Absolute sustainability … and how to assess it

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Absolute sustainability perspective

- Environmental sustainability and eco-efficiency
- Relative and absolute sustainability
- An absolute sustainability perspective on technology

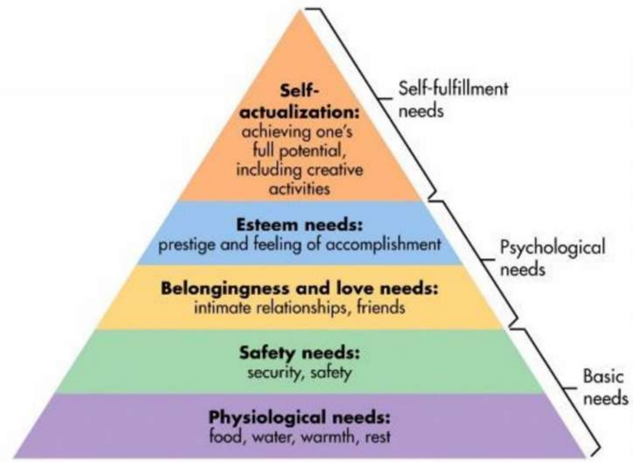
Defining sustainability

Brundtland Commission:

A sustainable development *"...meets the needs of the present without compromising the ability of future generations to meet their own needs"*

But what are the needs?

... and how will they be met?



Eco-efficiency

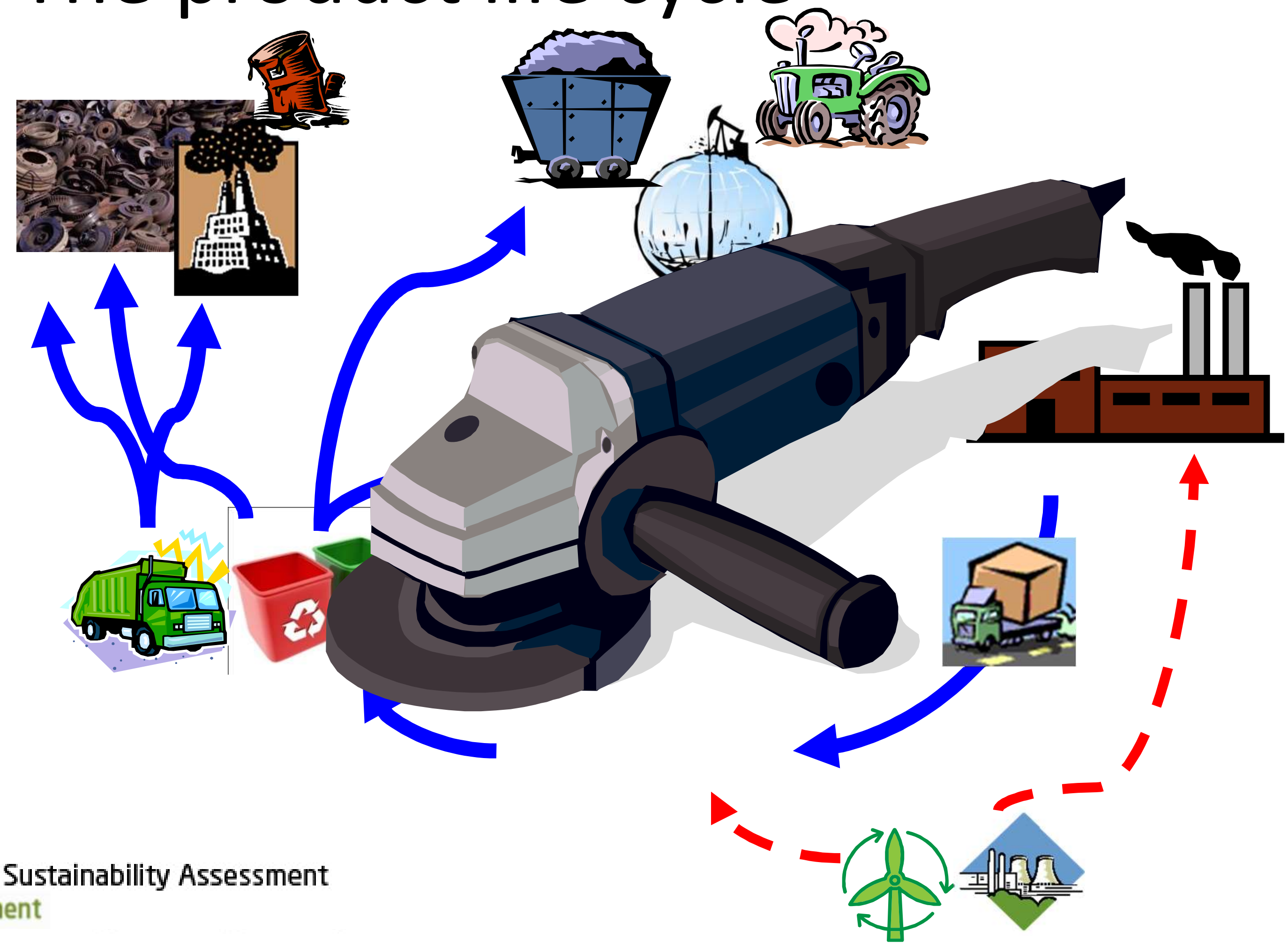
At the level of technologies or products, eco-efficiency can be defined as the ratio between the functional output and the environmental impacts that they cause

