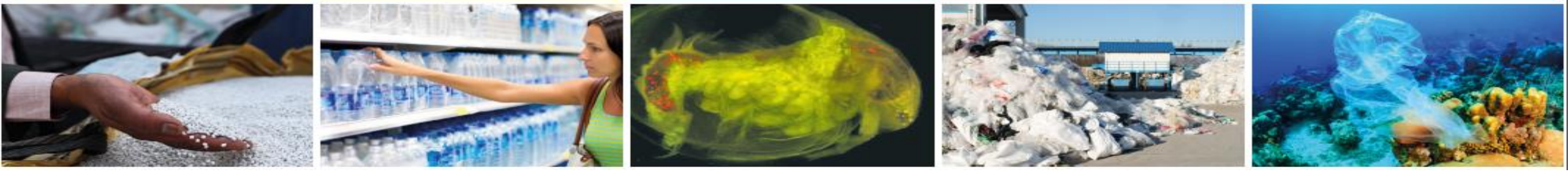

Towards an Plastic-Pollution-Budget

Jürgen Bertling, Fraunhofer UMSICHT

GEFÖRDERT VOM
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Plastik
in der Umwelt
Quellen • Senken • Lösungsansätze

FONA
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The Plastic Budget Project

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Plastik in der Umwelt

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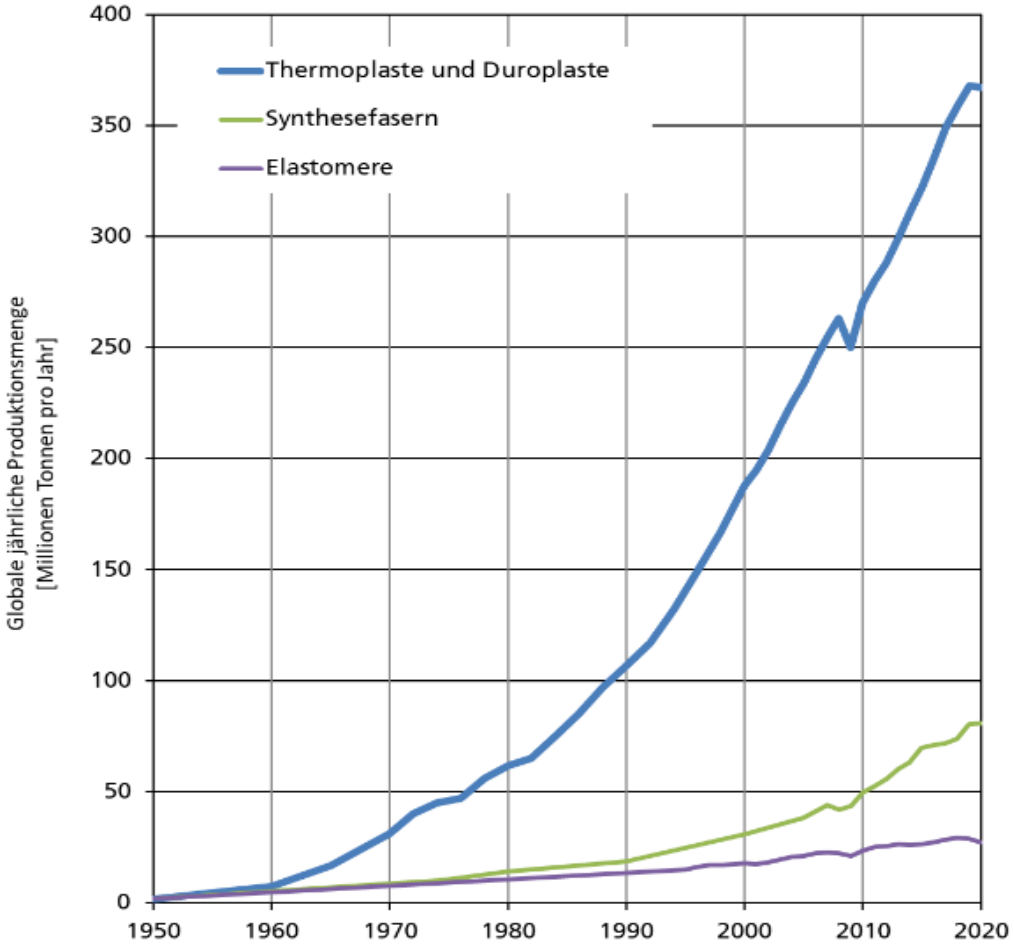
Project Data

