Bioeconomics
25. Japanese-German Symposium
Japan Society for the Promotion of Science and Deutsche Gesellschaft der JSPS-Stipendiaten e.V.

Opportunities and limits of a bio-economy as an integral part of the Circular Economy

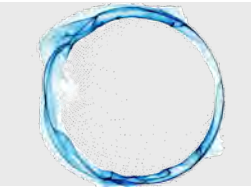
– or how to get plastics circular

Photo: Maarten Siebel

Vera Susanne Rotter

Technische Universität Berlin
Professor Circular Economy and Recycling Technologies

Opportunities and limits of a bio-economy as an integral part of the Circular Economy – or how to get plastics circular?



Guiding principles for the circular economy

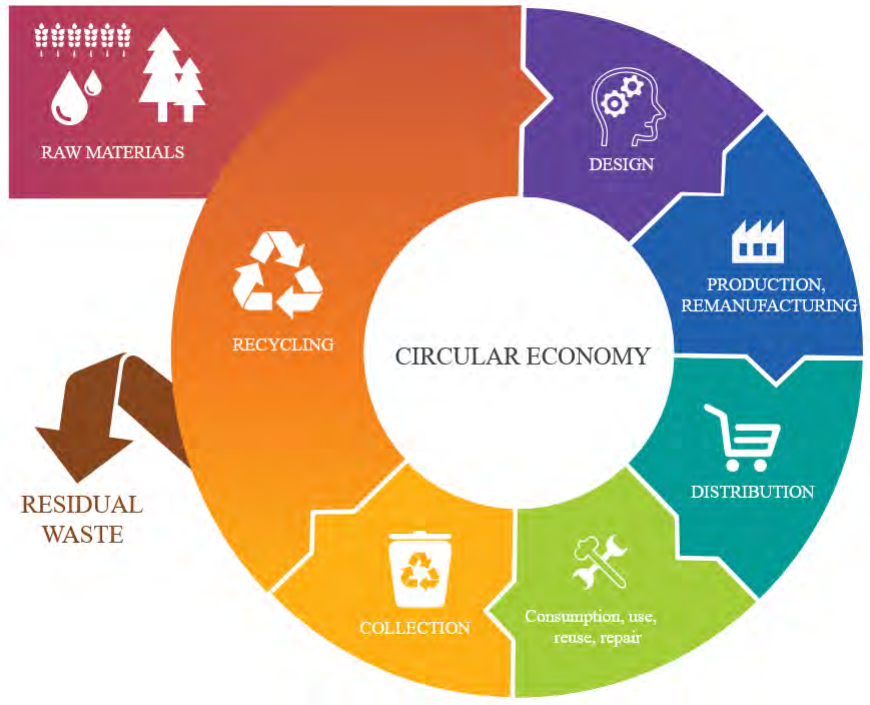
Plastics - an environmental threat?

Alternatives for the management of plastics in the circular (bio) economy

Prevention - … or why less could be more

Guiding principles for the circular economy

EU Definition CE



The **circular economy (CE)** is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended.

https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits

Concepts of circular economy

The term circular economy (Kreislaufwirtschaft) is anchored in German waste legislation since 1996

- Abf-KrWG (1996)
  - Keine Definition
  - § 4 Grundsätze der Kreislaufwirtschaft
    - (1) Abfälle sind

besondere durch die Verminderung ihrer Menge und

In 2012 term „waste“ was abolished in German waste legislation

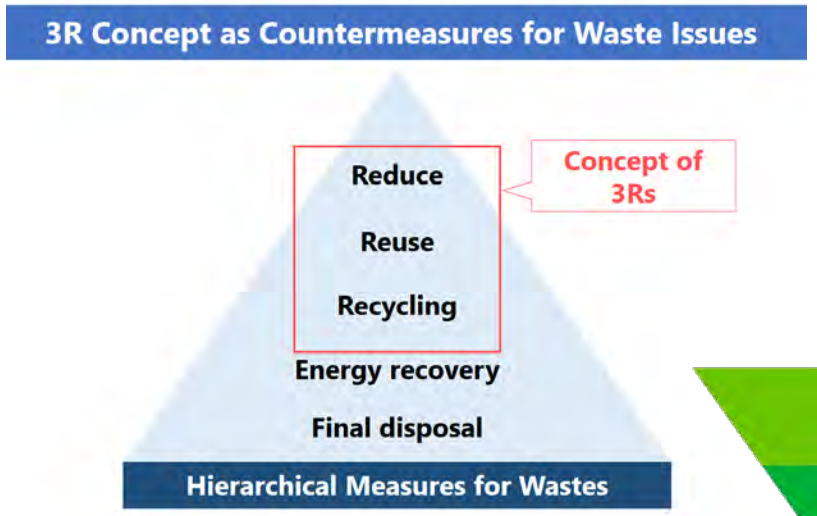
zur Gewinnung von Energie zu nutzen (er

The term circular economy is defined as “waste prevention” and “recycling” according to the German waste law

- KrWG (2012)
  - § 3 Begriffbestimmungen

    (19) Kreislaufwirtschaft im Sinne dieses Gesetzes sind die Vermeidung und Verwertung von Abfällen

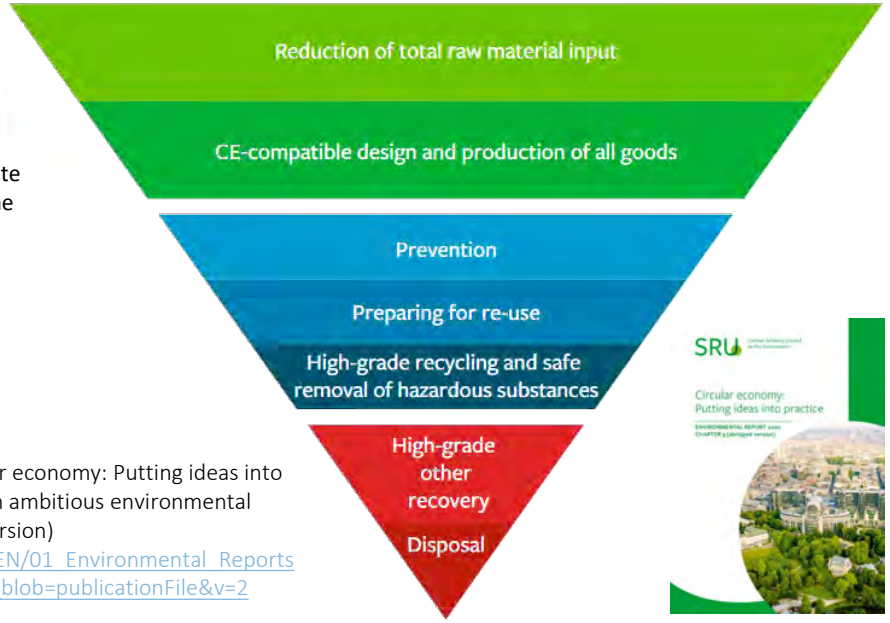
3R, the Waste Hierarchy and Zero Waste



Shinichi Sakai (Kyoto University) Background and Scope of 2nd State of 3R 10th Regional 3R and Circular Economy Forum in Asia and the Pacific WEBINAR 17th December 2020

