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Life cycle assessment (LCA)

Jan Weinzettel

e-mail: jan.weinzettel@czp.cuni.cz

Life cycle assessment (environmental)

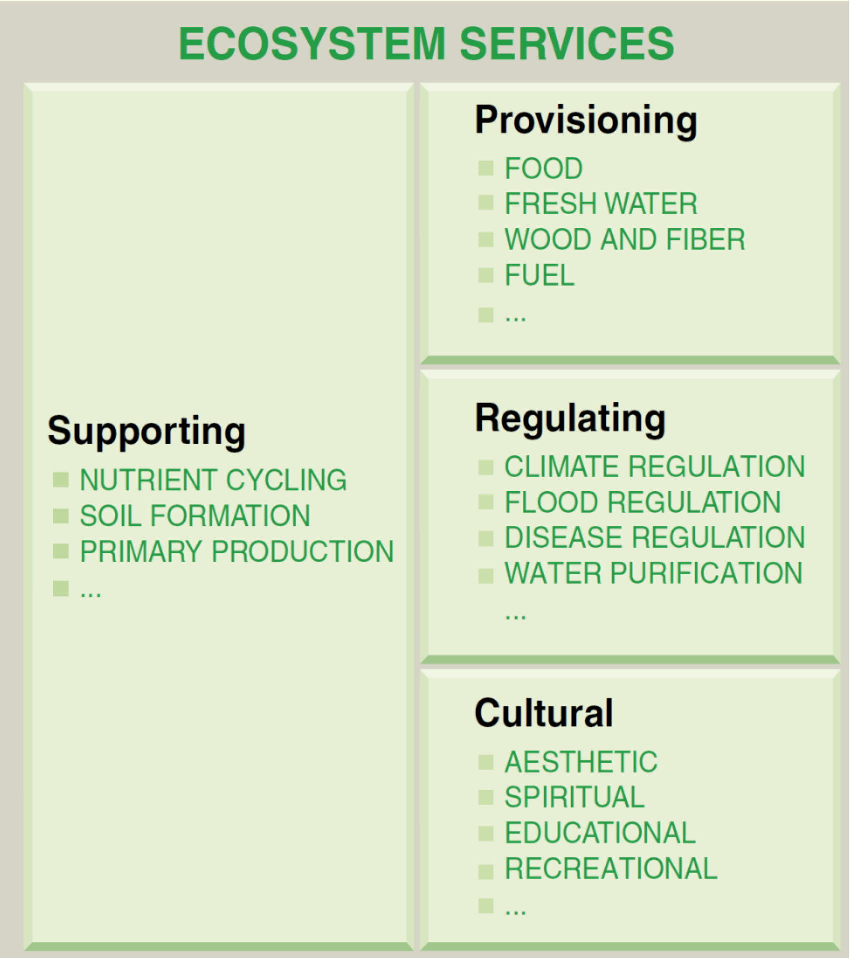
- A method to assess environmental performance/impacts of a product through its whole life cycle

Why environment/nature?

- Human health
  - What we breath, eat, drink, noise, …
- Human made capital
  - Corrosion, ageing, …
- Nature
  - Ecosystem services

Ecosystem services

- Functions of ecosystems utilized by humans
- Difficult to substitute
- Depend on ecosystems



Source: Mooney et al. 2005: *Ecosystems and human well-being: synthesis*, *Millenium Ecosystem Assessment*.

Effort to minimize negative environmental impacts

- Clean up old damages
- Prevent new
  - Searching for alternatives
- Limited resources and willingness for change
- We need to know what is better from the environmental perspective

Fossil fueled cars versus electric cars – what is better?

- Ideal type of answer
  - Product A has environmental impact of X
  - Product B has environmental impact of Y
  - If X > Y, product B is better than product A and vice versa

Fossil fueled cars versus electric cars – what is better?