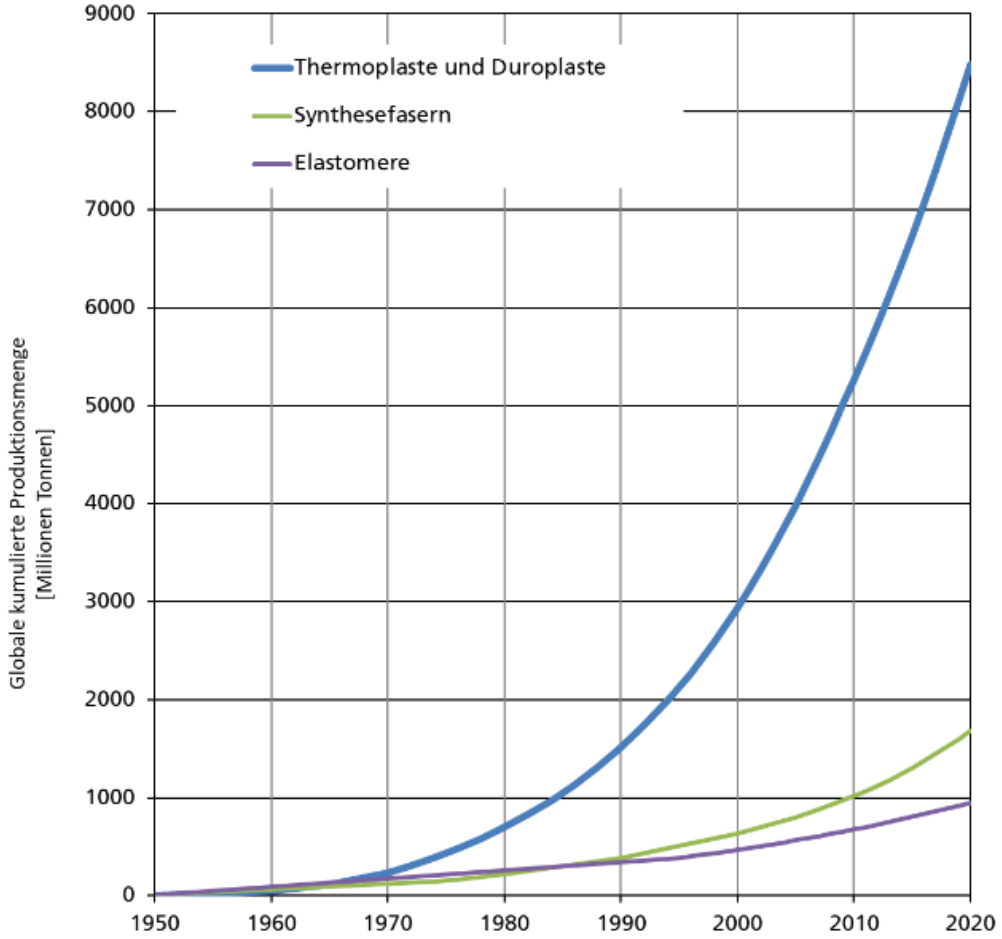
- Fraunhofer UMSICHT (coordination)
- Ruhr-Universität Bochum – Geografisches Institut (vorher KWI Essen)
- Funding by BMBF
- Duration: 12/2017 bis 08/2021

Objectives

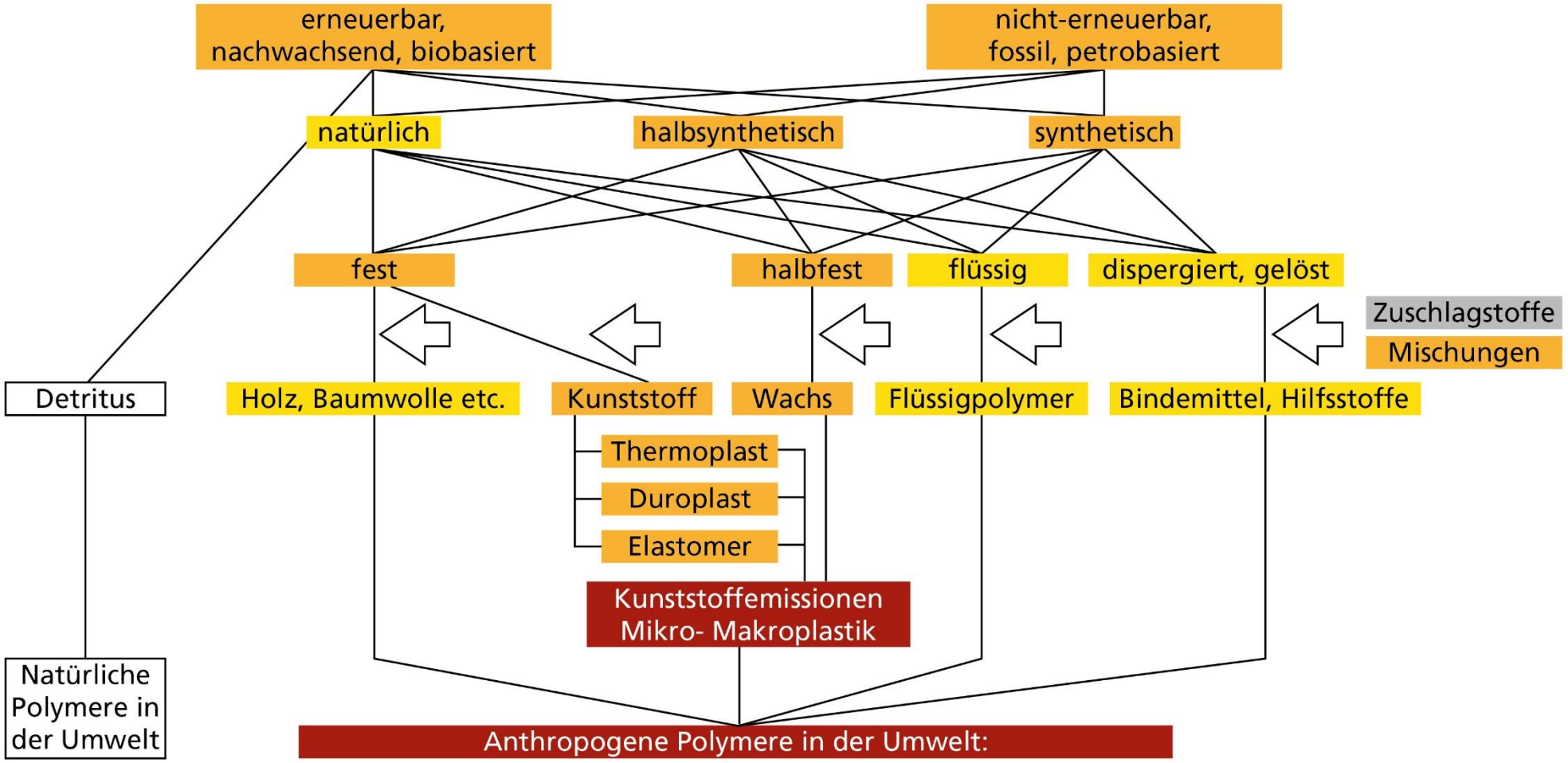
- Conduct source and quantity determinations for plastic emissions
- Development of a Plastic Pollution Budget
- Integration of Plastic emission in life cycle impact asessment
- Participation and Governance

The plastic success story!