$$\text{Eco-efficiency} = \frac{\text{Delivered service}}{\text{Environmental impact}}$$

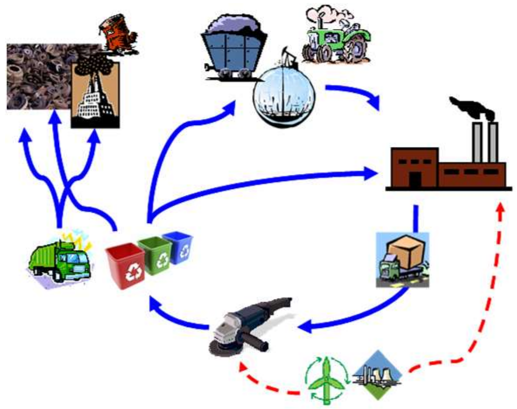
Improved eco-efficiency means creating more with less

… how is it measured?

The product life cycle



Quantifying eco-efficiency



For eco-efficiency, a systems perspective is needed;

- Adapting a life cycle perspective to avoid problem-shifting
- Considering all relevant types of impacts
- Addressing trade-offs between impacts (and sustainability dimensions)

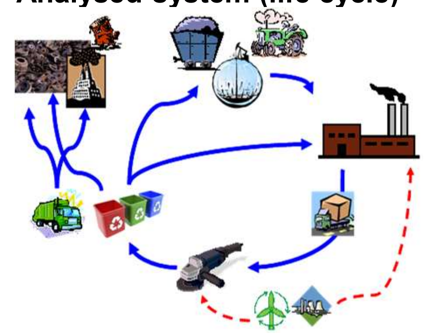
Environmental Life Cycle Assessment (LCA)