"**Zero Waste:** The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health."
Zero Waste International Alliance, 2018

https://zwia.org/zero-waste-definition/



German Advisory Council on the Environment Circular economy: Putting ideas into practice ENVIRONMENTAL REPORT 2020 "Towards an ambitious environmental policy in Germany and Europe chapter 3 (abridged version)
https://www.umweltrat.de/SharedDocs/Downloads/EN/01_Environmental_Reports/2021_01_environmental_report_chapter_03.pdf?__blob=publicationFile&v=2

Photo: Vera Susanne Rotter

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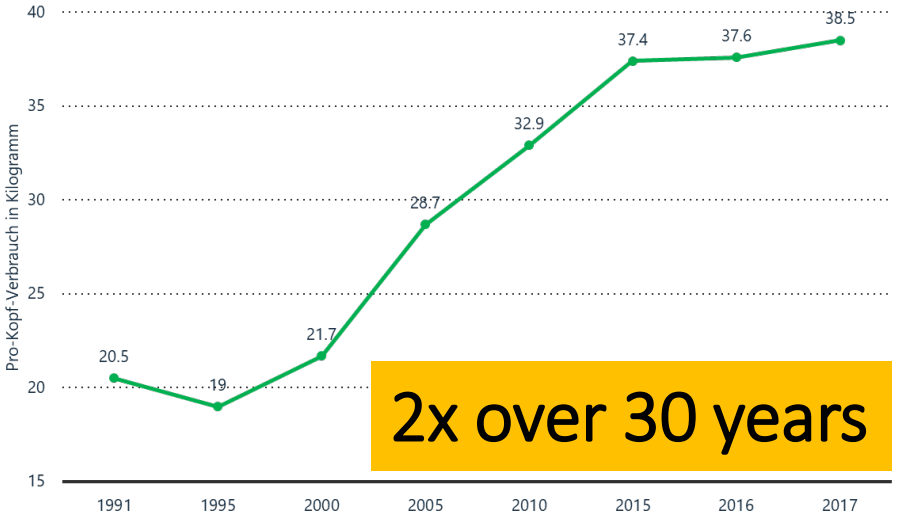
Plastics –
an environmental threat?