What are plastic emissions?



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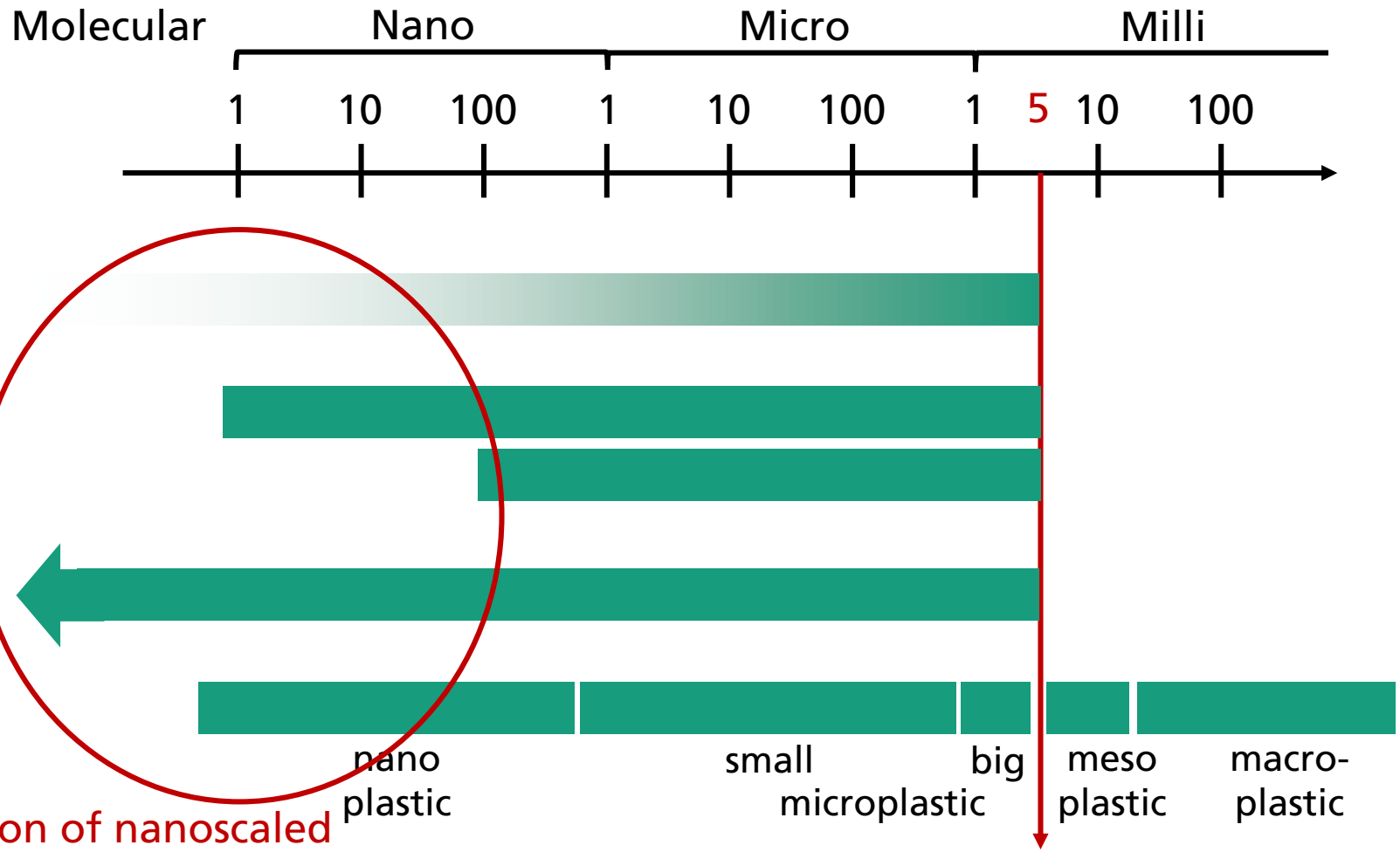

Thompson 2004

NOAA 2008

ECHA 2019
ECHA 2020
(after public consultation)

BUND/Friends of the Earth

ISO TR 21860 (2020)

Exclusion of nanoscaled polymedispersions/ watersoluble polymers?

Widely accepted, but why?

Will lower and upper limits lead to gaps and disproportionalities in regulation?

Examples of plastic emissions?









Estimation of Plastic emissions

Recovery

Application → Loss → Transfer → Release → Environment

Author	Region	Macroplastic (grams per person and year)	Microplastic (grams per person and year)	Type
Bertling et al. (2018, 2021)	DE	843	2 840	Loss
Essel et al. (2015)	DE	-	2 200 - 5 130	Loss
Zimmermann et al. (2019)	DE	650 – 2.500	1 813 - 3.049	Remaining
Sundt et al. (2014)	NO	-	1 590	Release (marine)
Magnussen et al. (2016)	SE	-	1 670 - 3 880	Loss
Lassen et al. (2015)	DK	-	965 - 2 440 600 - 3.100	Loss Release (marine)
Jambeck et al. (2015)	World	615 – 1.628		Release (marine)
Boucher et al. (2017)	World		236 – 660 102 - 320	Loss Release (marine)
Ryberg et al. (2019)	World Europe	794 313	390 896	Release (all) Release (all)

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Macroplastic: 1 kg / (cap yr)
Microplastic: 3 kg / (cap yr)
4 kg / (cap yr)
The plastic around us, is the tip of an iceberg!