DTU

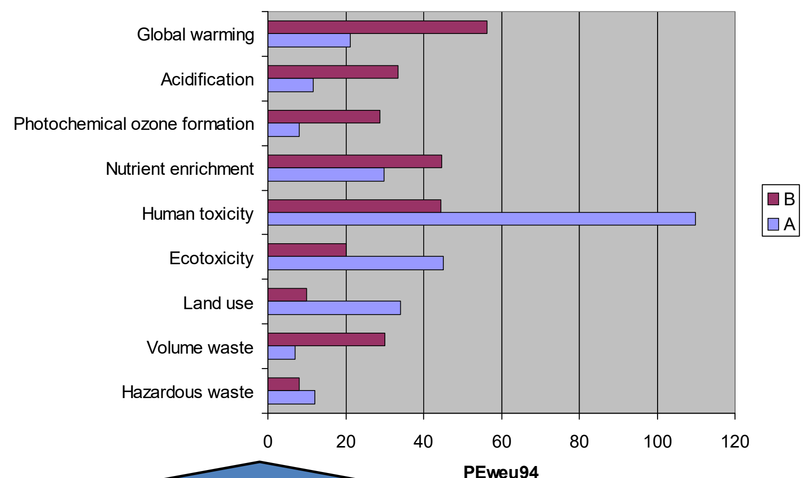
Inventory of environmental exchanges

		Emission	Emission
	CAS.no.	to air	to w ater
Substance		g	g
2-hydroxy-ethanacrylate	816-61-0	0,0348	
4,4-methylenebis cyclohexylamine	1761-71-2	5,9E-02	
Ammonia	7664-81-7	3,7E-05	4,2E-05
Arsenic (As)	7440-38-2	2,0E-06	
Benzene	71-43-2 (cur	5,0E-02	
Lead (Pb)	7439-92-1	8,5E-06	
Butoxyethanol	111-76-2	6,6E-01	
Carbondioxide	124-38-9	2,6E+02	
Carbonmonoxide (CO)	630-08-0	1,9E-01	
Cadmium (Cd)	7440-46-9	2,2E-07	
Chlorine (Cl2)	7782-50-5	4,6E-04	
Chromium (Cr VI)	7440-47-3	5,3E-06	
Dicyclohexane methane	86-73-6	5,1E-02	
Nitrous oxide(N2O)	10024-97-2	1,7E-02	
2,4-Dinitrotoluene	121-14-2	9,5E-02	
HMDI	5124-30-1	7,5E-02	
Hydro carbons (electricity, stationary combustic	-	1,7E+00	
Hydrogen ions (H+)	-		1,0E-03
i-butanol	78-83-1	3,5E-02	
i-propanol	67-63-0	9,2E-01	
copper (Cu)	7740-50-8	1,8E-05	
Mercury(Hg)	7439-97-6	2,7E-06	
Methane	74-82-8	5,0E-03	
Methyl i-butyl ketone	108-10-1	5,7E-02	
Monoethyl amine	75-04-7		7,9E-06
Nickel (Ni)	7440-02-0	1,1E-05	
Nitrogen oxide (NOx)	10102-44-0	1,1E+00	
NMVOC, diesel engine (exhaust)	-	3,9E-02	
NMVOC, pow er plants (stationary combustion)	-	3,9E-03	
Ozone (O3)	10028-15-6	1,8E-03	
PAH	ikke specifik	2,4E-08	
Phenol	108-95-2		1,3E-05
Phosgene	75-44-5	1,4E-01	
Polyeter polyol	ikke specifik	1,6E-01	
1,2-propylenoxide	75-56-9	8,2E-02	
Nitric acid	7782-77-6 (c	8,5E-02	
Hydrochloric acid	7647-01-0 (c	1,9E-02	
Selenium (Se)	7782-49-2	2,6E-05	
Sulphur dioxide(SO2)	7446-09-5	1,3E+00	
Toluene	108-88-3	4,8E-02	
Toluene-2,4-diamine	95-80-7	7,9E-02	
Toluene diisocyanat (TDI)	26471-62-5	1,6E-01	
Total-N	-		2,6E-05
Triethylamine	121-44-8	1,6E-01	
Unspecified aldehydes	-	7,5E-04	
Uspecified organic compounds	-	1,5E-03	
Vanadium	7440-62-2	1,8E-04	
VOC, diesel engine (exhaust)	-	6,4E-05	
VOC, stationary combustion (coal fired)	-	4,0E-05	
VOC, stationary combustion (natural gas fired)	-	2,2E-03	
VOC, stationary combustion (oil fired)	-	1,4E-04	
Xylene	1330-20-7	1,4E-01	
Zinc (Zn)	7440-66-6	8,9E-05	

Analysed system (life cycle)



Environmental profile of solutions



Relative and absolute sustainability

LCA supports **relative assessments of environmental sustainability** (*"more sustainable than…"*)?

- Same or higher functionality with less environmental impact

Absolute sustainability (*"sustain-able"*)?