Gasoline car

- High emissions during operation
- Zero electricity consumption
- Fuel tank

Electric car

- Zero emissions during operation
- High electricity consumption
- Battery

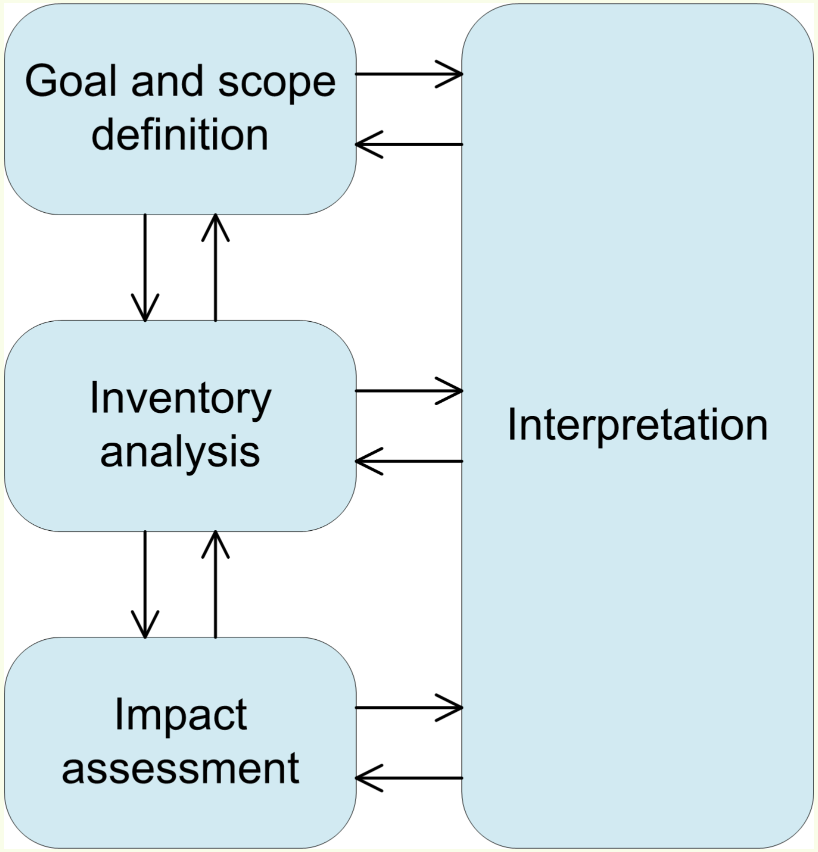
Different requirements during operation and production, different additional products, different environmental consequences.

Direct comparison impossible and meaningless, necessity to consider the whole life cycle of the product.

Requirements for the comparison

- Complete product systems / system boundaries
- Unification of environmental stressors into one single number / a set of environmental categories

Life cycle assessment



Goal and scope definition

- Goal of the study
  - Intended audience
  - Why the study is conducted
- Scope of the study (product system definition)
  - System boundaries
  - Function and functional unit
  - Reference flow
  - Scenario of the product life cycle
  - Selection of impact categories and characterization models

Product function, functional unit

- The purpose of a product is its function
- For a comparison of different products it is necessary to quantify the function and express the results per one unit of the function
- For example: one minute of phone call for mobile phone
  - What is the functional unit for a washing machine, a car, a hand dryer, a pen, a transformer?
- Additional functions determine the set of alternatives