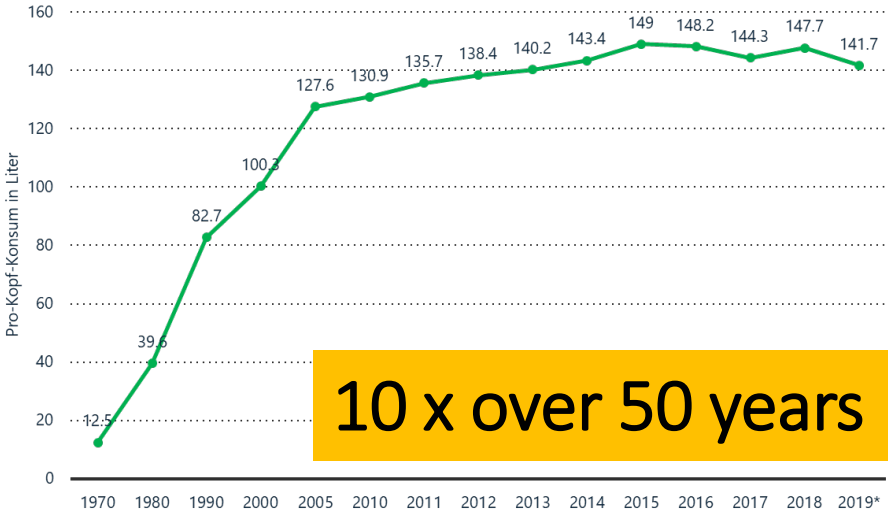
The flow rise

Plastic packaging materials –
per capita use in Germany 1991-2017



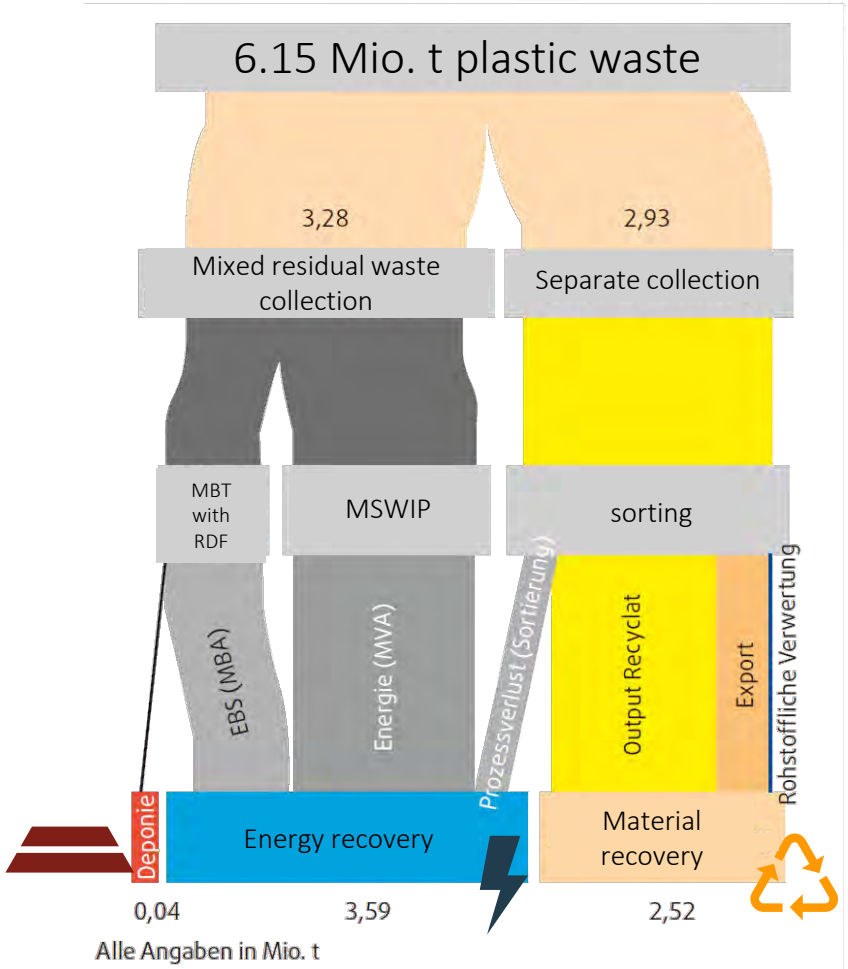
Quelle(n): GVM; ID 914363

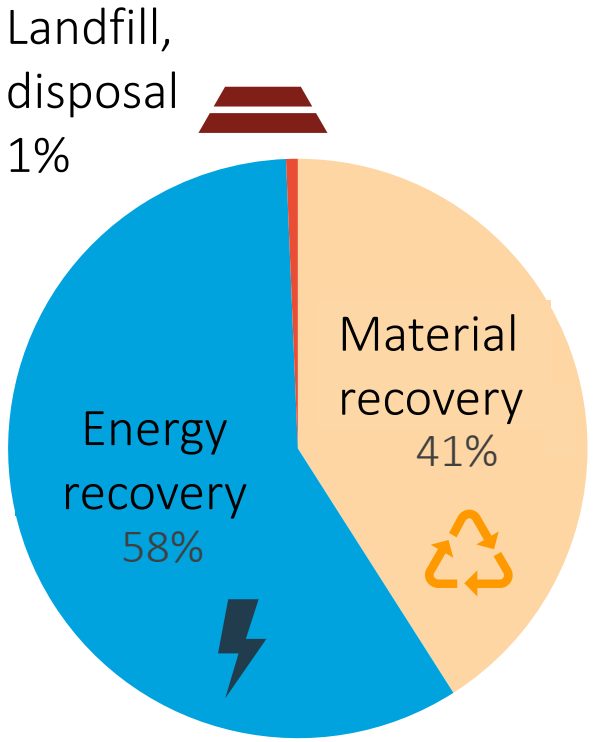
Mineral water -
Per capita consumption in Germany 1970-2019



Quelle(n): Verband Deutscher Mineralbrunnen; ID 2809

Material flows plastic waste in Germany 2017



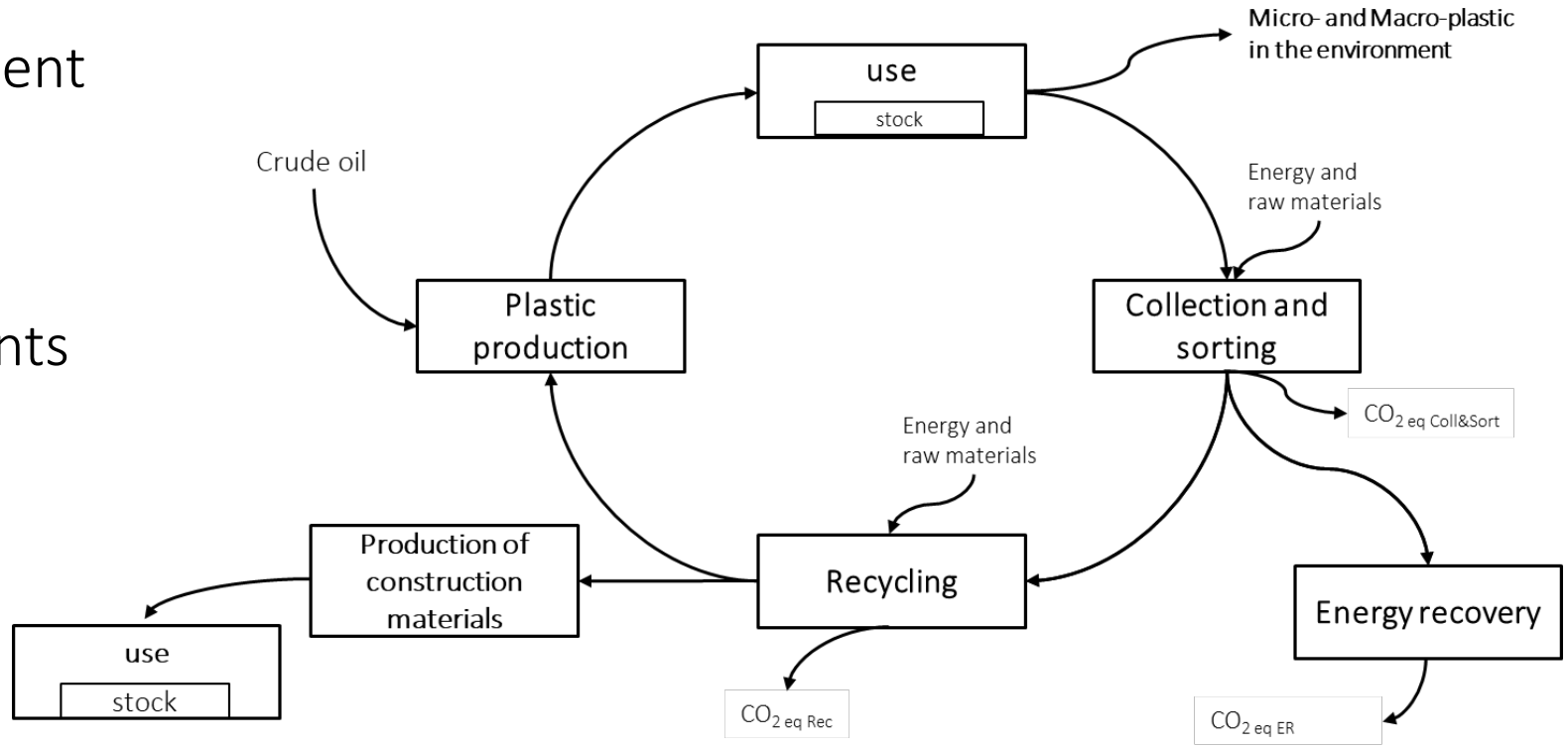


Datenquelle Conversio 2018, Neuberechnung der Verwertungsquoten auf Basis „Anlagenoutput“