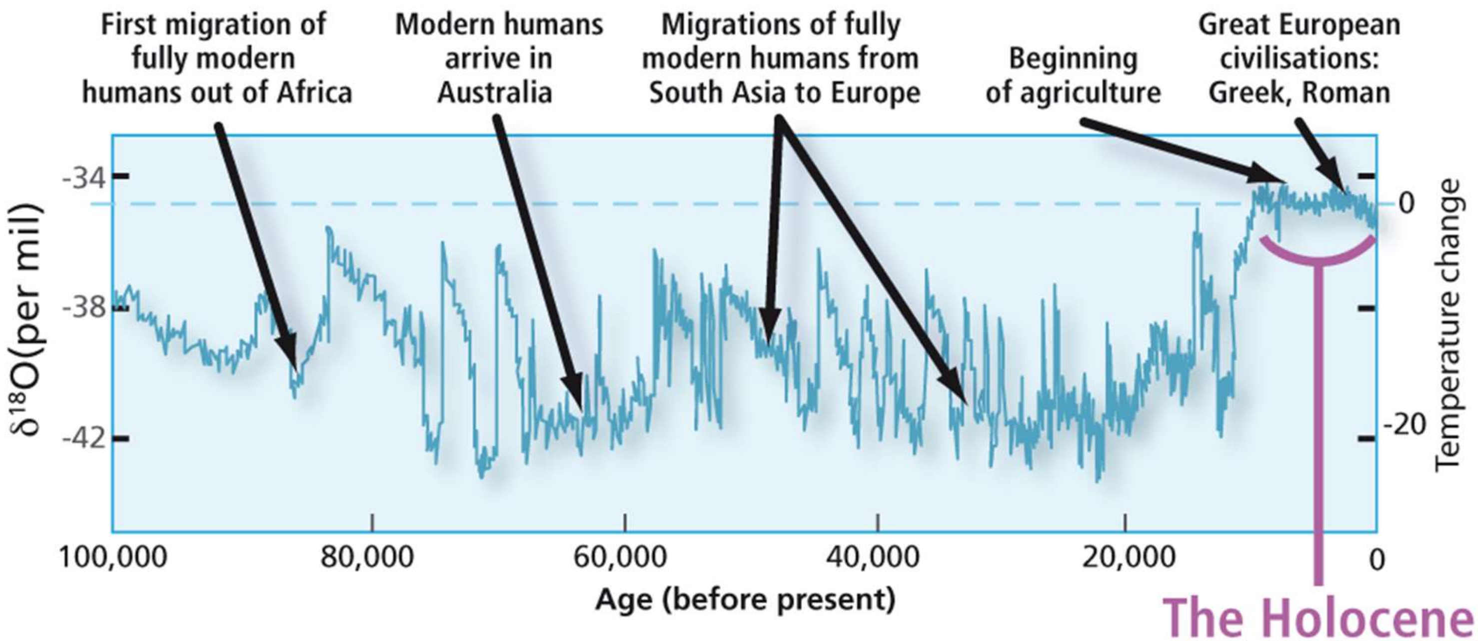
- Where is the boundary beyond which the activity becomes unsustainable?
- What is sustainable in absolute terms?

Sustainable?

Greenwashing
calls for
absolute metrics
in the sustainability
assessment
of products

