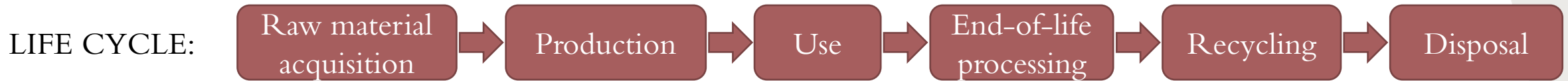# THE EUROPEAN COMMISSION'S PRODUCT ENVIRONMENTAL FOOTPRINT

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WHAT IS LIFE CYCLE ASSESSMENT (LCA)?

LIFE CYCLE: Raw material acquisition → Production → Use → End-of-life processing → Recycling → Disposal

- LCA addresses potential environmental impacts:
  - ❑ use of resources
  - ❑ environmental consequences of outputs

- ISO standards:
  - ❑ 14040 (Principles and framework);
  - ❑ 14044 (details);
  - ❑ 14067 (carbon footprint of products);
  - ❑ 14025 (environmental labelling)

LCA METHOD
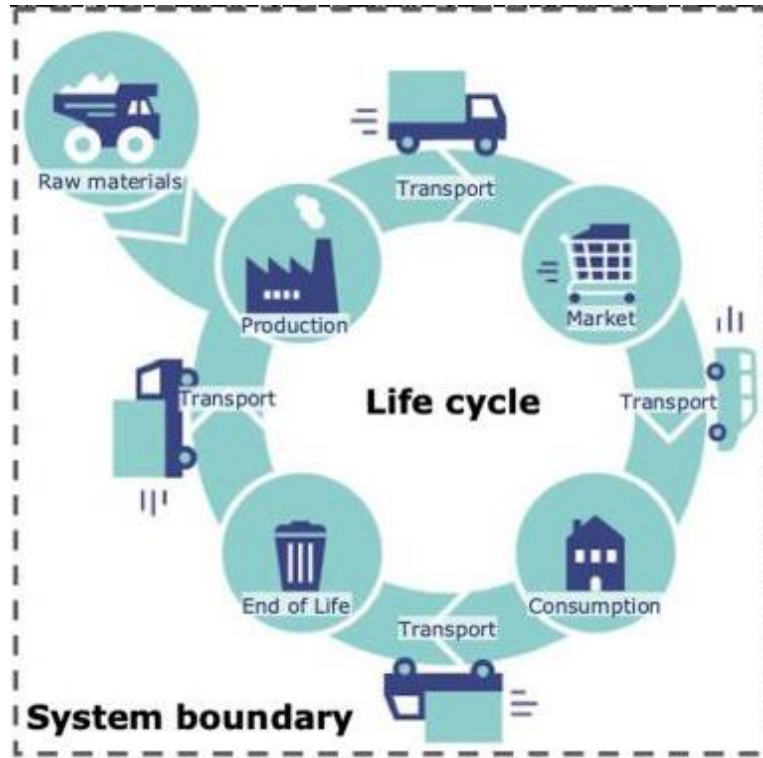
INPUTS
Water
Metals
Crude oil
Land
…
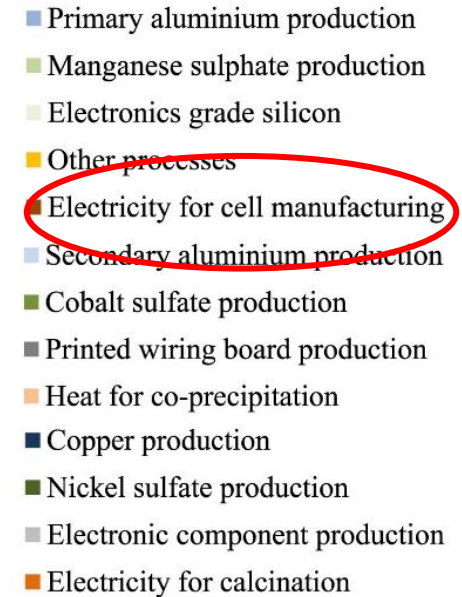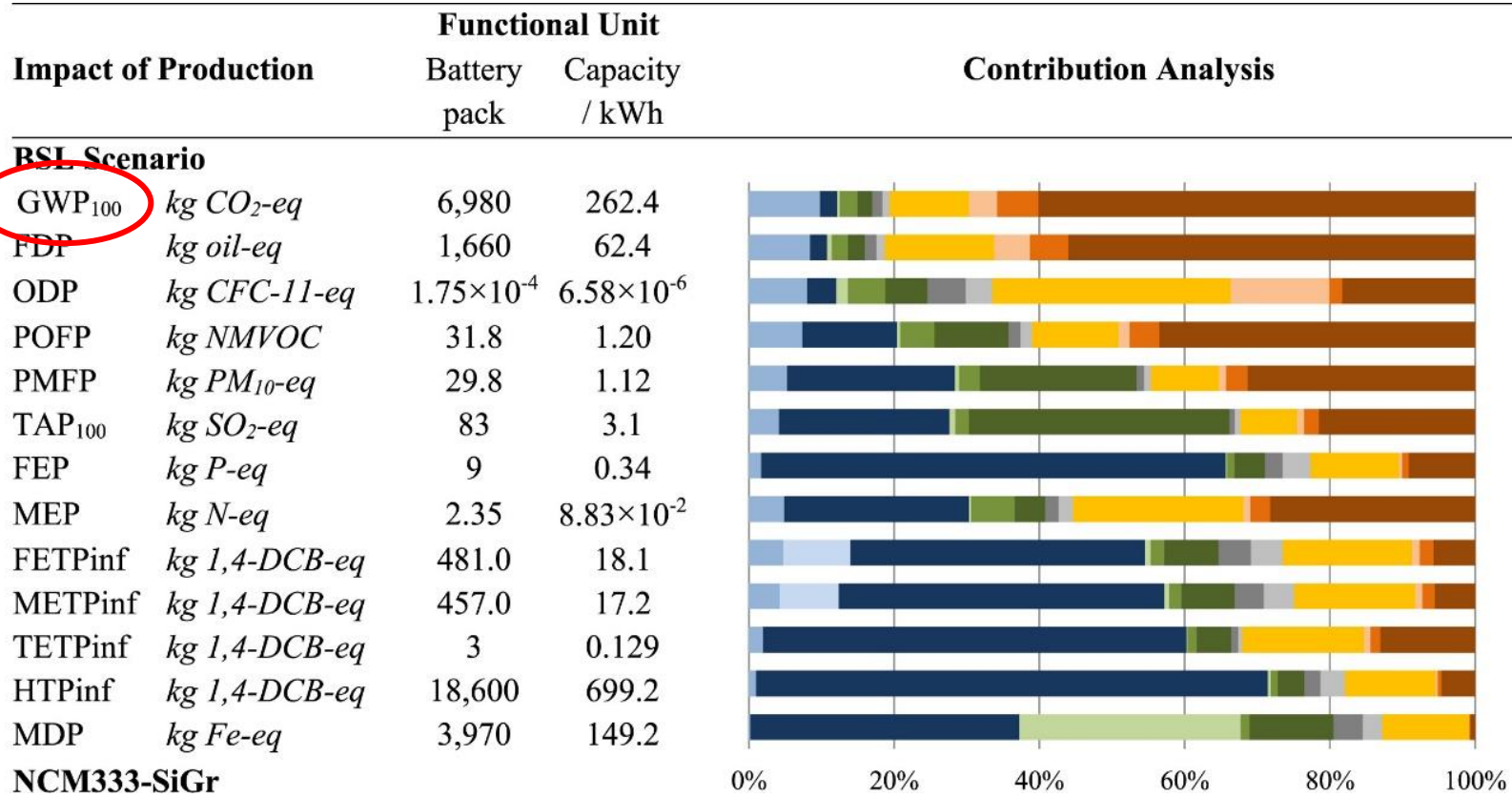
OUTPUTS
CO_2
SO_2
$PM_{2.5}$
Phosphate
…