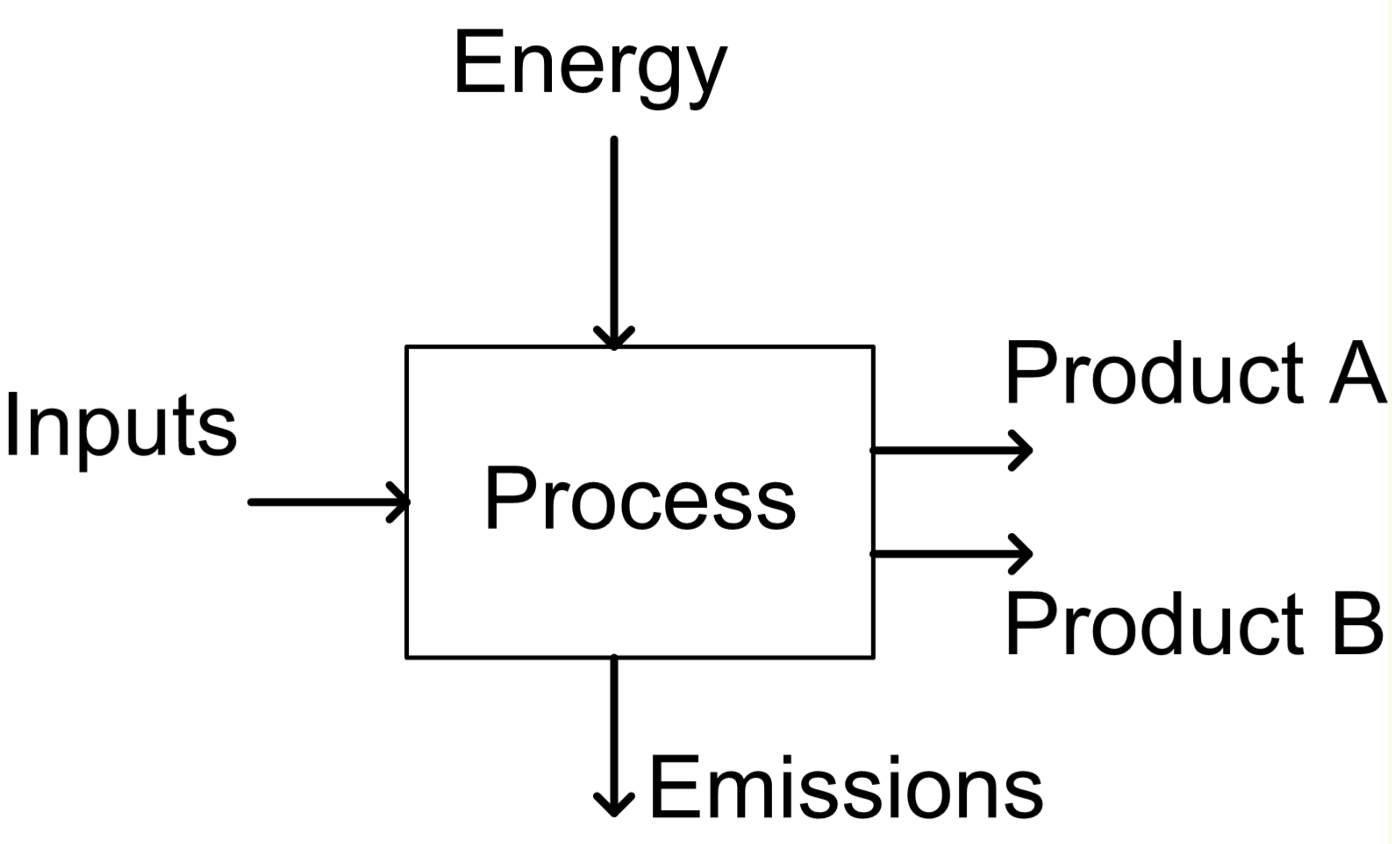
Life cycle scenario

- Assumptions about the products life cycle
  - Origin of materials (primary x secondary, region, …)
  - Transport during life cycle stages
  - How is the product used (how many times a week is the product used, how many functional units it will provide during the whole life time
  - Maintenance, failure and repair
  - End of life treatment, recycling rate
- Often necessary to consider more options and make a composition according to assumed probability of appearance
- A set of processes which are part of the product's life cycle is called "product system"

Impact on other processes

- How are other processes influenced by the studied product?
  - What is the source of electricity, which is consumed by the product? (e.g. in Norway 98 % of electricity is supplied by hydro power plants and 2 % by natural gas power plants
- Attributional LCA assumes average values
- Consequential LCA considers marginal changes

Process with more outputs



Allocation

- Partitioning the input and output flows of a process between two product systems
- It should be avoided
  - By dividing the process
  - Expanding the product system to include additional functions
- Where it cannot be avoided physical or economic relations can be used for partitioning

Inventory analysis

- Compilation and quantification of inputs and outputs for a product throughout its life cycle
- Elementary flows
  - Flows between the product system and the environment
- To collect data bout all elementary flows of the product system
  - Direct measurement
  - Databases
  - Literature
  - …

Impact assessment I

- Inventory includes a list of too many emissions with different environmental characteristics
- It is possible to aggregate them into few impact categories with a common unit for each category
- For example, greenhouse gases can be expressed in kg of CO_2-equivalents for category global warming potential

Impact assessment II

- Mandatory steps
  - Selection of impact categories, their indicators and characterization models
  - Classification
    - Assignment of the inventory data into to the chosen impact categories
  - Characterization
    - Transformation of the elementary flow into impact category indicator using characterization factor
- Optional steps
  - Normalization
    - Calculation of the results relative to a reference value
  - Grouping and weighting
    - Grouping of more impact categories into one

Ecoindicator

- Human health (unit: DALY = Disability adjusted life years);
- Impact on ecosystems (PAF.m^2yr = Potentially affected fraction of species);
- Resource consumption (MJ surplus)
- Allows to express impacts in one single unit (unit: Pt = point)

CML 2000

Scope	Impact category	Unit
Global	Abiotic depletion (ADP)	kg Sb eq
Global	Global warming (GWP100)	kg CO_2 eq
Global	Ozone layer depletion (ODP)	kg CFC-11 eq
Regional	Human toxicity (HTP)	kg 1,4-DB eq
Regional	Fresh water aquatic ecotoxicity (FWAT)	kg 1,4-DB eq
Regional	Marine aquatic ecotoxicity (MAT)	kg 1,4-DB eq
Regional	Terrestrial ecotoxicity (TE)	kg 1,4-DB eq
Regional	Photochemical oxidation	kg C_2H_4 eq
Regional	Acidification	kg SO_2 eq

