General Structure of Life Cycle Impact Assessment

Lecture

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Topics

- Life cycle impact assessment structure
- Simple vs complex LCIA methods
- Regionalisation
- Assignment

Definition Life Cycle Impact Assessment

Effects of the resource use and emissions generated in a product life cycle are grouped and quantified into a limited number of impact categories which may then be weighted for importance (UNEP Life Cycle Initiative)

History of LCIA (I)

- 1970-1990

  No standardization of methodology
  Claims of environmental friendly products

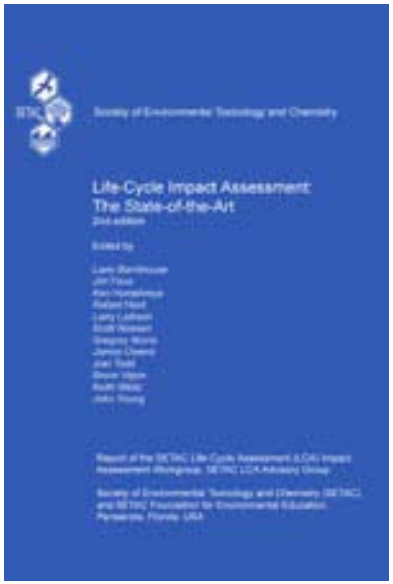
- 1990-2000

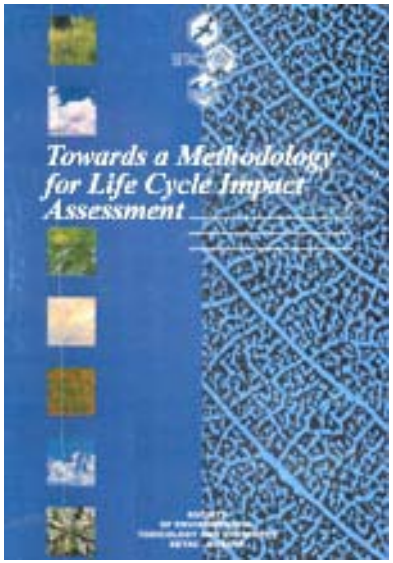
  SETAC codes of practice (1993)
  ISO standards (1993-1999)

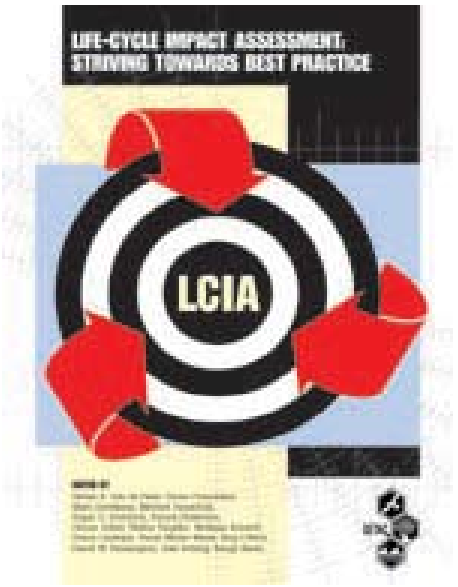
- 2000-now

  SETAC LCIA working groups (2002)
  SETAC/UNEP Life cycle initiative (2002-) International research projects (2009-)

History of LCIA(II)







Steps in Life Cycle Impact Assessment

a) Selection and definition of impact categories, indicators and models
b) Classification
c) Characterisation
d) Normalisation
e) Aggregation and /or weighting

a. Selection of impact categories

midpoints

Resources	Pollution	'Physical stress'
- Abiotic resources - Biotic resources - Land use	- Climate change - Ozone depletion - Acidification - Human toxicity - Eco-toxicity - Eutrophication - Photochemical ozone formation - Radioactivity - Waste heat - Odour - Noise	- Victims