Tools for the Governance of Plastic Emissions

- **Plastic Pollution Equivalent (PPE)**
  - Labeling of products/services/processes
  - Impact Category in Life Cycle Analysis

- **Plastic Pollution Budget (PPB)**
  - Threshold Value for plastic emissions of
    - Nations
    - Individuals
    - Branches
    - Organizations

Plastic Pollution Equivalent (PPE)

$$PPE = \sum_{i=1}^{m} \left(m_{plastic\ emission,i} \sum_{j=1}^{n} \left[T_{i,j} \frac{\tau_{R,i,j}}{\tau_{R,ref}} \right] \right) \quad mit \quad \sum_{j=1}^{n} (T_{i,j}) = 1$$

Residence time

Distribution to final compartments

All emissions of a product/process/service

Quantification of Losses

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» **Tire, textile, insulation material, outdoor paints,…**

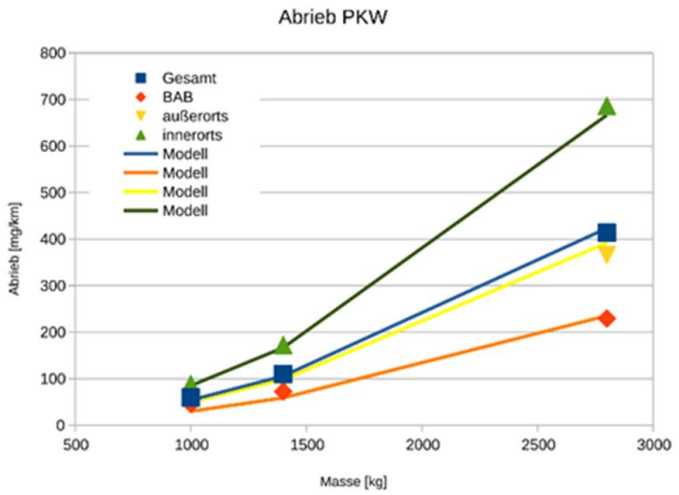
- Lack of experimental results in real environments
- transfer from lab scale experiments rarely possible

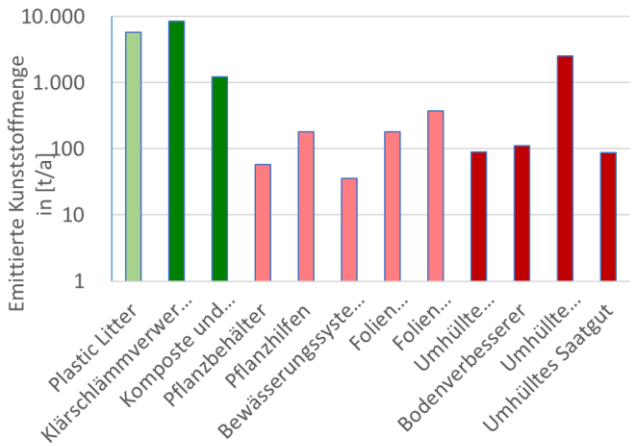
Estimates increase pressure for more valid data!

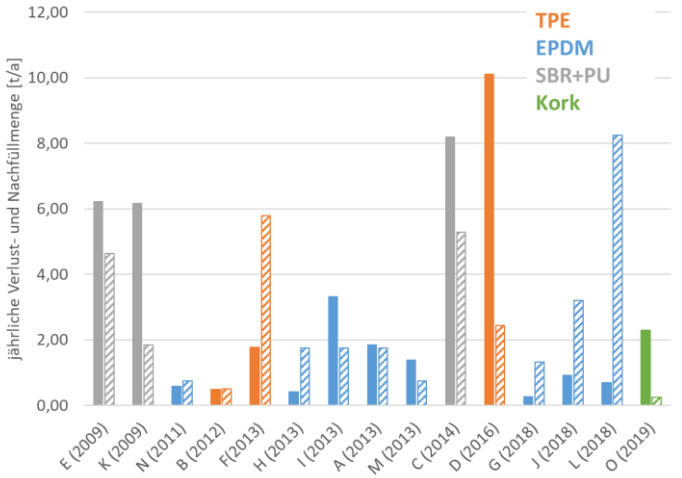
» **Plastic Litter**

- No systematic (quantitative) approaches
- Main focus on rising awareness (Clean-ups)

Main difficulty: estimation of the non captured!







Transfer Pathes of Plastic Emissions

» Transfer Rates are rough estimates from environmental monitoring

Kunststoffemission	Eintritts-kompartiment	Finaler Verbleib (T_j)			
		Boden	Meer-wasser	Fluss-sediment	Meeres-sediment
NR/SBR	Boden	100 %	0 %	0 %	0 %
	Frischwaser	0 %	0 %	89 %	11 %
	Meerwasser	0 %	0 %	0 %	100 %
	Atmosphäre	94,7 %	0 %	4,7 %	0,6 %
Polymers with a density ≥ 1 g/cm^3 (PA, PBAT, PBS, PBSA, PBSe, PBSeT, PC, PCL, PET, PHB, PHBV, PLA, PS, PU, PVC, Starch-blend)	Boden	97 %	0 %	2,7 %	0,3 %
	Frischwaser	0 %	0 %	89 %	11 %
	Meerwasser	0 %	0 %	0 %	100 %
	Atmosphäre	94,7 %	0 %	4,7 %	0,6 %
Polymers with a density < 1 g/cm^3 (HDPE, LDPE, PE, PEA, PES, PP)	Boden	97 %	3 %	0 %	0 %
	Frischwaser	0 %	100 %	0 %	0 %
	Meerwasser	0 %	100 %	0 %	0 %
	Atmosphäre	94,7 %	5,3 %	0 %	0 %