Interpretation

- Evaluation and quality control of LCA study
  - Completeness
  - Consistency
  - Sensitivity analysis
  - Uncertainty analysis
  - Data quality analysis
  - Presentation of the results and their interpretation

Sensitivity analysis

- Changing some characteristics of the product system in order to determine the importance of their accuracy for the results
- E.g. primary versus secondary materials, recycling rates, lifetime, …
- Helps to understand the product system

Uncertainty analysis

- All parameters have some uncertainty
- The aim is to assess the uncertainty of the results
- Often by Monte Carlo analysis
  - LCA results are recalculated for parameters generated within their probability functions more than 1000 times – the distribution of the results corresponds to their uncertainty

Use of LCA

- Product development and improvement
- Strategic planning
- Public policy making
- Marketing
- …

Aim of LCA

- To avoid shifting of environmental burden across
  - Life cycle stages
  - Regions
  - Environmental areas
  - Polluting substances

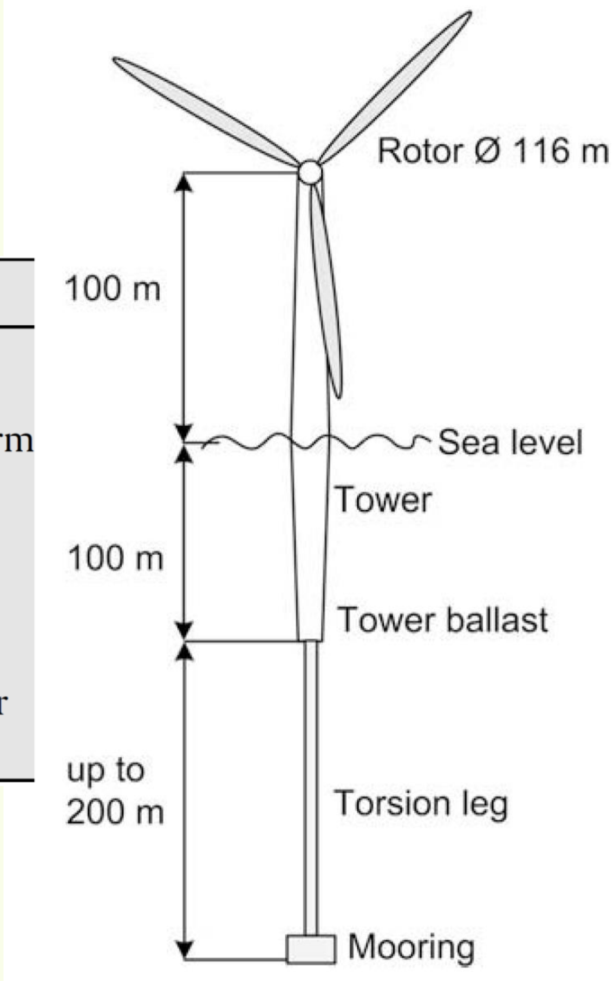
PUMA, environmental profit and loss accounts

	Water use	GHGs	Land use	Air pollution	Waste	TOTAL	
	€ million	€ million	€ million	€ million	€ million	€ million	% of total
	33%	32%	26%	7%	2%	100%	
TOTAL	47	47	37	11	3	**145**	100%
PUMA operations	<1	7	<1	1	<1	**8**	6%
Tier 1	1	9	<1	1	2	**13**	9%
Tier 2	4	7	<1	2	1	**14**	10%
Tier 3	17	7	<1	3	<1	**27**	19%
Tier 4	25	17	37	4	<1	**83**	57%
EMEA	4	8	1	1	<1	**14**	10%
Americas	2	10	20	3	<1	**35**	24%
Asia/Pacific	41	29	16	7	3	**96**	66%
Footwear	25	28	34	7	2	**96**	66%
Apparel	18	14	3	3	1	**39**	27%
Accessories	4	5	<1	1	<1	**10**	7%