Units are generally reference equivalents, e.g. kg CO2-eq/kg for climate change

a. Selection of impact categories

Endpoints

- Damage to human health (Years of Life Lost)
- Damage to ecosystem quality (Disappeared fraction of species)
- Damage to resources (Extra energy demand)
- Damage to the man-made environment (Euros)

b. Classification of interventions

Qualitatively determine per environ-mental intervention to which impact categorie(s) it contributes

e.g. benzene contributes to human toxicity, ecotoxicity and photochemical ozone formation

c. Characterisation of interventions

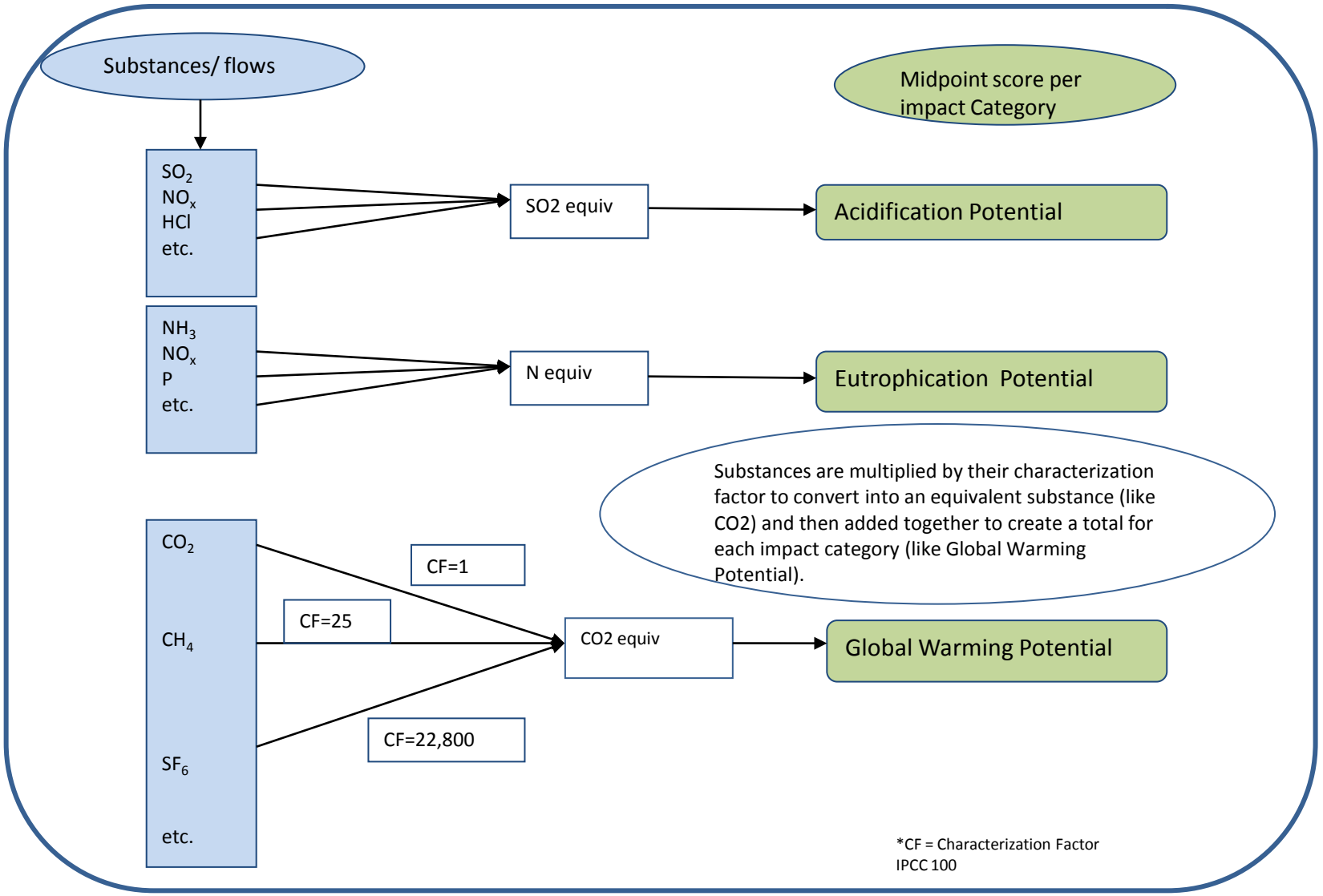
Quantitatively determine the impact score per environmental category