Transfer Pathes of Plastic Emissions

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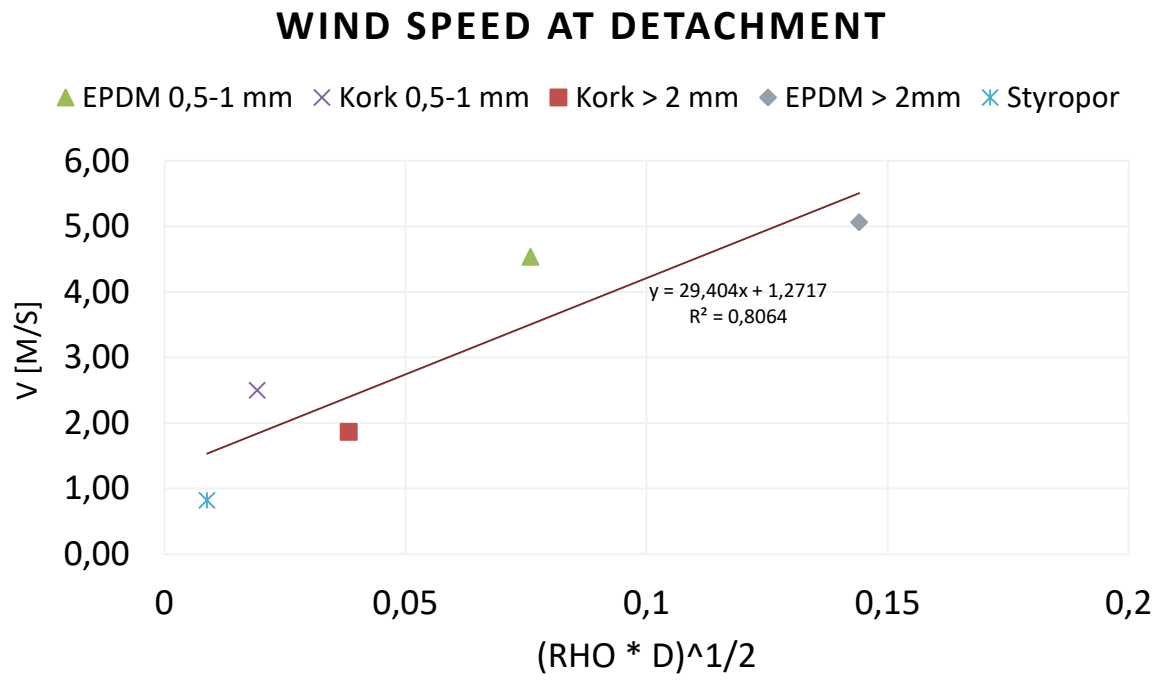
- **Modelling Transfer**
  - **wind, stormwater, surface characteristics**
  - **size, shape, density of plastic emission**



Residence Time

» **Surface Degradation Rate**

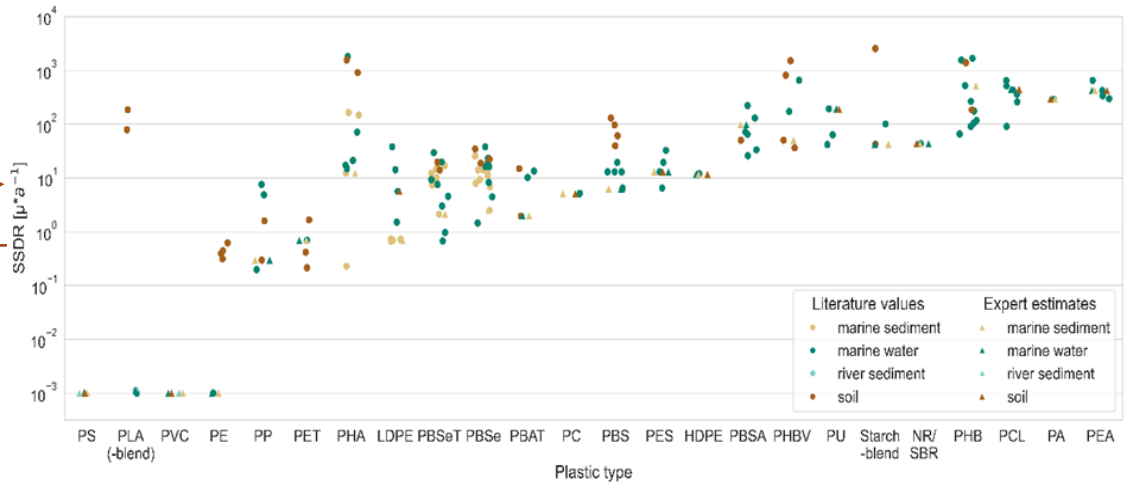
$$v_d = \frac{1}{2}\frac{d_0}{t}\left(1 - \sqrt[a]{1 - \frac{\Delta m}{m_0}}\right)$$

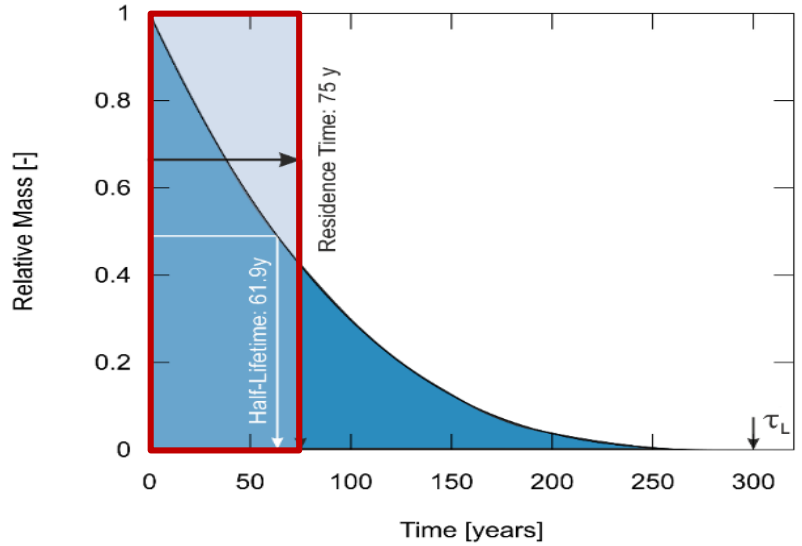
size

$$\tau_L = \frac{d_0}{2\, v_d}$$

$$\tau_R = \int_0^{\tau_L} \left(1 - \frac{t}{\tau_L}\right)^a dt = \frac{1}{a+1}\tau_L$$