IMPACT FACTORS

particulate matter formation – PMFP

ozone depletion – ODPinf

Ionising radiation

human toxicity – HTPinf

climate change – GWP100

water depletion – WDP

freshwater ecotoxicity – FETPinf

freshwater eutrophication – FEP

terrestrial ecotoxicity – TETPinf

terrestrial acidification – TAP100

natural land transformation – NLTP

marine eutrophication – MEP

marine ecotoxicity – METPinf

metal depletion – MDP

fossil depletion – FDP

LCA CAN ASSIST WITH…

1. Identifying **hotspots**: areas to focus on to improve environmental performance of products

2. Informing **decision-making** in industry, government or non-government organisations

3. Marketing, e.g. implementing an *ecolabelling* scheme

LCA FOR IDENTIFYING HOTSPOTS

Impact of Production		Functional Unit		Contribution Analysis
		Battery pack	Capacity / kWh	
BSL Scenario				
GWP$_{100}$	$kg\ CO_2\text{-}eq$	6,980	262.4	
FDP	$kg\ oil\text{-}eq$	1,660	62.4	
ODP	$kg\ CFC\text{-}11\text{-}eq$	1.75×10^{-4}	6.58×10^{-6}	
POFP	$kg\ NMVOC$	31.8	1.20	
PMFP	$kg\ PM_{10}\text{-}eq$	29.8	1.12	
TAP$_{100}$	$kg\ SO_2\text{-}eq$	83	3.1	
FEP	$kg\ P\text{-}eq$	9	0.34	
MEP	$kg\ N\text{-}eq$	2.35	8.83×10^{-2}	
FETPinf	$kg\ 1,4\text{-}DCB\text{-}eq$	481.0	18.1	
METPinf	$kg\ 1,4\text{-}DCB\text{-}eq$	457.0	17.2	
TETPinf	$kg\ 1,4\text{-}DCB\text{-}eq$	3	0.129	
HTPinf	$kg\ 1,4\text{-}DCB\text{-}eq$	18,600	699.2	
MDP	$kg\ Fe\text{-}eq$	3,970	149.2	
NCM333-SiGr				

Legend:
- Primary aluminium production
- Manganese sulphate production
- Electronics grade silicon
- Other processes
- Electricity for cell manufacturing
- Secondary aluminium production
- Cobalt sulfate production
- Printed wiring board production
- Heat for co-precipitation
- Copper production
- Nickel sulfate production
- Electronic component production
- Electricity for calcination

Kallitsis *et al. Journal of Cleaner Production* 254, 2020, 120067.