$$IS = \sum_{x} \sum_{i} CF_{x,i} \cdot m_{x,i}$$

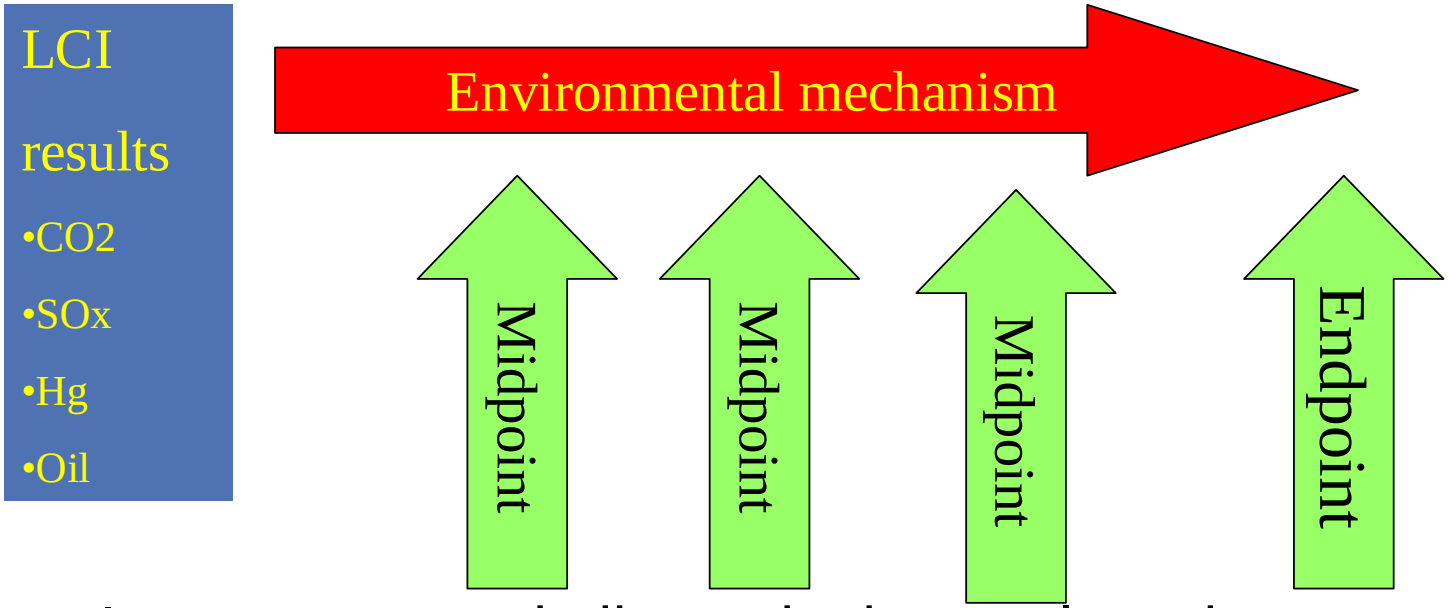
IS = impact score
CF = characterisation factor
m = life cycle intervention
x = substance
i = emission compartment

A Characterisation Factor is a quantitative representation of the (relative) importance of a specific intervention

e.g. the Global Warming Potential (GWP100) of Methane is 22 kg CO2-eq./kg or the human damage factor (HDF) of PM10 is 300 DALYs/kton

