its use. If you lack time, you can choose to skip scoring one or multiple stages of the product life cycle.

   Sidenote and explanation to players:
   In practice, regarding the use phase, aspects such as maintenance and lifetime of a product cause impact and will influence the LCA.

   Tip: Once your players start discussing a second scoring round, note down in table 1 (see below) the impact scores of the previous round.

7. Once you have finished the entire product life cycle, let the groups discuss the following 3 questions one by one:

- What stage of the product life cycle has the highest environmental impact? Why? Discuss the answers with the groups.
  This question is the reason you have laid the correct scoring cards on top of its corresponding playing cards with the scoring visible.

  Answer: The playing card thrown with the highest number of points as stated on the top right corner of the card.

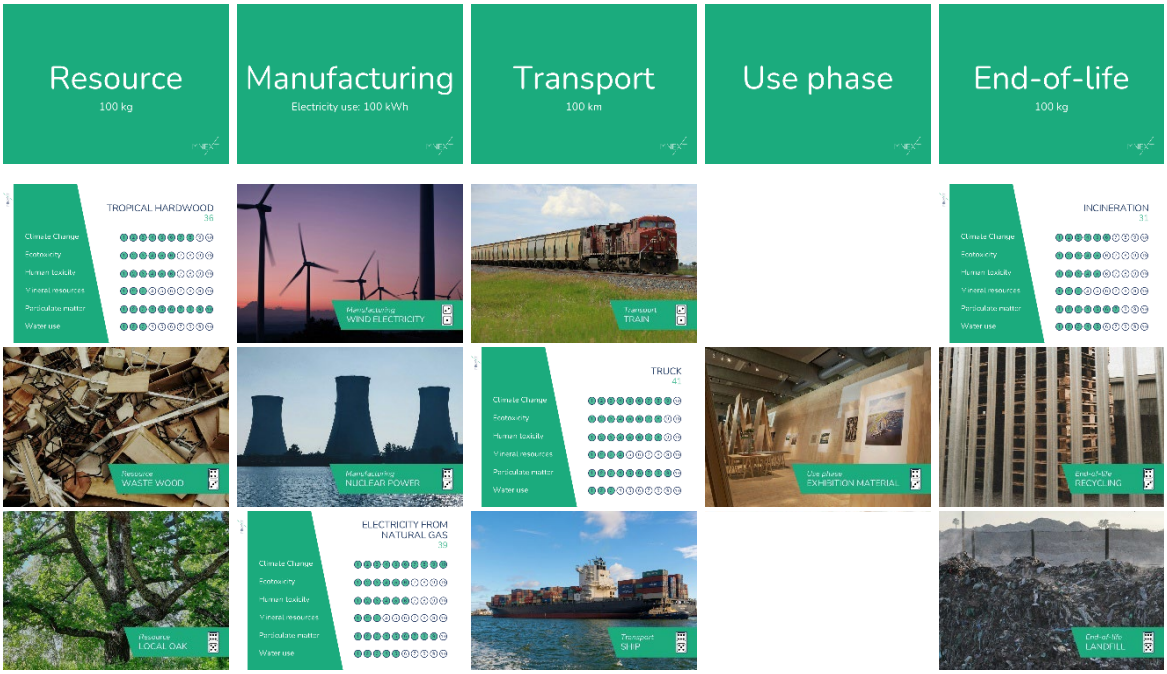
- What environmental impact is the most impactful along the product life cycle? Discuss the answers with the groups.
  You must do some math. This question is the reason we gave the tip to already write down the impact scores of a previous round in table 1 (below) once you have the time for it when players are busy scoring a next stage.

  Answer: The category with the highest amount of total impact points along the product life cycle.

Table 1: Calculation sheet for the impact scores per impact category along the product life cycle

	Resource	Manufacturing	Transport	Use-phase	End-of-life	Total
CC				X		
ET				X		
HT				X		
MR				X		
PM				X		
WU				X		

Turn all playing cards that were facing upside down back around (except for the ‘Use phase’), so the alternatives are visible to the players. An example is shown below, it will look different when different alternatives were thrown:



- You can make 1 change to the product life cycle to improve it, what would you change? Why? Discuss the answers with the groups.

  Of course, you can only make a change within a single stage of the product life cycle (so only a resource for another resource or a form of transportation for another form of transportation).

  Only the environmental impact for the chosen product life cycle is visible to the players, the environmental impact of the alternatives not. The latter is up to the players for discussion. You as host should extract the correct answer from table 2 below.

Answer: The change that is causing the biggest difference in points when looking at the environmental impact points given at the top right corner of the cards.

Unless the game started with 'Waste wood' as resource, changing to 'Waste wood' is the correct answer as it makes the biggest difference in decreasing environmental impact (points).

Table 2: Overview of environmental impact score per process per stage. Overview is in the same order as when the stage options were laid down correctly.