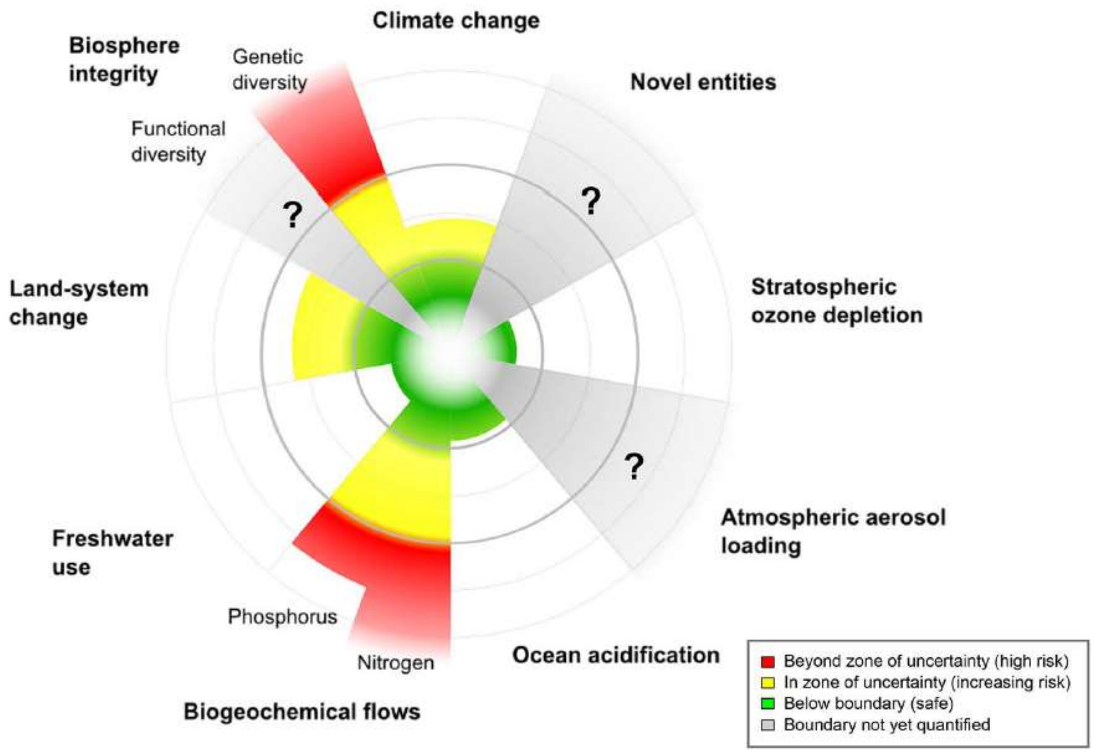
The sustainability challenge

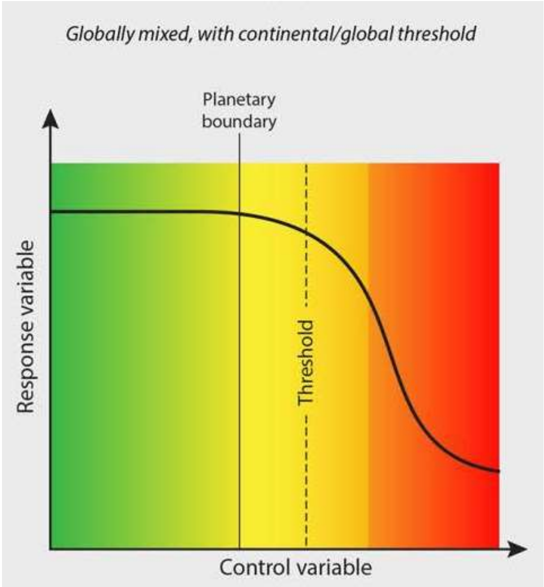
Keeping the planet in the holocene



International Geosphere Biosphere Programme (2015)
http://www.igbp.net/globalchange/anthropocene.4.1b8ae20512db692f2a680009238.html (accessed 06 04 2015)

Planetary boundaries





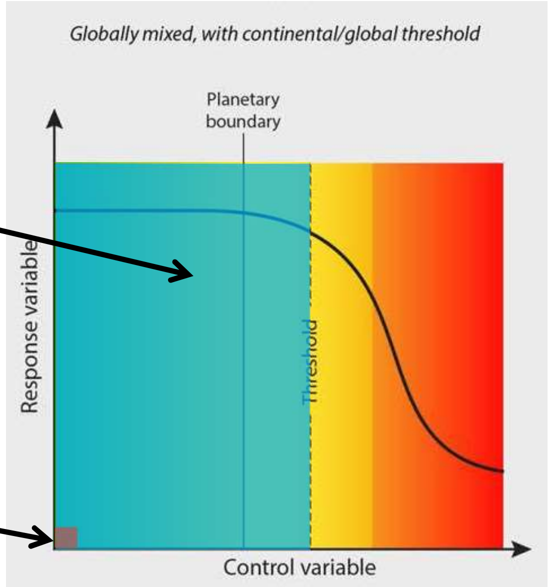
Steffen W, Richardson K, Rockström J et al. (2015) Planetary boundaries: Guiding human development on a changing planet. Science 347(6223), 736-746