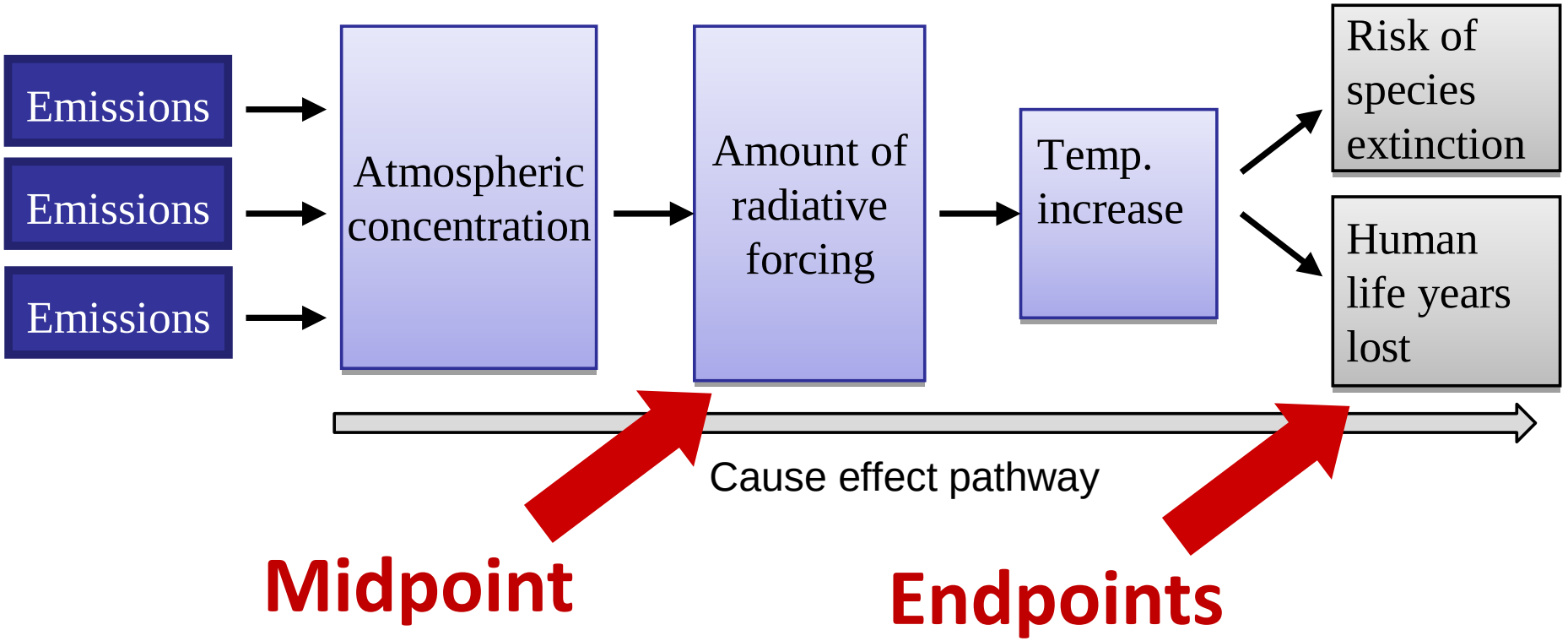

Substances/ flows
Midpoint score per impact Category
SO_2
NO_x
HCl
etc.
SO2 equiv
Acidification Potential
NH_3
NO_x
P
etc.
N equiv
Eutrophication Potential
Substances are multiplied by their characterization factor to convert into an equivalent substance (like CO2) and then added together to create a total for each impact category (like Global Warming Potential).
CO_2
CH_4
SF_6
etc.
CF=1
CF=25
CF=22,800
CO2 equiv
Global Warming Potential
*CF = Characterization Factor
IPCC 100

- Schematic cause-response pathway
- Endpoint reflects “issue of concern”, like flooding, extinction of species, or human lives lost