Quelle: Baron, Sperlich, Rotter (2020) Ersetzt die hochwertige Verwertung die Vermeidung? Eine Betrachtung des Stoffstroms Kunststoffe, Müll und Abfall 9 ·20 Seite 440-450

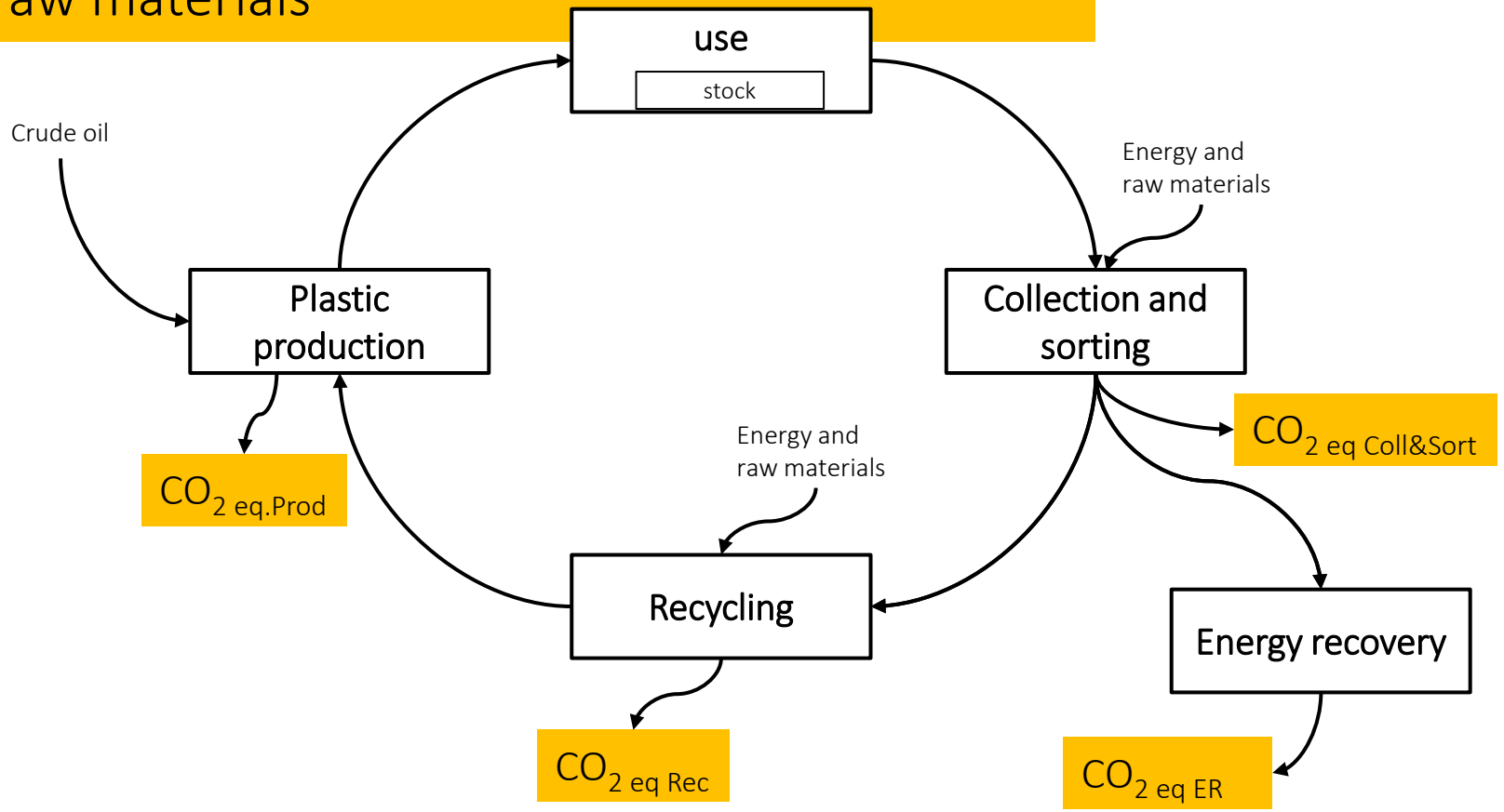
Challenges along the life cycle

- Climate impacts
- Plastics in the environment
- Downcycling
- Accumulation of polutants



Plastics and climate impacts

Energy intensive production, logistic and combustion of fossil raw materials



Plastics and climate impacts

	Emission factor combustion kg_{CO2}/ kg_{KS}	Emission factor production $kg_{CO2Eq.}$/ kg_{KS}
High Density Polyethylene (HDPE)		1.8[2]
Low Density Polyethylene (LDPE)	3.1 [1]	1.9[2]
Linear Low Density Polyethylene (LLDPE)		1.8[2]
Polypropylene (PP)	3.1[1]	1.6[2]
Polystyrene (PS)	3.4[1]	2.4[2]
Polyethylene (PET)	2.3[1]	2.2[2]
Polyvinyl Chloride (PVC)	1.4[1]	2.0[2]
average emission factor plastics mix [3]	2.7	2.5
End use plastics 2017 [t][4]		1.18*10[7]
Incinerated amount 2017 [t][4]		3.29*10[6]
Indirect emissionen production of plastics for enduse tCO_2 Eq. per annum]		2.95*10[7]
Direct emissions from combustion [tCO_2 Eq. per annum]		8.89*10[6]

Quelle: Baron, Sperlich, Rotter (2020) Ersetzt die hochwertige Verwertung die Vermeidung? Eine Betrachtung des Stoffstroms Kunststoffe, Müll und Abfall 9 ·20 Seite 440-450

Assumption: mode of plastics management does not change (business as usual scenario),