A sustainable level of impact

- Respect environmental limits
- Assign"pollution space" to our activities

Total pollution space

Pollution space assigned to technology, product, company, individual, country, …



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Sustainable per capita impacts

Impact category	Current impact	Sustainable impact
Climate change	8.1 ton CO_2-eq	0.98 ton CO_2-eq
Ozone depletion	0.041 kg CFC-11-eq	0.078 kg CFC-11-eq
Photochemical ozone formation	57 kg NMVOC-eq	2.5 kg NMVOC-eq
Terrestrial acidification	$7.8 \cdot 10^2$ mol H+ eq	$1.4 \cdot 10^3$ mol H+ eq
Terrestrial eutrophication	$3.5 \cdot 10^2$ mol N eq	$1.8 \cdot 10^3$ mol N eq
Freshwater eutrophication	0.62 kg P eq	0.46 kg P eq
Marine eutrophication	9.4 kg N eq	31 kg N eq
Freshwater ecotoxicity	$6.7 \cdot 10^2$ [PAF].m^3.dagy	$1.0 \cdot 10^4$ [PAF].m^3.day
Land use, soil quality	9 tons eroded soil	1.2 tons eroded soil
Water depletion	395 m^3	490 m^3

Laurent A, Olsen SI, Hauschild MZ (2011) Normalization in EDIP97 and EDIP2003: updated European inventory for 2004 and guidance towards a consistent use in practice. Int J Life Cycle Assess 16, 401-409
Bjørn A, Hauschild M (2015) Introducing carrying capacity based normalization in LCA: framework and development of midpoint level references. Int J Life Cycle Assess, 20(7), 1005-1018.

Consumer perspective

- A personal impact budget:
  - How large a part of my environmental space is occupied by this product or activity?
  - Is it worth that much to me if my consumption must stay within the sustainability boundaries?
  - Sustainable impact budget, a personal environmental sustainability space

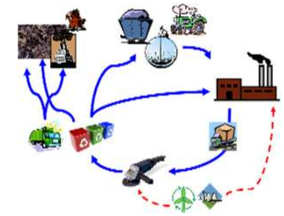
The sustainable product?

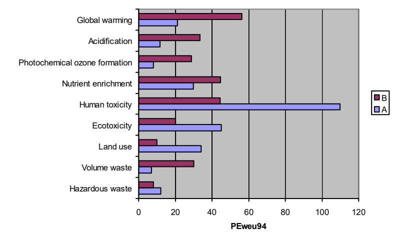
- How large are the environmental impacts of the product?
- How does it compare to
  - The share of my sustainable space that I wish to spend on it (*consumer perspective*)?
  - The space that we can allow for it in our portfolio (*company perspective*)?
    … considering the growth in our market volume (rebound effect)?
  - The space that we can allow this product or technology to occupy out of our total space (*command and control economy societal perspective*)

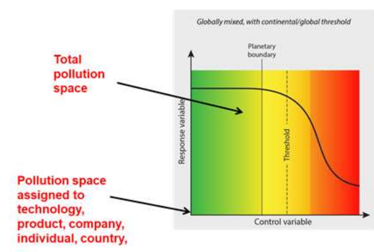
… and then there are the social and economical sustainability dimensions

Take home messages

- All products and technological systems have a life cycle and multiple potential (environmental) impacts
- We must consider both to avoid problem shifting when designing technology for sustainability
- Better is not always good enough
- We must apply an absolute perspective to determine whether a technology or product supports sustainability in absolute terms
- ***Absolute sustainability means meeting the needs of present and future generations within the biophysical limits of our planet***







Raworth, 2017