LCA LIMITATIONS

Leaves much to interpretation by the practitioner

Functional unit needs to be appropriate, specific and at a relevant scale

Credit for avoided burden is either left out, or gives misleading results

Inadequate assumptions or errors significantly affect the final LCA results

Highly dependent on the data; not all data is available or accurate/up-to-date

Consequences of a product/service often overlooked – e.g. biofuel land use

Uncertainty in the data and consequent LCA difficult to quantify

Not all environmentally-relevant data can be quantified

Not always a clear "winner" – e.g. different scores for different impact factors

LCA is iterative: data, product and supply chain changes require revision

Biodiversity impacts not well covered

J.F. Peters *et al. Renewable and Sustainable Energy Reviews* 67 (2017) 491–506.
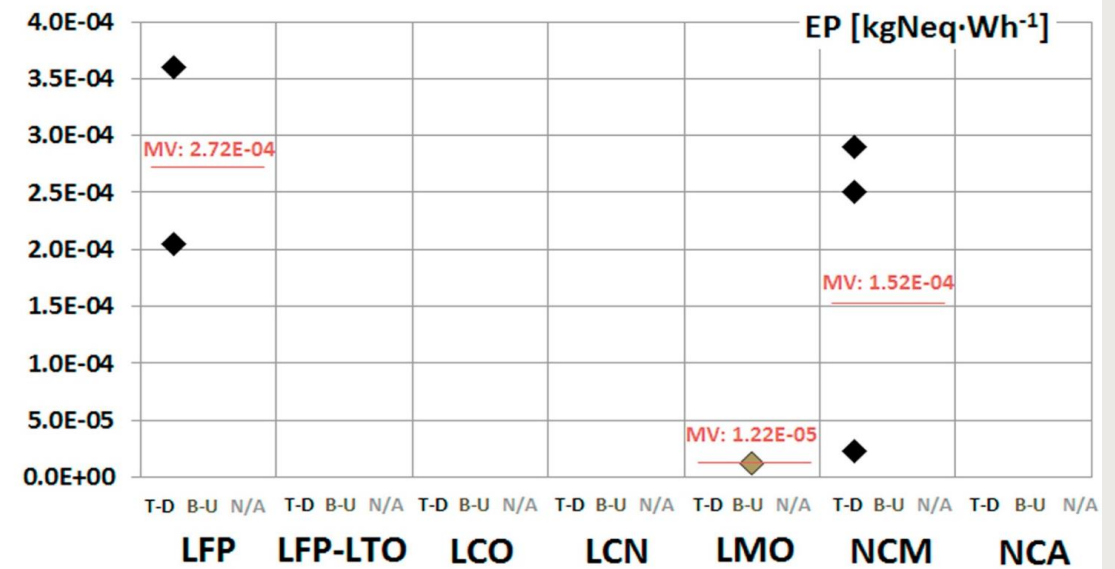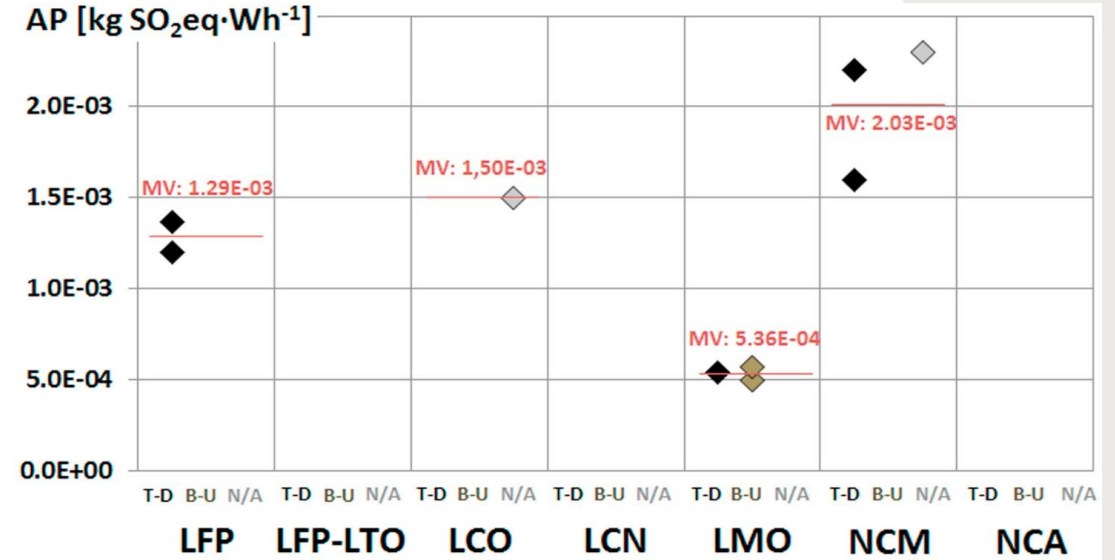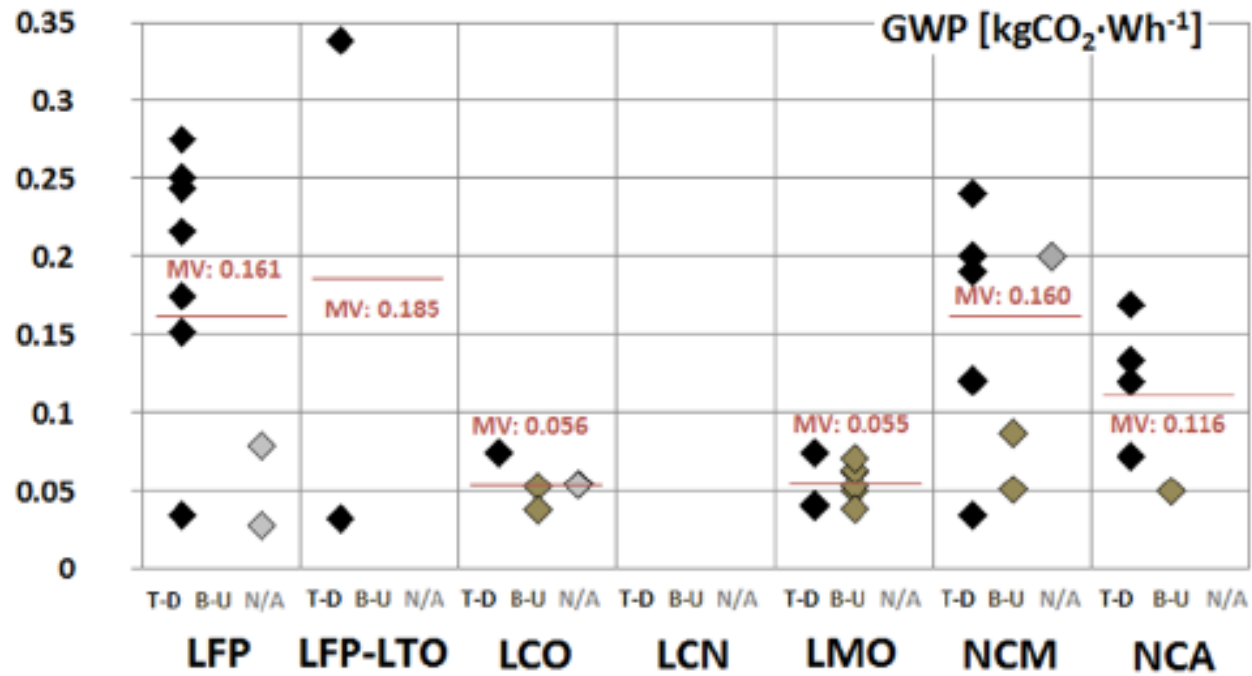
BURDEN SHIFTING

- Reducing impacts on one area/place/stage, but can just be shifting them to other areas

Five types of shifting

1. Impact factor: reduce CF, but increase water use (e.g. Li – brine vs hard rock)

2. Life cycle stage: may improve materials, but harder to recycle (e.g. LFP vs NMC)

3. Time: nuclear waste – a problem for the future

4. Location: change supplier, but the burdens just shift to the other country; especially problematic if regulations are less stringent

5. Pillar: burden moves to greater cost or social impacts

- Therefore a **holistic, global** assessment is essential

- Too many ecolabels!