Consequence: cumulated emissions approx. 290 Mio. t von 2020 bis 2050

→ 3,7 % of the remaining carbon budget (1,75 °C target) will be used

Plastics in the environment

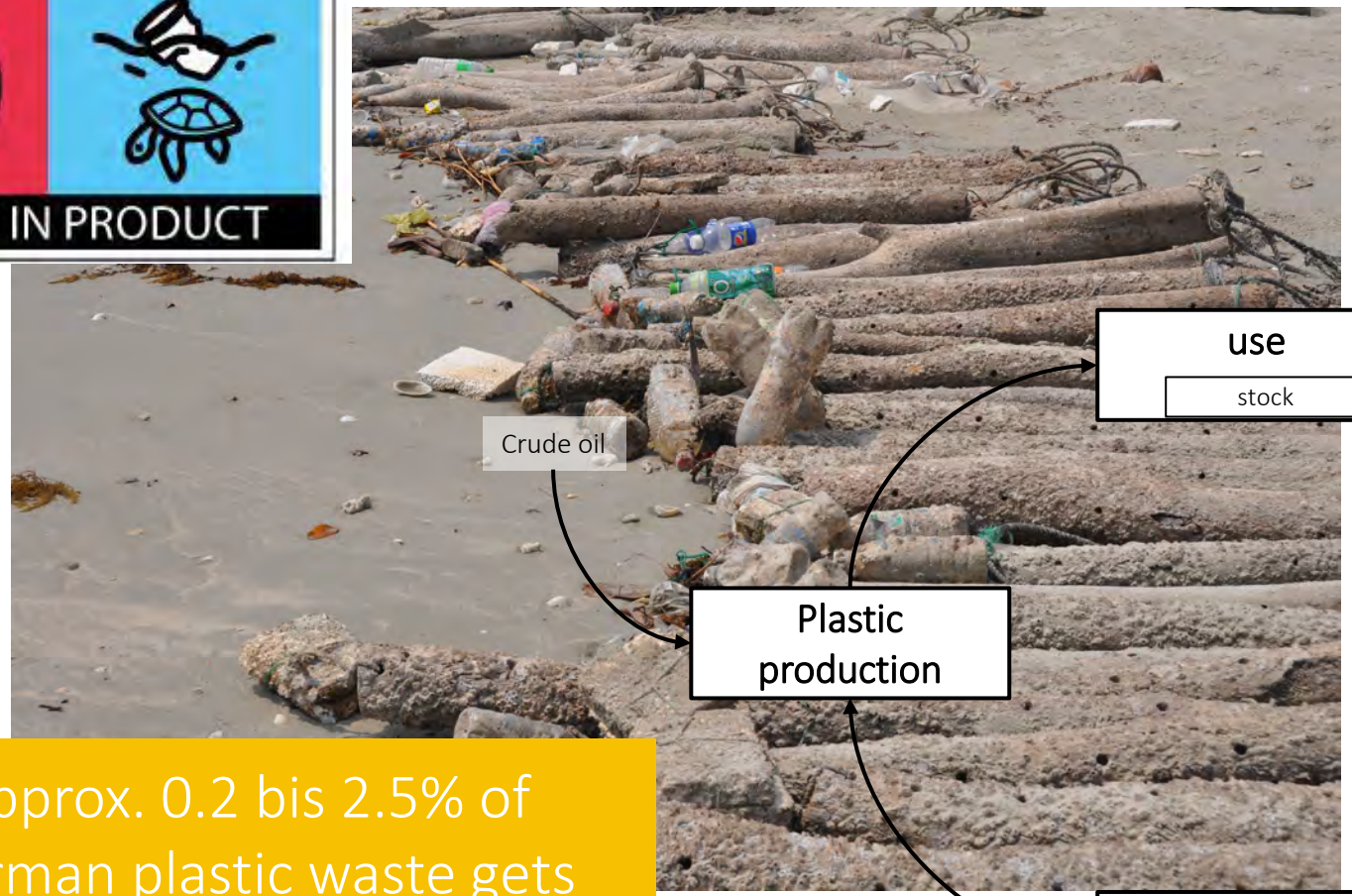
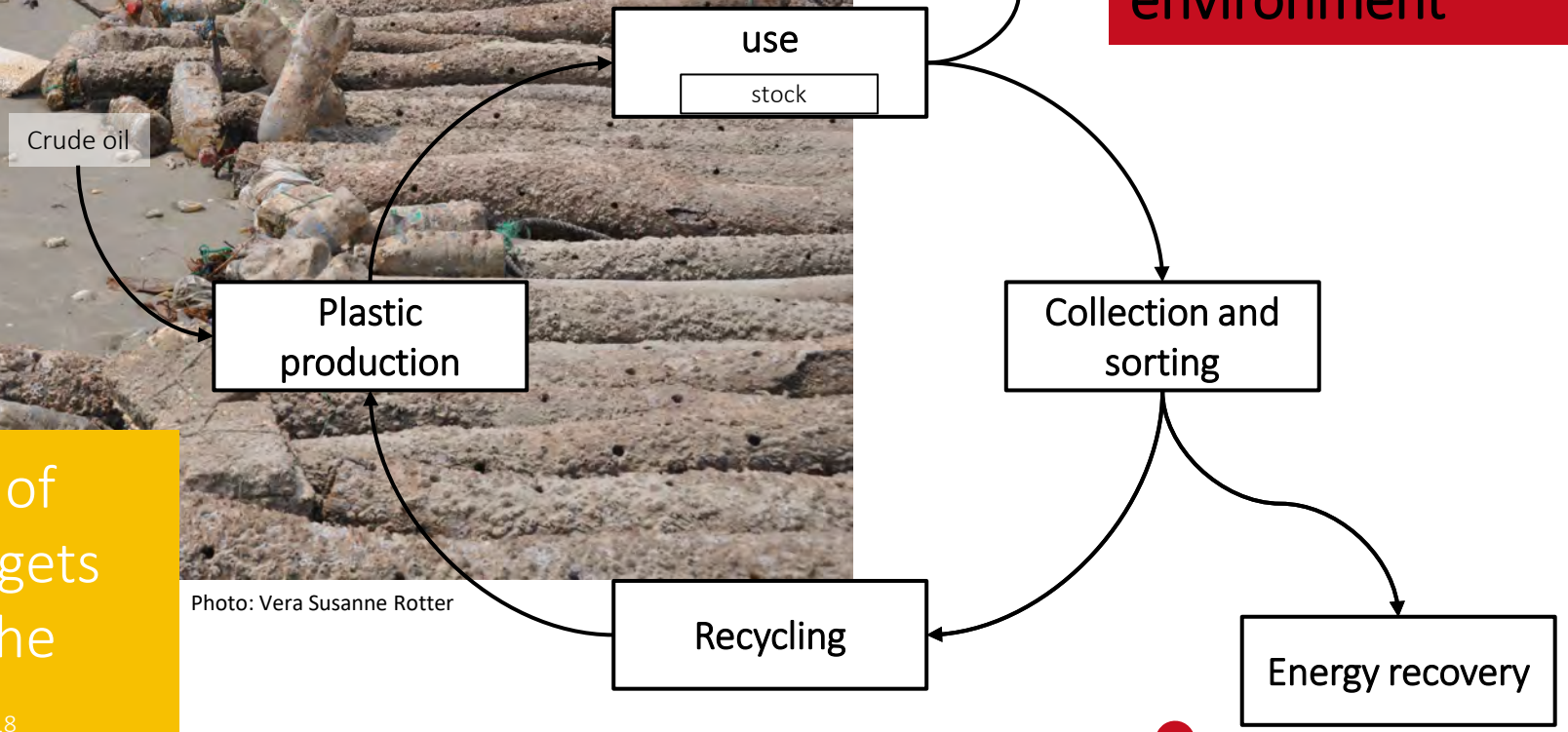


Photo: Vera Susanne Rotter

Micro- and Macro-plastic in the environment



approx. 0.2 bis 2.5% of German plastic waste gets through littering in the environment Umsicht, 2018

Challenges along the life cycle

Photo: Vera Susanne Rotter

Crude oil

use
stock

Plastic production

Collection and sorting

Downcycling?