Resource	Manufacturing	Transport	Use-phase	End-of-life
36	32	34	n.a.	31
0	33	41	n.a.	26
30	39	28	n.a.	31

Lessons to learn from the game:

- ✓ LCA is about the full life cycle of a product
- ✓ For LCA you can use different life cycle impact methodologies, most of them distinct at least 13 different environmental impact categories. One of the most used methodologies is ReCiPe 2016, which includes 18 different environmental impact categories
- ✓ Most of the environmental impact categories are expressed in a different unit, therefore (most of them) are not mutually comparable.
- ✓ In this game, the environmental impact categories that are included:
    - Climate change → kg CO_2 eq
    - Ecotoxicity → kg 1,4-dichlorobenzene eq
    - Human toxicity → kg 1,4-dichlorobenzene eq
    - Mineral resources → kg Cu eq
    - Particulate matter → kg $PM_{2.5}$ eq
    - Water use → m^3

- ✓ Ecotoxicity distinct between effects on marine, freshwater and terrestrial environment (in this game, the ecotoxicity is mostly represented by terrestrial ecotoxicity)
- ✓ Human toxicity distinct two categories, one representing carcinogenic substances and one representing non-carcinogenic substances (in this game, human toxicity non-carcinogenic is taken)
- ✓ It is possible that (residual) resources don't have any environmental burden or if the burden is unknown, it can be assumed to be free of any environmental burden (in this game, the example of waste wood)

- ✓ The manufacturing phase in this game only includes the need for electricity. On top of that, the game also assumes just one source of electricity is used, while often used electricity is a mixture of different sources (wind, solar, nuclear, natural gas, hydro, biomass, etc).
  Also, it can be that you don't even need electricity or that you need much more than just electricity, for example heat, cooling water or chemical additives.
  It is also possible that you don't only need input (material or energy), but you could also have outputs like gaseous emissions into the environment or discharge of wastewater.
- ✓ The end-of-life phase in this game does not include credits.
  Credits are environmental benefits or savings that are subtracted from a product's overall environmental impact. For example, when you generate electricity in a powerplant that is combusting waste. The generated electricity can then be used and avoids the need to generate this electricity via another source, meaning that potential impact is avoided. The same principle can be applied for recycling materials or capturing gas from landfills.
- ✓ Identification of the most impactful stage of a product life cycle.
- ✓ Identification of the most impactful environmental impact category along a product's life cycle.
- ✓ When using ReCiPe 2016 impact methodology, the 18 environmental impact categories can be 'summarized' into just 3 impact categories by conversion to effects on human health (DALY), ecosystems (species loss over time) and resource availability ($).
- ✓ Environmental impacts can also be converted to environmental prices to calculate environmental damage costs.

Be aware:

- Due to complexity with datasets, not all processes within a stage have an exact aligned scope. The scope of each process is described on top of the reasoning cards, however, parts might be missing.
- The product life cycle was designed needing:
    - Resource: 100kg of resource material
    - Manufacturing: 100kWh of electricity
    - Transport: 100km for a total weight of 100kg of material
    - End-of-life phase: 100kg of material to be treated.
- The tropical hardwood's environmental impact is the only process composed of 2 datasets, one being the impact of the hardwood, the other for including a required shipment over 10.000km via a container ship from a tropical region to its destination (NL).
- The game does not intend to teach the players about the impact of specific materials or processes. The scoring is representative for the categories shown, but a higher or lower total score of a process doesn't necessarily mean that in practice the one or the other is the better alternative. For example, nuclear power (33 points in the game) is not in definition worse than wind electricity (32 points in the game). When considering more environmental impact categories than 6, the rank on total score might become different.
  Therefore, nuclear power could become better than wind electricity, contrary, the difference between the two can become greater in advantage of wind electricity.
  It is very important to mention also that the last step in translation of scientific data towards the 'correct' scoring of each process's environmental impact was done manually and can contribute to a different difference in scoring than represented by the game.
  Read the scoring section for further elaboration and understanding of this remark.

The scoring:

As mentioned in the explanation section, the scoring used in the game is based on reality as much as possible. Verified scientific data was used from databases Ecoinvent and LCA for Experts. Datasets were used that should represent the process shown on the cards of the LCA game. A more detailed description of each process is given on the reasoning cards.

However, as explained in the lessons to learn section, most environmental impacts have different units and are therefore not comparable with each other. For this game, we applied a form of normalization by multiplying the data with environmental prices. The pricing of the environmental impact categories were taken from the Environmental prices handbook 2024, CE Delft.

- Climate change → kg CO_2 eq (€0,13 / kg)
- Ecotoxicity → kg 1,4-dichlorobenzene eq (€0,0014 / kg)*
- Human toxicity → kg 1,4-dichlorobenzene eq (€0,097 / kg)
- Mineral resources → kg Cu eq (€0,014 / kg)
- Particulate matter → kg $PM_{2.5}$ eq (€168 / kg)
- Water use → m^3 (€0,14 / m^3)

*Due to the fact ecotoxicity was sometimes a combination of terrestrial ecotoxicity and freshwater ecotoxicity, this value was estimated.

After this multiplication, all absolute values were converted to the same unit in Euro's. To make the game playable, a scoring of maximum 10 points was used. The fictive part comes in at defining the ranges in Euro's that correlate to a certain amount of points. This is also another reason - maybe the main reason - why we mention in the be aware section that the game does not intend to teach the players specifically about materials or processes and that the scoring does not per definition means that one is better than the other.

All outcomes were assigned a total number of points based on their value. We have applied the following classification to define the amount of points:

Value in €	Points
< 0,0001	1
0,0001 - 0,001	2
0,001 - 0,005	3
0,005 - 0,01	4
0,01 - 0,1	5
0,1 - 0,4	6
0,4 - 0,8	7
0,8 - 2	8
2 - 8	9
> 8	10

This table clears up the last remark of the 'Be aware' section, as the above ranges were manually decided and the distribution of points is not linear. Besides, an impact category gets 10 points despite if the environmental impact is either €8 or €80 or more.