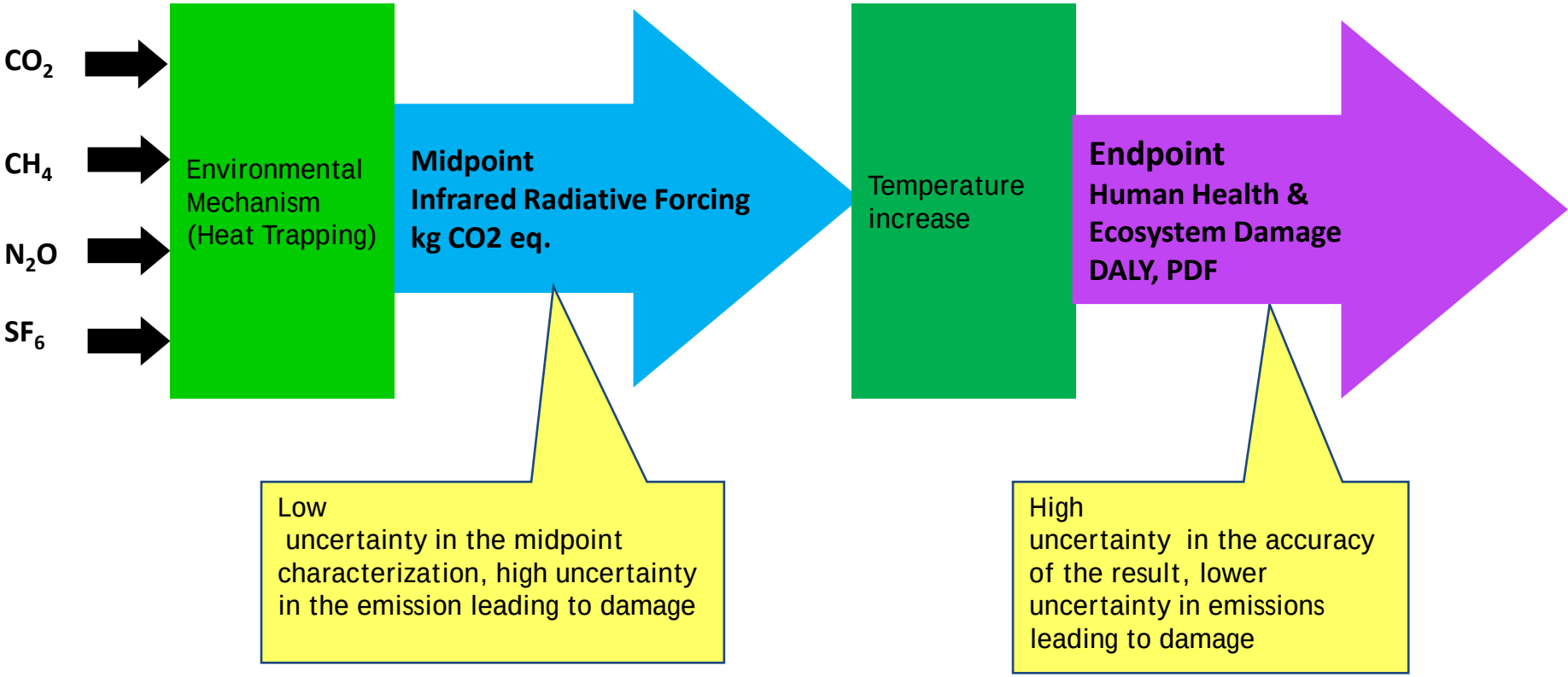


- Impact category indicator is chosen along the environmental mechanism (midpoint)

Example: global warming



Midpoint is the first point in the pathway where impacts are unified



ReCiPe, 2008

d. Normalisation

- Normalization is used to relate the environmental burden of a product (or service) to the burden in its surroundings. In other words, “Normalization relates the micro world of an LCA study to the macro world in which the product/service is embedded”
- Normalization is an optional step
- Calculation per impact category:

  NS = IS/NF

  NS = the normalized impact score (year)

  IS = impact of the product system results prior to normalization (e.g. kg CO2-eq)

  NF = impact of the reference (e.g. kg CO2-eq/year in the world in 2005)

e. Weighting

Aggregation of the normalisation scores to a single environmental index with help of weighting factors (e.g. climate change is 10 times ‘worse’ compared to acidification or human health is ‘equally important’ compared to ecosystem quality)

$$WS = \sum_{e} WF_e \cdot NS_e$$

WS = environmental index
WFe = weighting factor for impact category e
NSe = Normalisation score for impact category e