Energy recovery

Recycling

Production of construction materials

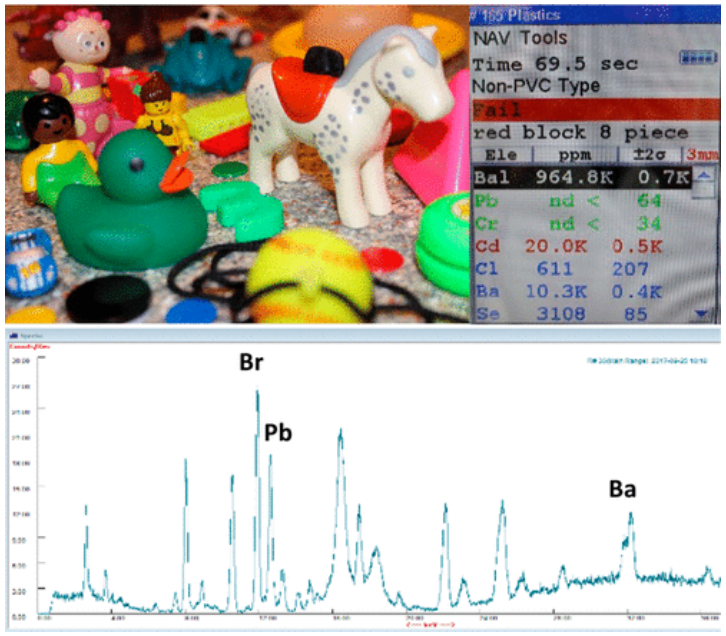
use
stock

?

Construction material substitutes

Circularity of products in cascade use is doubtful

Challenges along the life cycle



Andrew Turner
Environmental Science & Technology 2018 52 (5), 3110-3116
DOI: 10.1021/acs.est.7b04685

Missing sequestration of pollutants and sink function of recycling processes

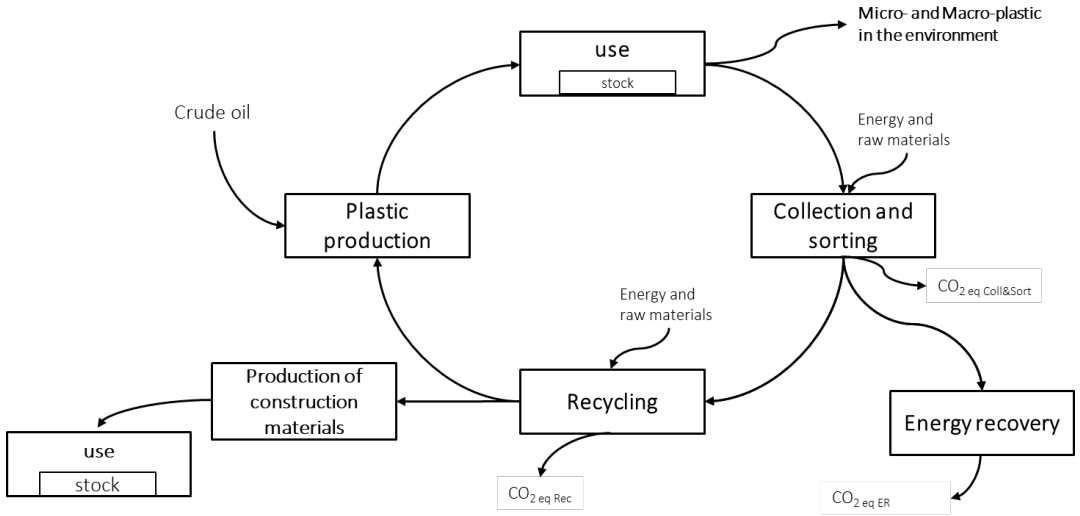
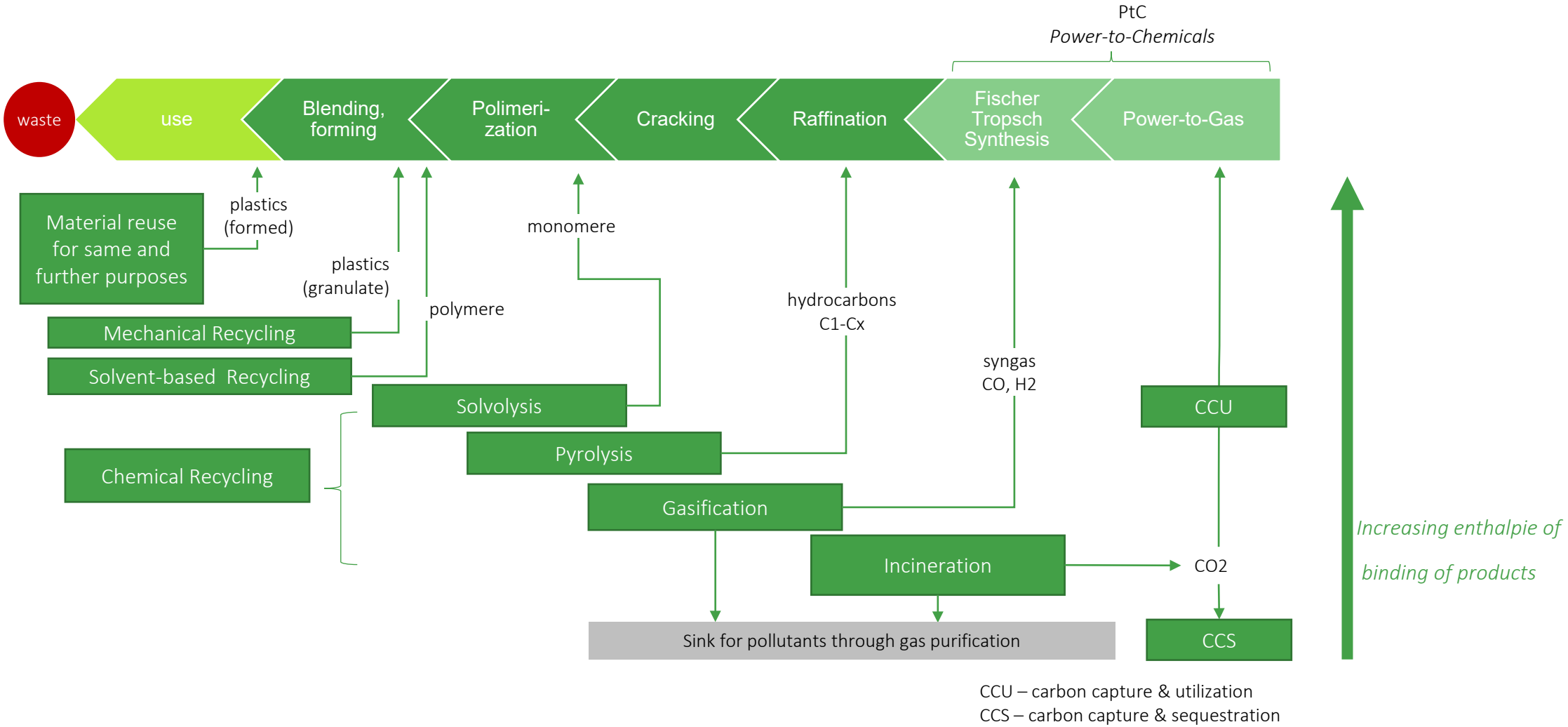