shape

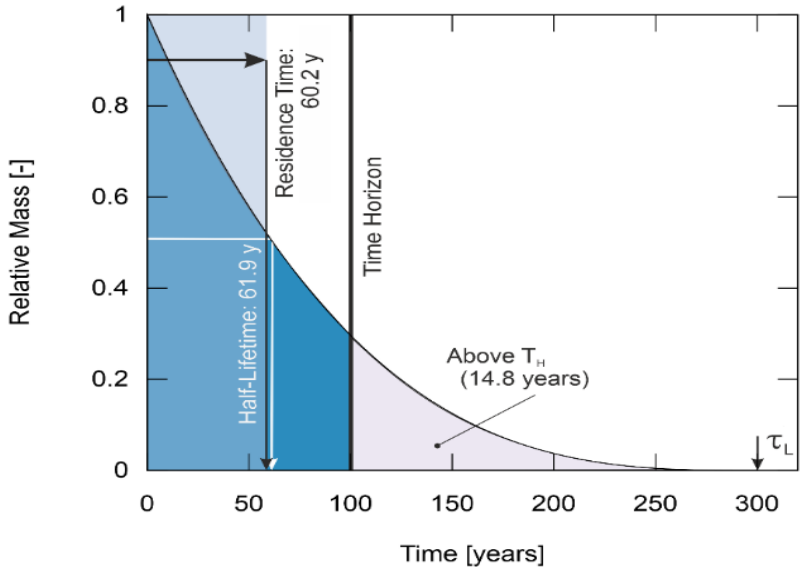




Reference Time and Time Horizon

» Time Horizon

- 100 years (3 generations)
- Very slow degrading polymers can be set to 100 years



» Reference Time

- 1 year (readily degradable)
- All plastic emissions that have a longer residence time therefore receive a higher PPE

Plastic Pollution Equivalent (PPE)

» Interpretation of the PPE

- Virtual Mass considering the persistence
- measured in kg_{PPE} (analog to $kg_{-CO2-eq}$)




» Examples (Data for illustration only)

• Driving a car (15.000 km, 110 mg/km):	1.650 g NR/SBR	16,5 kg_{PPE}
• Sanding of an outer door without dust collection	10 g Acrylates	0,5 kg_{PPE}
• 1 Coil of thread for a lawn trimmer:	100 g PA	5,1 kg_{PPE}
• 1 year of cosmetics with microbeads:	12 g PE	1,1 kg_{PPE}
• Littering of 10 Coffee-to-go.Disposable Cups:	150 g PS	13,5 kg_{PPE}
• Littering of 10 Coffee-to-go Biodegradable Cups:	150 g PHB/Cellulose	0,2 kg_{PPE}

Plastic Pollution Budget (PPB)

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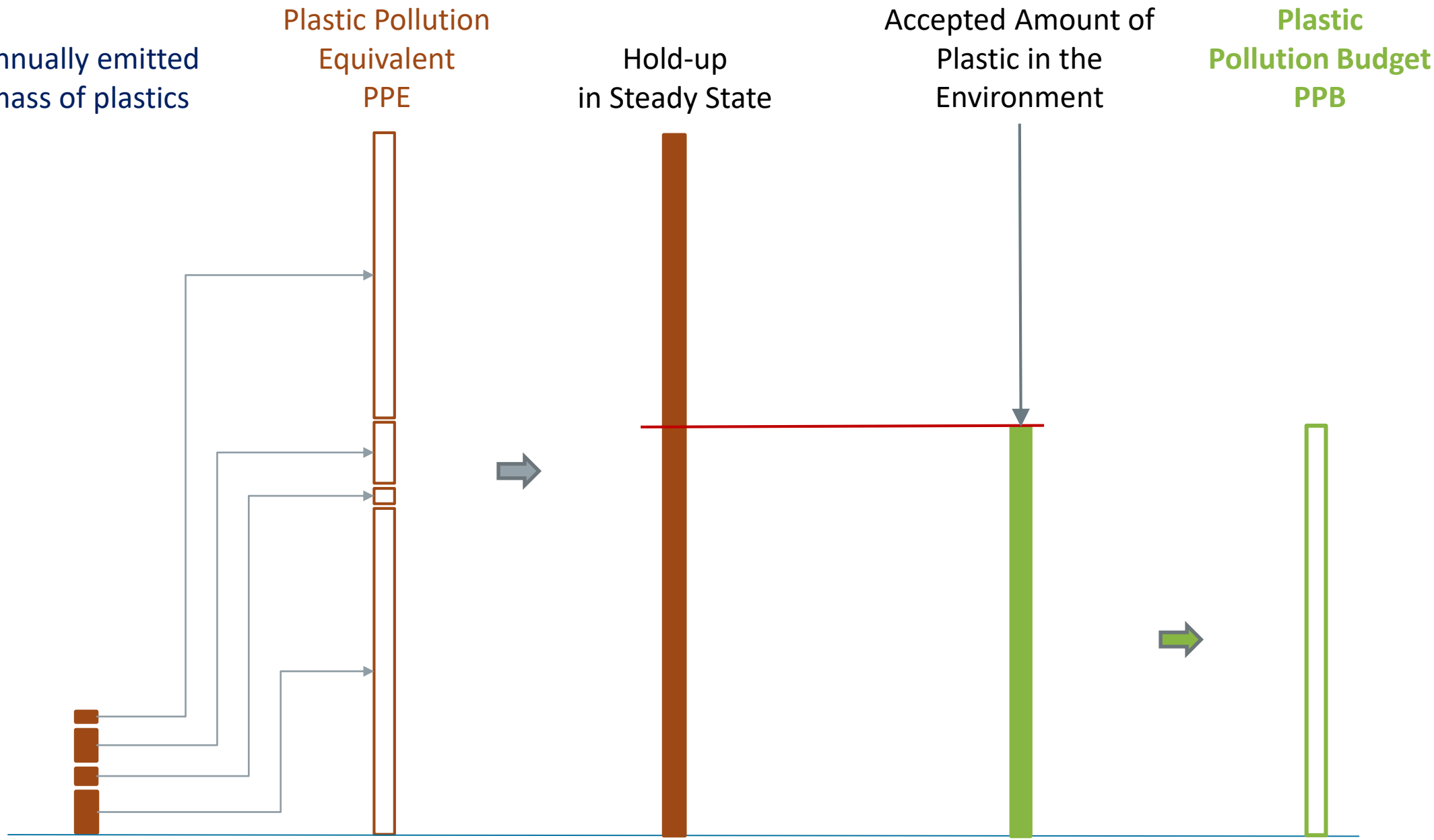
» Interpretation of the PPE