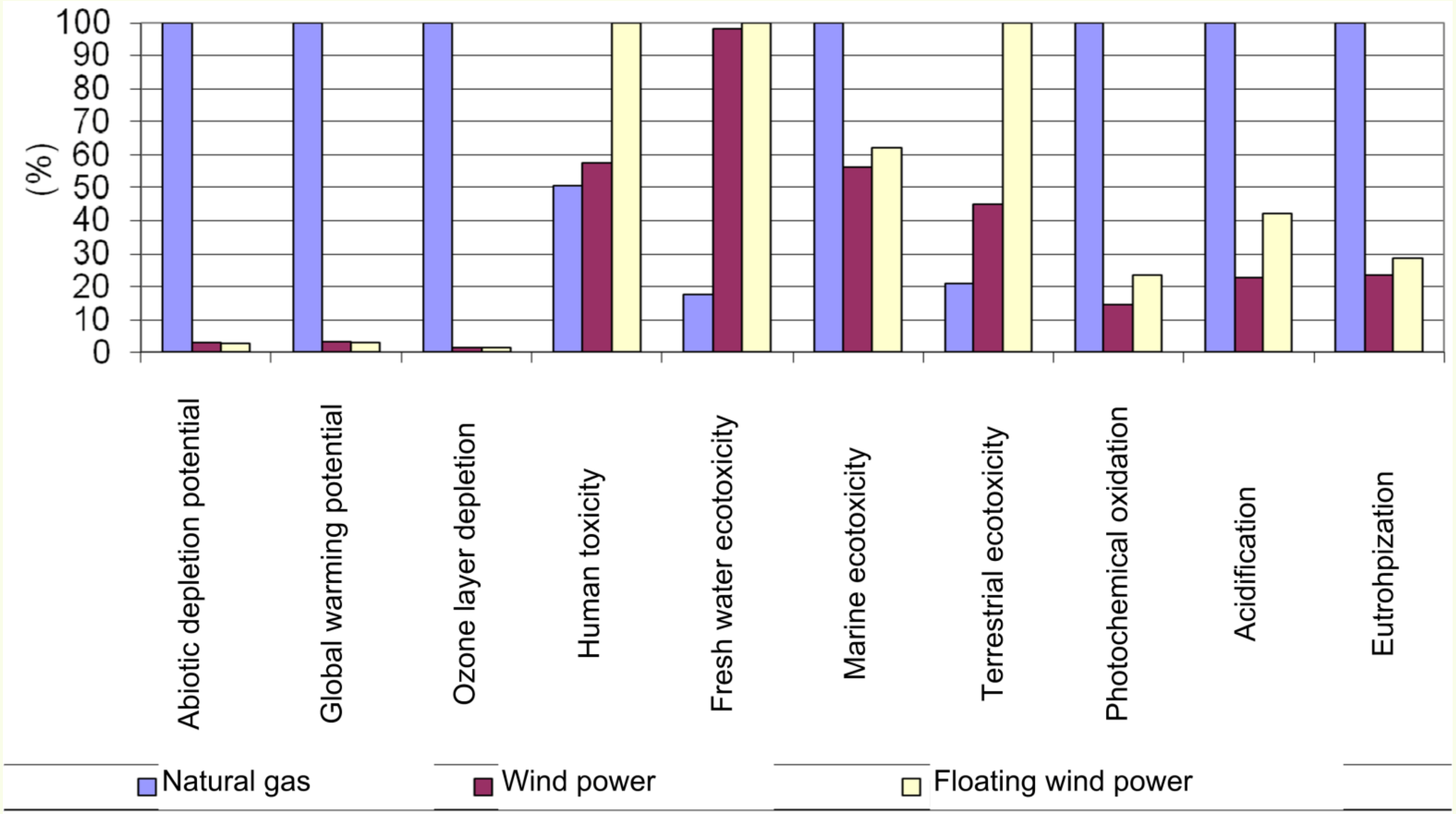
http://about.puma.com/wp-content/themes/aboutPUMA_theme/financial-report/pdf/EPL080212final.pdf

LCA of a floating wind power plant

Functional unit	1 MJ	Delivered to onshore area
Lifetime	20 Years	The average technical lifetime of whole wind farm.
Windmills in a farm	40	The number of power plants in the farm connected to one transition station.
Distance from shore	50 km	The average distance of the wind farm to the shore.
Average load	53%	Estimated, according to Sway data.
Nominal power	5 M_W	Nominal power of one wind turbine.
Transition station	1	There will be one transition station for whole wind farm.



Impact assessment (floating power plant)



Energy payback time

Process	Energy requirements(MJ primary / m2 modul)
Silicon winning and purification	2200
Silicon wafer manufacturing	1000
Module manufacturing	300
Module encapsulation materials	200
Other equipment	500
Aluminum frame	400
Total	4600

Panel efficiency:	17 %
Efficiency of electricity conversion:	75 %
Solar radiation energy:	1100 kWh / m^{2}rok

Electric vehicles

- http://www.youtube.com/watch?v=YKTdNoI0Ie8

- Thank you for your attention

- Any questions are welcome