Midpoint versus endpoint

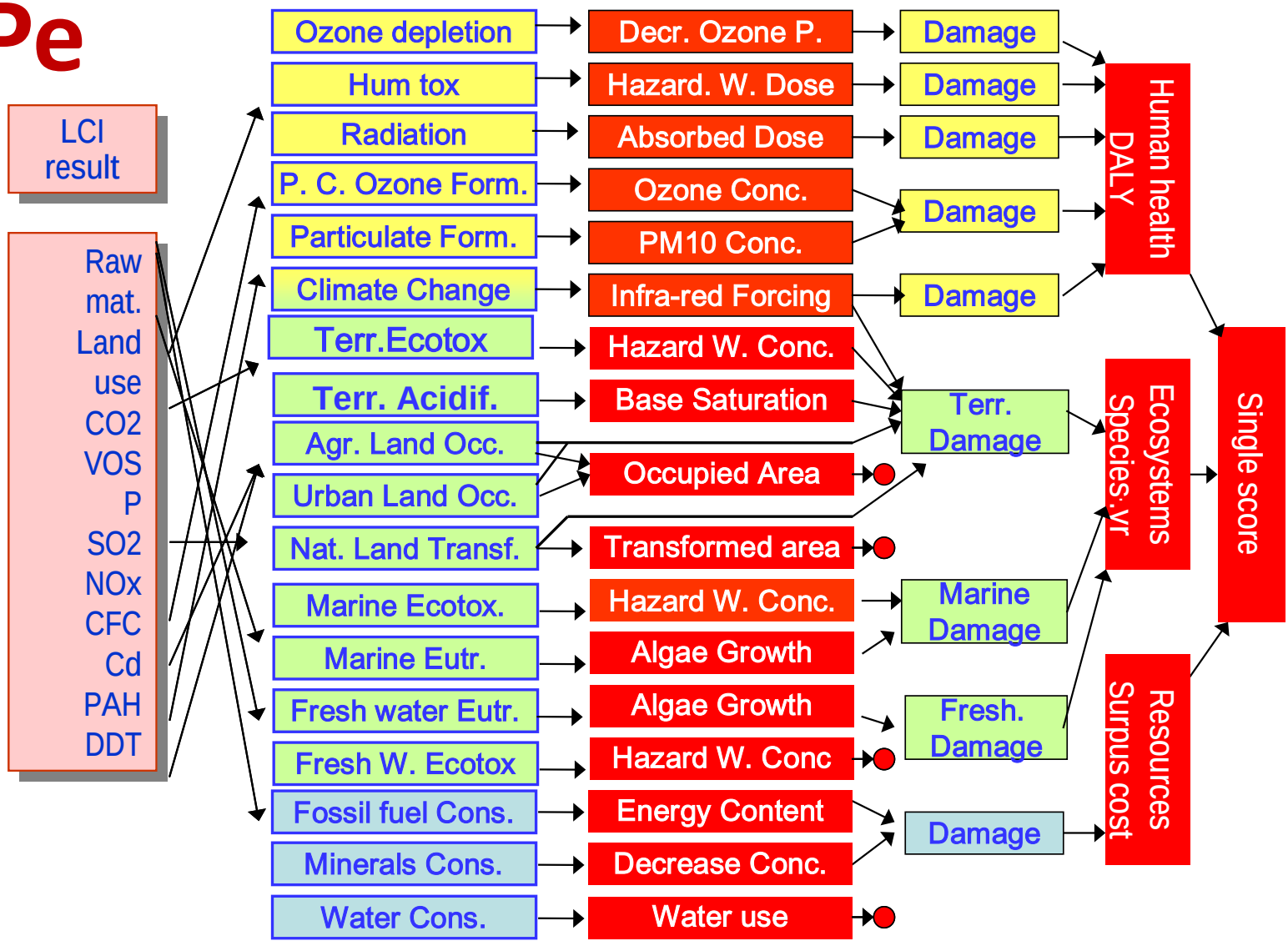
- Endpoint simplifies weighting between impact categories
- Endpoint simplifies comparison of stressors with different modes of action
- But … high uncertainty in the modeling of the full cause-effect chain in endpoint assessment
- Midpoint characterisation factors are considered more robust comparted to endpoint characterisation factors

LCIA methods

ReCiPe 2008

Combining the Ecoindicator 99 and CML-method, i.e. providing midpoint and endpoint characterisation factors for the same set of interventions using the same models for quantifying the cause-effect chain

ReCiPe


LCI result
Raw mat.
Land use
CO2
VOS
P
SO2
NOx
CFC
Cd
PAH
DDT
Ozone depletion
Hum tox
Radiation
P. C. Ozone Form.
Particulate Form.
Climate Change
Terr.Ecotox
Terr. Acidif.
Agr. Land Occ.
Urban Land Occ.
Nat. Land Transf.
Marine Ecotox.
Marine Eutr.
Fresh water Eutr.
Fresh W. Ecotox
Fossil fuel Cons.
Minerals Cons.
Water Cons.
Decr. Ozone P.
Hazard. W. Dose
Absorbed Dose
Ozone Conc.
PM10 Conc.
Infra-red Forcing
Hazard W. Conc.
Base Saturation
Occupied Area
Transformed area
Hazard W. Conc.
Algae Growth
Algae Growth
Hazard W. Conc
Energy Content
Decrease Conc.
Water use
Damage
Damage
Damage
Damage
Damage
Terr. Damage
Marine Damage
Fresh. Damage
Damage
Human health DALY
Ecosystems Species.yr
Resources Surpus cost
Single score