- Virtual Mass considering the persistence
- If the PPE is the anual emission of a practice than it equals to the Hold-Up that results over longer period if the practice continues (steady state).

» Derivation of the PPB

- If the PPB is based on the accepted hold-up of plastic in the environment, than it equals to the annually acceptable PPE


Annually emitted mass of plastics
Plastic Pollution Equivalent PPE
Hold-up in Steady State
Accepted Amount of Plastic in the Environment
Plastic Pollution Budget PPB

What is the acceptable amount of plastic in the environment?

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» **Nothing?**

- Than we must completely ban the use of plastics.

» **Working hypothesis:**

- Today‘s quantity of plastic in the environemt is just about acceptable.
- Jambeck et al. estimated 75-200 million tons in 2015 for the marine environment only
- UNEP estimates additional 710 million tons from 2016 to 2040.
- Considering that already some degradation has occured we estimate:

- **250 million tons**

PPB

- 250 Mt_{PPE}/year globally
- **32 kg_{PPE}/(person year)**
- 2,6 Mt_{PPE}/year Germany

Same emission rights for all

- **In the future, the acceptable quantity and the share of emission rights must be agreed upon in political processes.**

How much is 32 kg_{PPE}?

» **Annual Plastic Pollution Budget (PPB)**

- **32 kgPPE/(person year)**

» **Comparing to Plastic Pollution Equivalent of some practices (PPe)**

• Driving a car	16,5 kg_{PPE}
• Sanding of a outer door without dust collection	0,5 kg_{PPE}
• 1 Coil of thread for a lawn trimmer	5,1 kg_{PPE}
• 1 year of cosmetics with microbeads:	1,1 kg_{PPE}
• Littering of 10 Coffee-to-go.Disposable Cups:	13,5 kg_{PPE}
• **PPE-total**	**36,7 kg_{PPE}**

» **PPE > PPB**

Can we make it?

Szenario	Material share annual PPE [kg_{PPE}/year]				Emitted amount [kg/year] Total annual PPE [kg_{PPE}/year]	Distance to target (32 kg_{PPE}/year]
	Easily degradable PHA, PCL...	medium degradable (NR, PLA…)	little degradable (PES, PA….)	hardly degradable (PO, PS, PVC…)		absolut
„Business as usual“	1 %	34 %	20 %	45 %	← **4,0**	
	0,04	13,6	40	162	→ 215,6	→ +183,6

Yes, we can!

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„Business as usual“	1 %	34 %	20 %	45 %	4,0	
	0,04	13,6	40	162	215,6	+183,6
„Biological turn“	**50 %**	**40 %**	**5 %**	**5 %**	4,0	
	2	16	10	18	46	+14
„Awareness“	1 %	34 %	20 %	45 %	**1,0**	
	0,01	3,4	10	41	54,4	+22,4
„Combined“	**50 %**	**40 %**	**5 %**	**5 %**	**1,0**	
	0,5	4	2,5	4,5	11,5	-20,5
„Balanced“	**35 %**	**40 %**	**20 %**	**5 %**	**1,5**	
	0,6	8	15	18	31,2	**-0,8**

A Circular Plastics Economy has to consider degradability

Wei, R., Tiso, T., Bertling, J. *et al.* Possibilities and limitations of biotechnological plastic degradation and recycling. *Nat Catal* 3, 867–871 (2020)