Photo: Vera Susanne Rotter

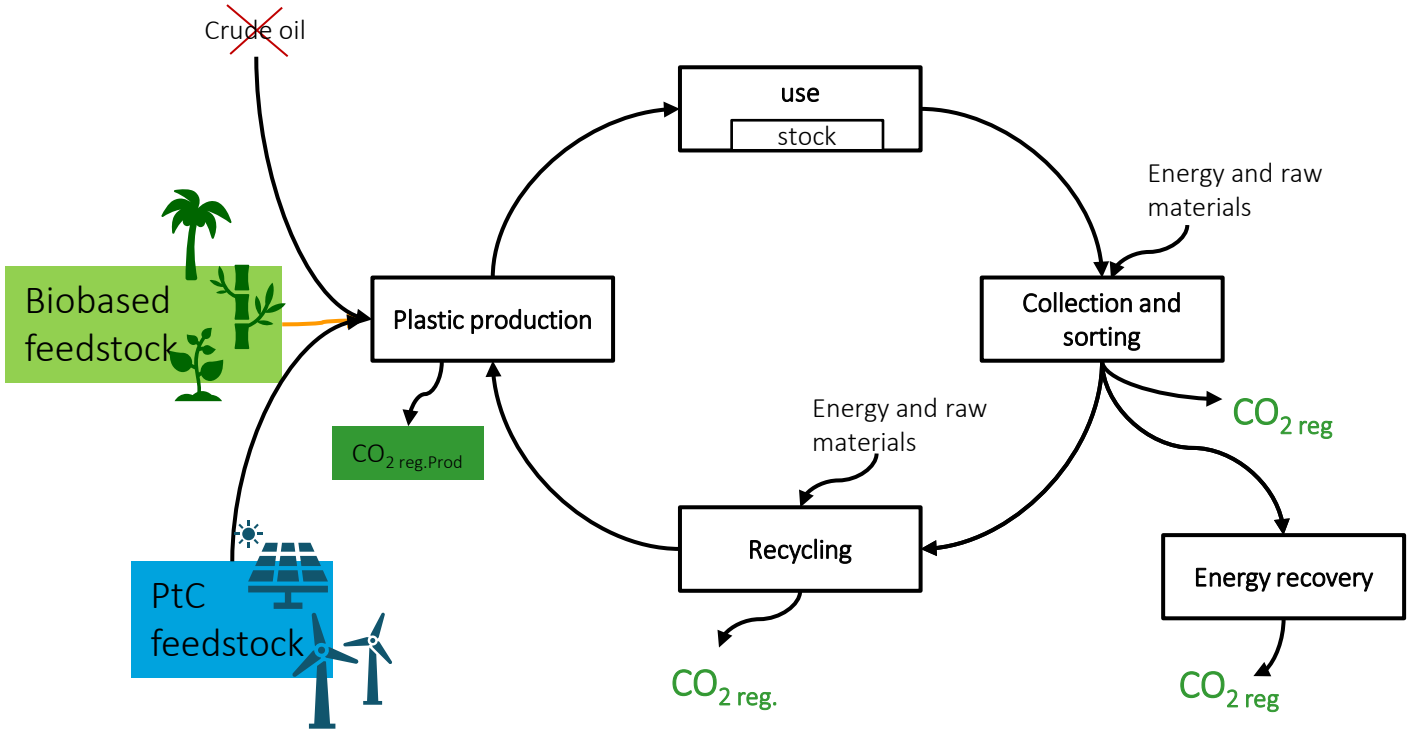
Alternatives for the management of plactics …solutions for a problem