Regionalised LCIA on a global scale

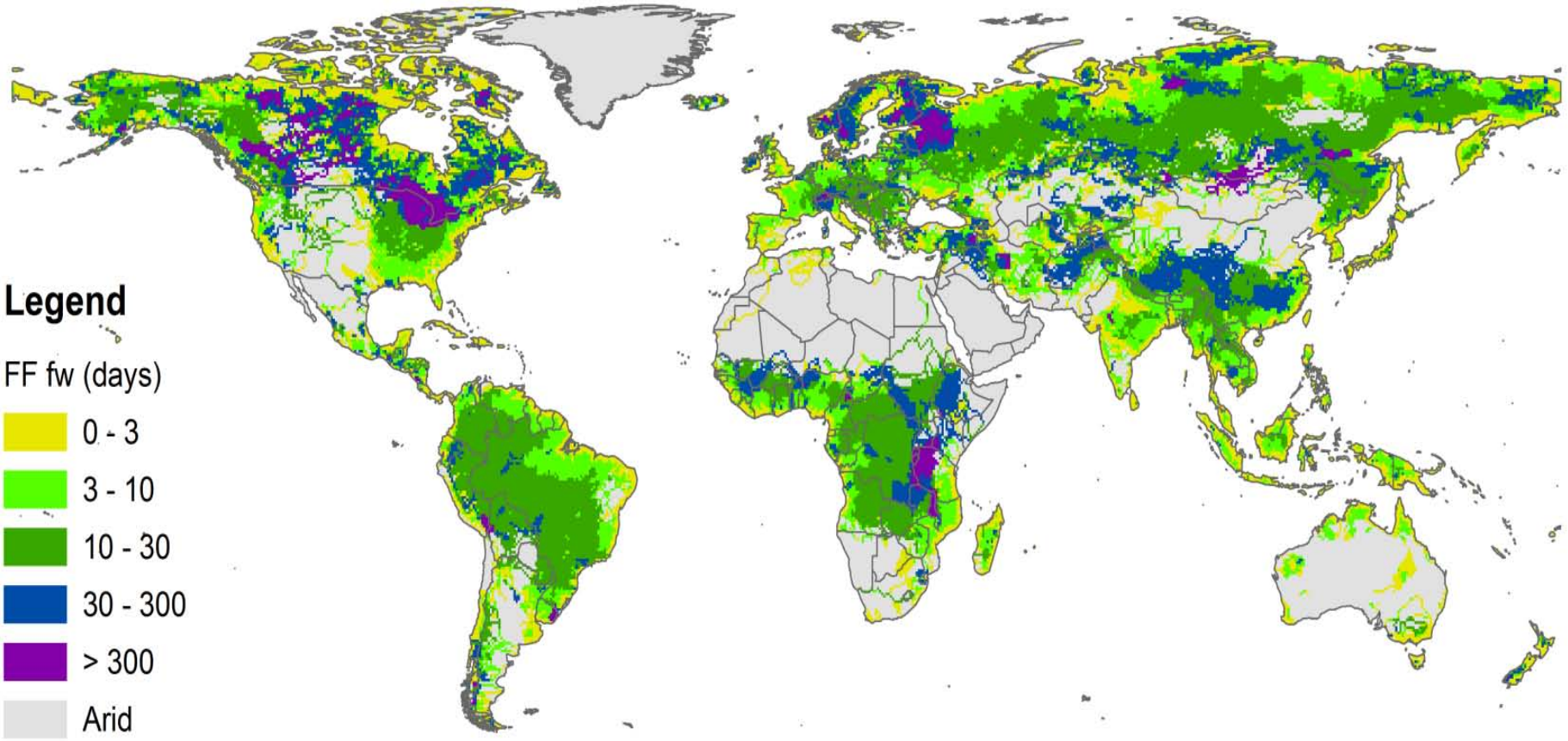
Region-specific LCIA

- Acidification
- Eutrophication
- Photochemical ozone formation
- Toxicity On the level of nations, continents, Ecoregions, ...?

Research question

Do region-specific characterisation factors show other product rankings compared to generic characterisation factors?

Midpoint: Phosphorous



Helmes et al., 2012. Int. J. LCA