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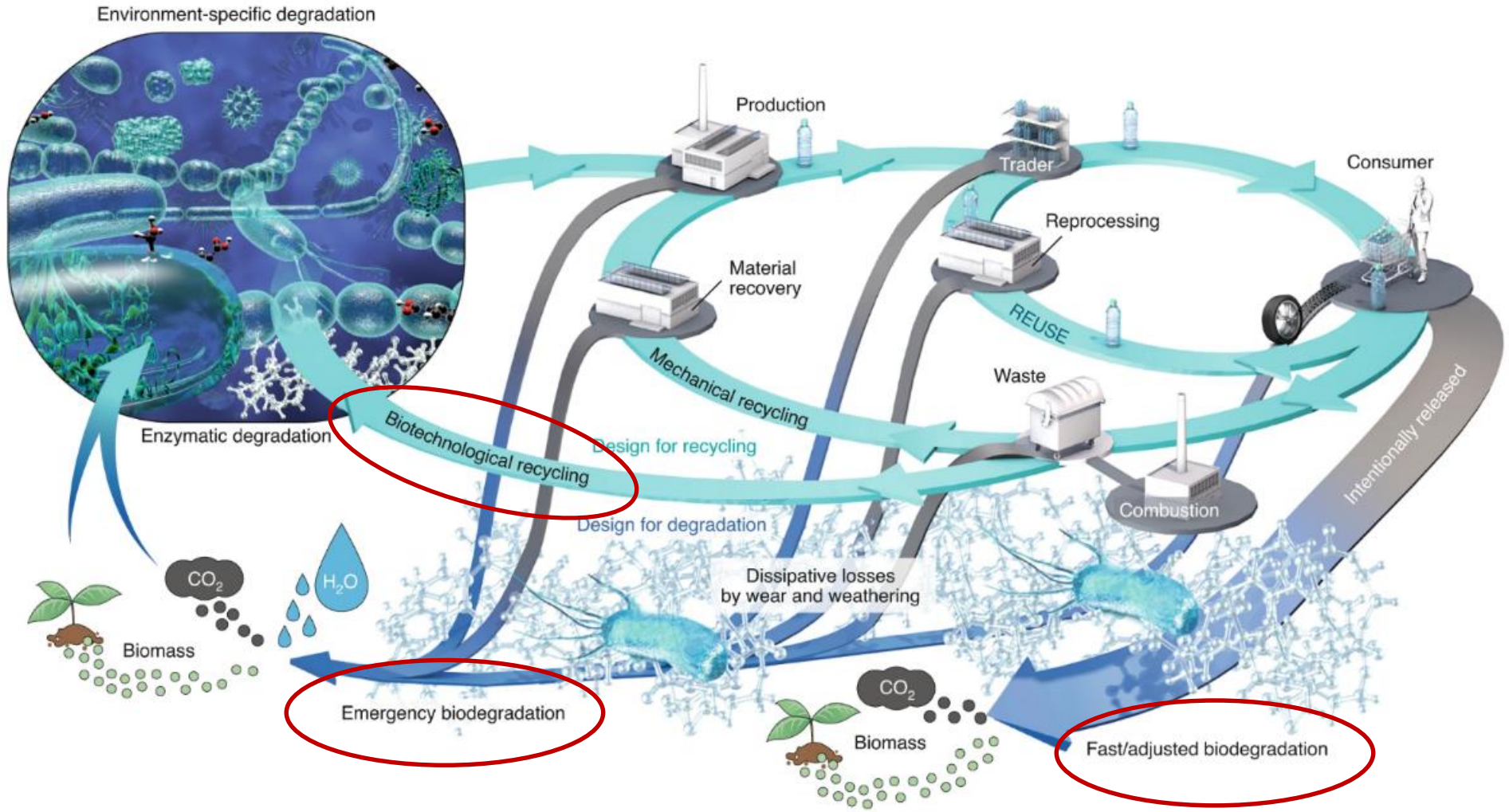


What can PPE and PPB be used for?

» **PPE for Product Labelling**

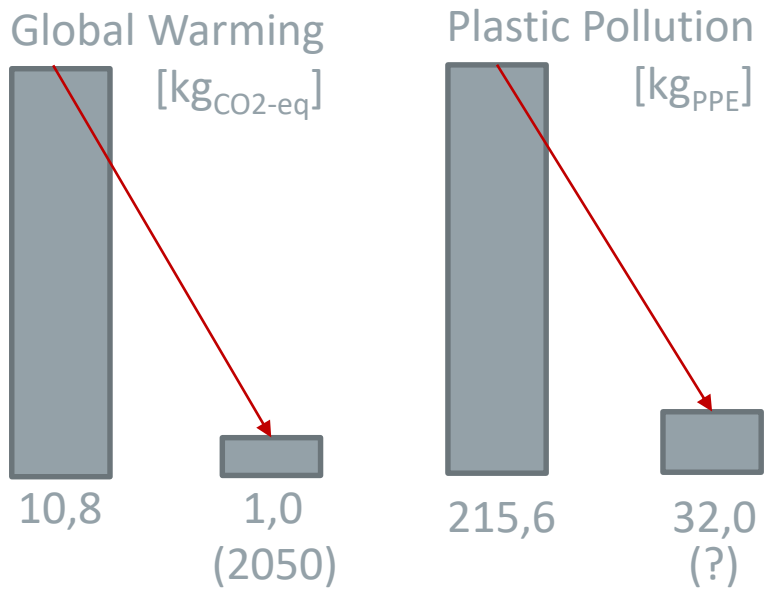
- Making decisions between products like tires (abrasion), textiles (synthetic fibre loss), outdoor paints (weathering),
- Giving information on how much littering a product contributes to the PPB
- Giving pressure to better degradable alternatives
- Implementation of a pollution depending tax or fee (-> dual systems)

» **PPE-Integration in LCA (**Int. Jour. of Life Cycle Assessment; https://doi.org/10.1007/s11367-022-02040-1)

- Plastic losses are not covered today
  (-> Losses reduce impact in other categories)
- Holistic assessment possible to show conflicts)
  (e. g. Global warming vs. Plastic emissions)

» **PPB for defining reduction targets**

- For nations
- For branches
- For companies
- For individuals



What we need?

- More accurate quantification of losses (by polluters)
- Determinaton of transfer paths/fraction (by science)
- Degradation test in real environment and simulation tools especially for hardly degrading polymers (by
- Expansion to other polymers (soluble polymers, modified natural fibers, paper, viscose, cotton)

- A political initiative and incentives to transform PPE into measures against plastic pollution.

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Thank you for your attention!

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