- Greenwash, lack of transparency

PRODUCT ENVIRONMENTAL FOOTPRINT

LCA

- Aims to promote transparency and make consumer choice easier
- Based on LCA Standards
- Defines cohesive rules for the options left open by the ISO standard
- Aims for: reliable, comparable and verifiable
- Defines rules for specific product categories/industries (PEFCR)
- Not mandatory yet – in pilot phase (except construction)
- Started 2013; due to be completed by end 2024
- Measurement and communication

PEF METHODOLOGY v3.0

LCA VS PEF

SAME

- Science-based
- Quantifies impacts over life cycle
- Includes:
  - ❑ Emissions to soil, air, water
  - ❑ Resource use and depletion
  - ❑ Impact of land and water usage

DIFFERENT

- Single method, more stringent rules
- Strict data rules
- Modelling rules for e.g. electricity use
- Benchmarking
- Improved impact assessment methods, esp. toxicity
- Guidelines for including biodiversity
- Uncertainty included
- Mandatory normalisation & weighting
- Circularity formulae for recycling
- Verification & validation step

PEF METHOD
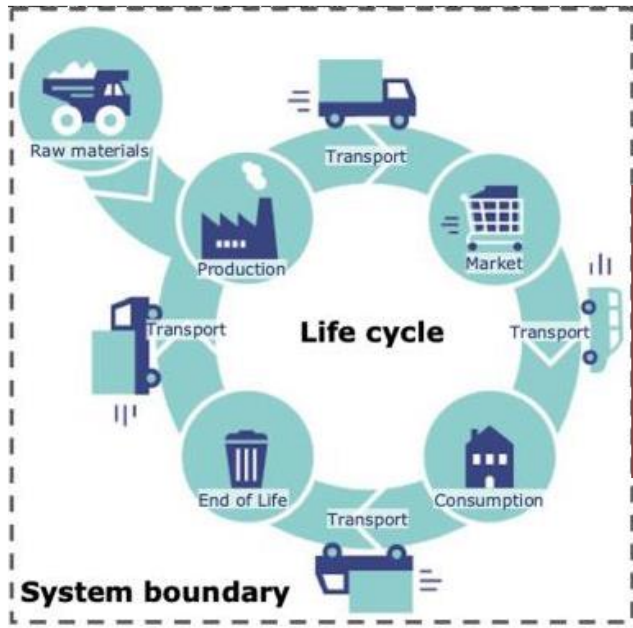
INPUTS
Water
Metals
Crude oil
Land
…

OUTPUTS
CO_2
SO_2
$PM_{2.5}$
Phosphate
…

16 IMPACT FACTORS

Carbon footprint (kg CO_2eq)

Resource use – minerals & metals

Resource use – energy carriers

Ozone depletion

Ionising radiation

Respiratory inorganics

Photochemical ozone formation

Land use

Human toxicity – cancer

Human toxicity – non-cancer

Terrestrial eutrophication

Marine eutrophication

Freshwater eutrophication

Freshwater ecotoxicity

Acidification

Water scarcity

SINGLE VALUE

As wide as possible!

PEF: DATA

- Strict data collection & quality requirements
- Developing PEF database for EU industries
- Can mix with Ecoinvent
- Bill of materials (list of materials with quantities & grades)
- Detailed modelling rules for:
  - ❑ Manufacturing processes
  - ❑ Electricity use
  - ❑ Transport
  - ❑ Agricultural production
- Minimum requirements:
  - ❑ Completeness
  - ❑ Methodological appropriateness and consistency
- Quality scores for each data point: excellent (1) – poor (5)
- Primary data: must have average quality <1.5

PEF DATABASE v2.0
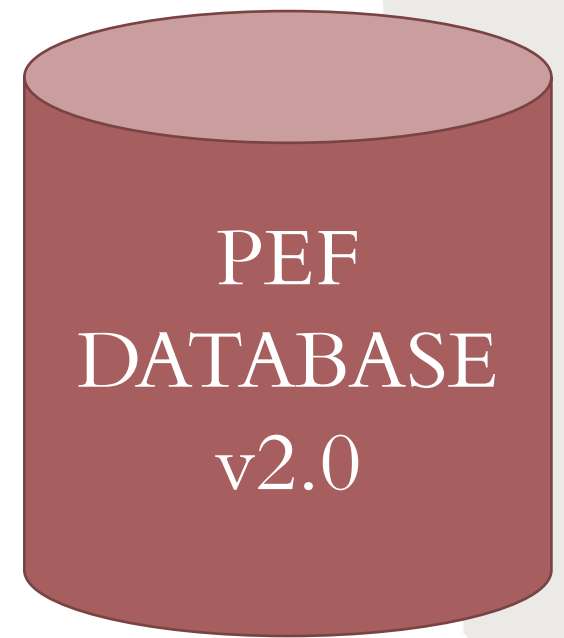
PEF: CATEGORY RULES

- Specific products have peculiarities

- Product specifics detailed in PEF Category Rules

- Complement the general PEF rules

- Standardise how an LCA for products in that category is to be conducted

- Focus on **what matters most** for this category

- Pilot studies identify most important elements

- Defines a communication vehicle (e.g. ecolabels)

- PEFCR Guidance v6.3
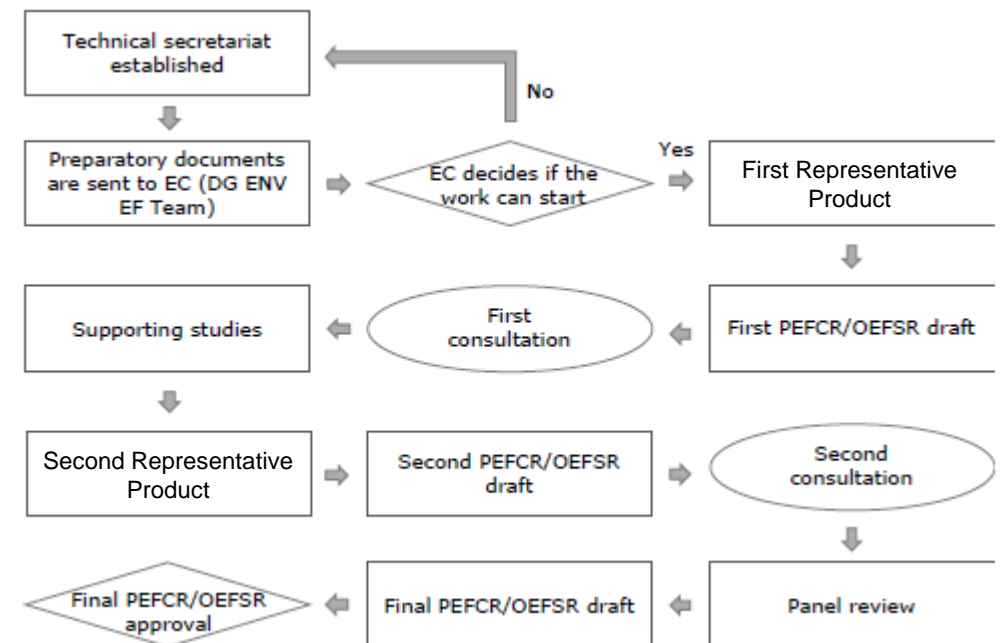
https://eplca.jrc.ec.europa.eu/permalink/PEFCR_guidance_v6.3-2.pdf

PEFCRS SO FAR (29)

SUCCESSFUL (19)

- Batteries
- Decorative paint
- Leather
- Beer
- IT equipment
- Agricultural feed
- Dairy products
- Pasta
- Wine
- Bottled water
- Pet food
- Household liquid laundry detergents
- Metal sheet
- Photovoltaics
- T-shirts
- UPS
- Intermediate paper products
- Hot & cold water pipe systems
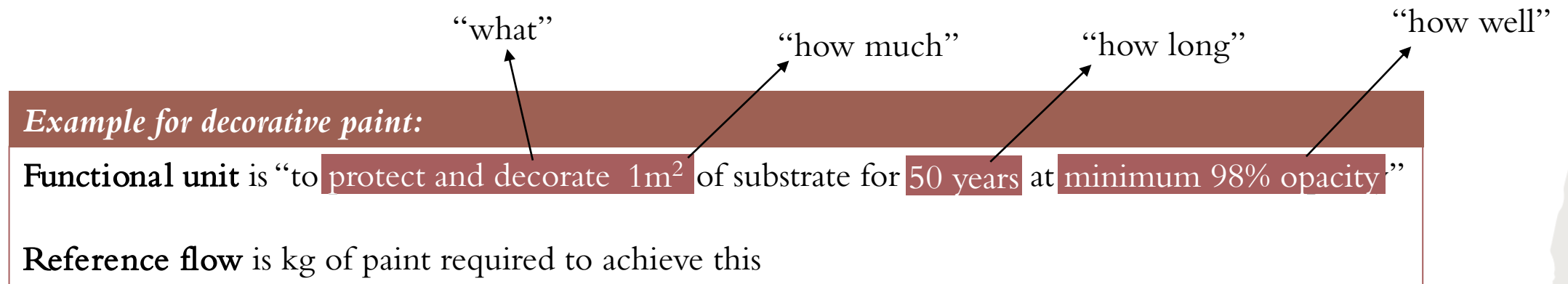- Thermal insulation

IN PROGRESS (5)

- Apparel
- Cut flowers & potted plants
- Flexible packaging
- Synthetic turf
- Olive Oil

FAILED (5)

- Coffee
- Red meat
- Marine fish
- Stationary
- Non-leather shoes

PEF: FUNCTIONAL UNIT

- Defined according to:
  - ❑ what: the function or service provided
  - ❑ how much: the extent of the function or service
  - ❑ how long: the duration or the lifetime
  - ❑ how well: the expected level of quality

- Reference flow: quantity required to fulfil this defined function

"what"   "how much"   "how long"   "how well"

Example for decorative paint:

Functional unit is "to protect and decorate 1m^2 of substrate for 50 years at minimum 98% opacity"

Reference flow is kg of paint required to achieve this

PEF: REPRESENTATIVE PRODUCT

- Average product sold in the EU market

- Representative for the considered product group

- Used as a benchmark for the category

- May be a real or a virtual product (i.e. non-existent product based on weighted average)

- Used to run the first PEF, to identify:
  - ❏ Most important life cycle stages
  - ❏ Most important impact factors
  - ❏ Data needs
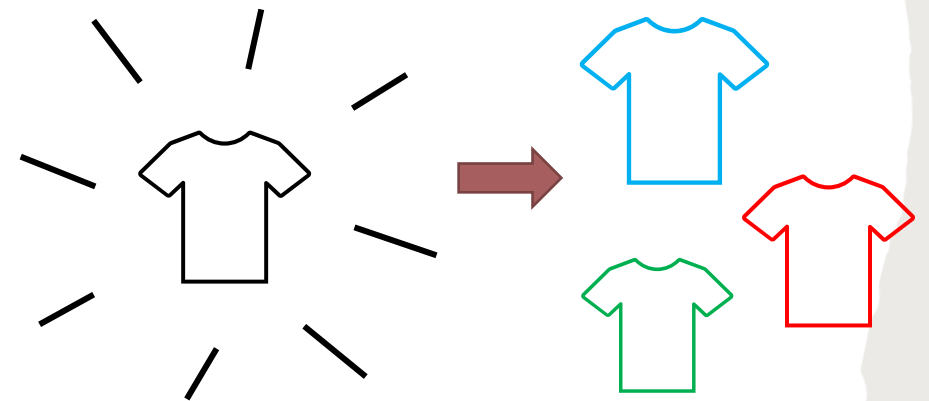
PEF: IMPACT ASSESSMENT

Mandatory steps:

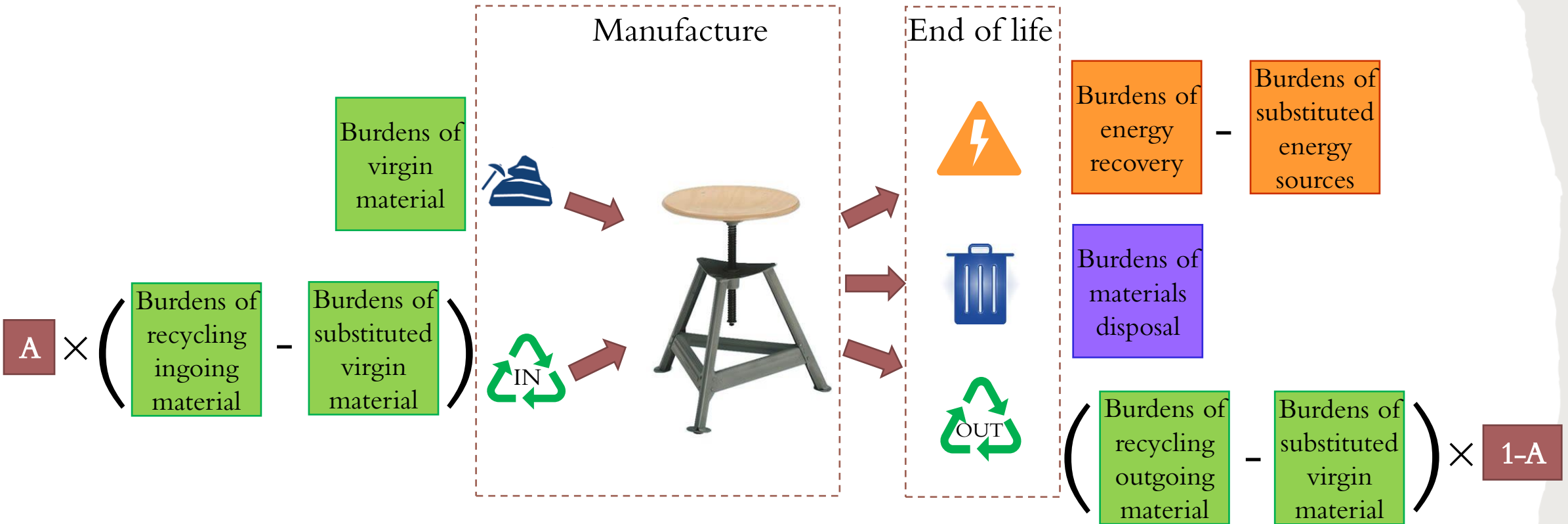- Classification - assign material/energy inputs and outputs to EF impact categories

- Characterisation – calculate magnitudes and aggregate (LCI value x characterisation factor)

- Normalisation – relative to a reference unit

- Weighting – relative importance of impact category

Result: single overall score*

⋆ Sala et al., Development of a weighting approach for the Environmental Footprint, DOI 10.2760/945290 (2018)

PEF: CIRCULAR FOOTPRINT FORMULA

Material + Energy + Disposal

$$A \times \left(\begin{array}{c} \text{Burdens of} \\ \text{recycling} \\ \text{ingoing} \\ \text{material} \end{array} - \begin{array}{c} \text{Burdens of} \\ \text{substituted} \\ \text{virgin} \\ \text{material} \end{array} \right)$$

Manufacture

Burdens of virgin material

IN

End of life

Burdens of energy recovery − Burdens of substituted energy sources

Burdens of materials disposal

$$\left(\begin{array}{c} \text{Burdens of} \\ \text{recycling} \\ \text{outgoing} \\ \text{material} \end{array} - \begin{array}{c} \text{Burdens of} \\ \text{substituted} \\ \text{virgin} \\ \text{material} \end{array} \right) \times (1{-}A)$$

OUT

Low supply & high demand, favours producers of recycled materials
High supply & low demand, favours recyclers of "waste" materials

PEF: INTERPRETATION

- Iteratively improve PEF model performance to meet goals and quality requirements

- Must include:
- ❑ Robustness assessment (check for completeness, sensitivity, consistency)
- ❑ Hotspot analysis (most relevant impact categories, life cycle stages, processes, flows)
- ❑ Uncertainty (qualitative or quantitative using e.g. Monte Carlo simulation)

- Results reported for **total life cycle** and the **total life cycle excluding the use stage**.

PEF: ISSUES

- Created in 2013 – out of date environmental science

- Doesn't prioritise EU's latest circular economy goals

- Some PEFCRs have failed in development, due to lack of consensus

- PEFCR functional units inadequate to ensure fair comparison of products

- Missing impact categories for biodiversity and indirect land use change

- Benchmarking method not established

- Uncertainty about PEF's effect on LCA costs

- Unclear how the results of a PEF study should be communicated

* Pedersen & Remmen, Challenges with product environmental footprint: a systematic review, DOI 10.1007/s11367-022-02022-3 (2018)

ORGANISATION ENVIRONMENTAL FOOTPRINT

- Goods or service-providing organisations

- Products excluded

- Aggregate data representing flows of resources and waste that cross the organisation's boundary

- Once OEF is calculated, it may be disaggregated to the products

- OEFSR = OEF Sector Rules

- OEFCRs for Retail and Copper sectors finalised so far

- Aligns with GHG Protocol Scope 3 and ISO 14069

FURTHER READING

Environmental Footprint Simple Guide (2021)
https://circabc.europa.eu/ui/group/6e9b7f79-da96-4a53-956f-e8f62c9d7fed/library/537534a4-9c76-40a1-b488-e9127db2befd/details?download=true

Environmental Footprint, European Platform on LCA | EPLCA
https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html

Guidance on how to develop Product Environmental Footprint Category Rules
https://eplca.jrc.ec.europa.eu/permalink/PEFCR_guidance_v6.3-2.pdf

Annex I. Product Environmental Footprint Method
https://environment.ec.europa.eu/system/files/2021-12/Annexes%201%20to%202.pdf

Suggestions for updating the Product Environmental Footprint (PEF) method
https://eplca.jrc.ec.europa.eu/permalink/PEF_method.pdf

Pedersen & Remmen, Challenges with product environmental footprint: a systematic review, DOI
https://doi.org/10.1007/s11367-022-02022-3 (2018)

Thank you for your attention