Comparison of recycling options

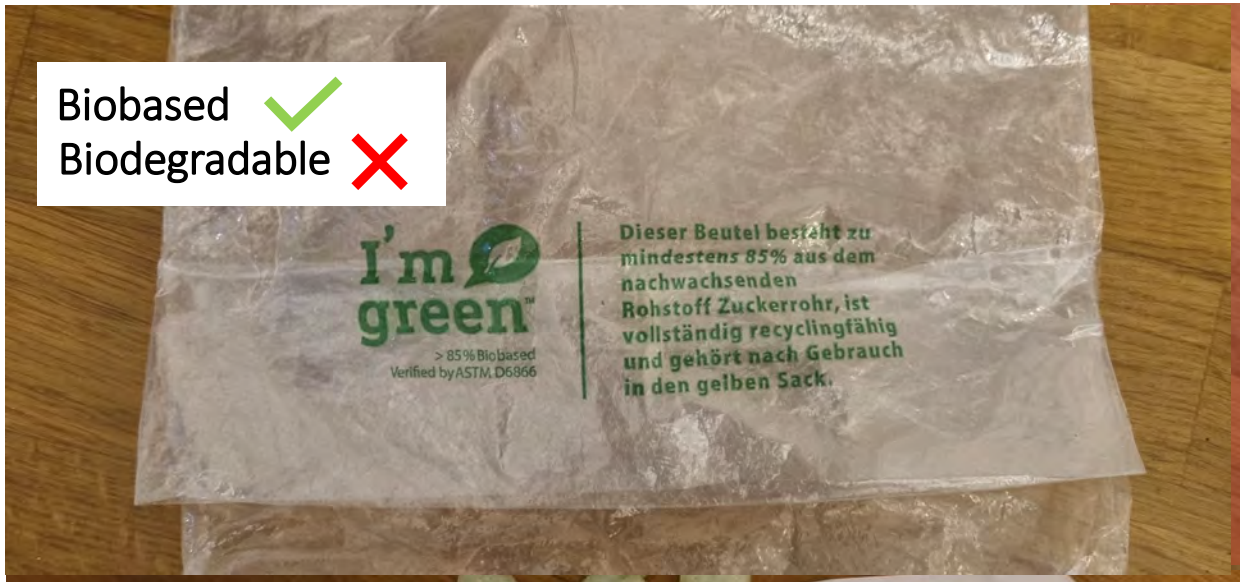


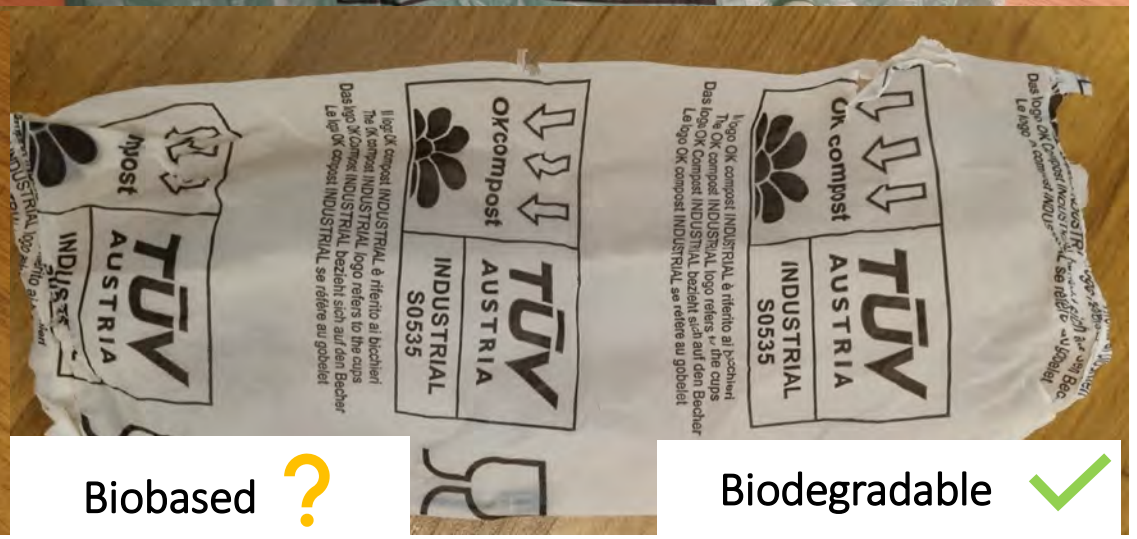
Quelle: Baron, Sperlich, Rotter (2020) Ersetzt die hochwertige Verwertung die Vermeidung? Eine Betrachtung des Stoffstroms Kunststoffe, Müll und Abfall 9 ·20 Seite 440-450

Alternative feedstock - Bioplastics



Alternative feedstock - Bioplastics





Alternative feedstock – are bioplastics circular?

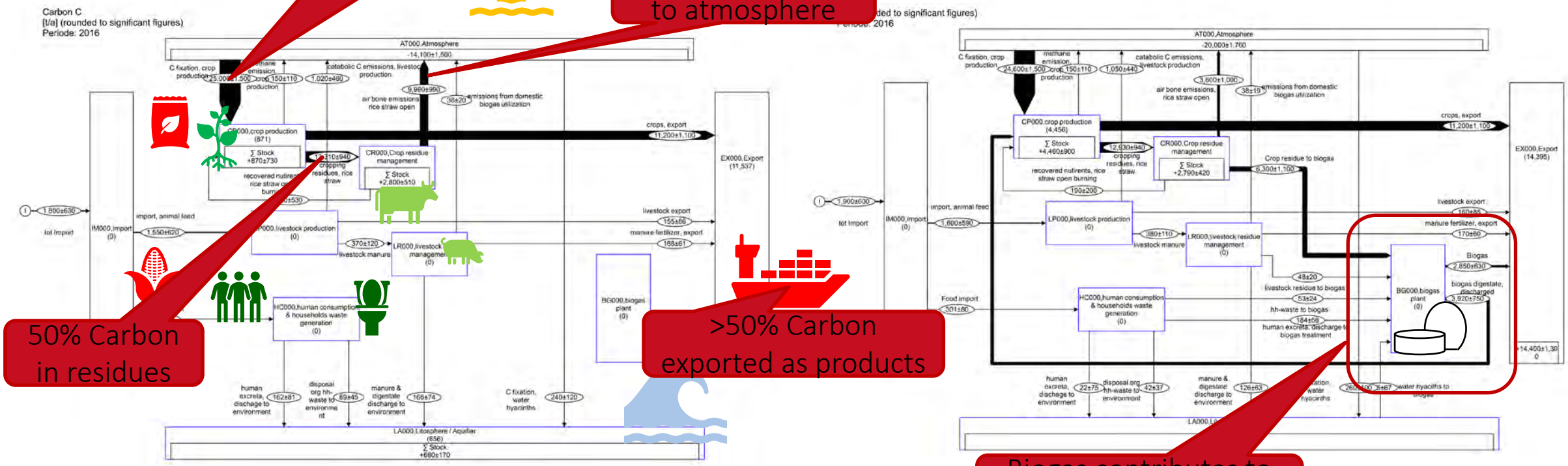
Alternative feedstock – are Bioplastics circular?

MFA of agro-food systems case Hậu Mỹ Bắc B - Tiền Giang province, VN

Carbon C [Mg/a]

Carbon capture through crop farming

45% Carbon lost to atmosphere



50% Carbon in residues

>50% Carbon exported as products

Biogas contributes to carbon sequestration

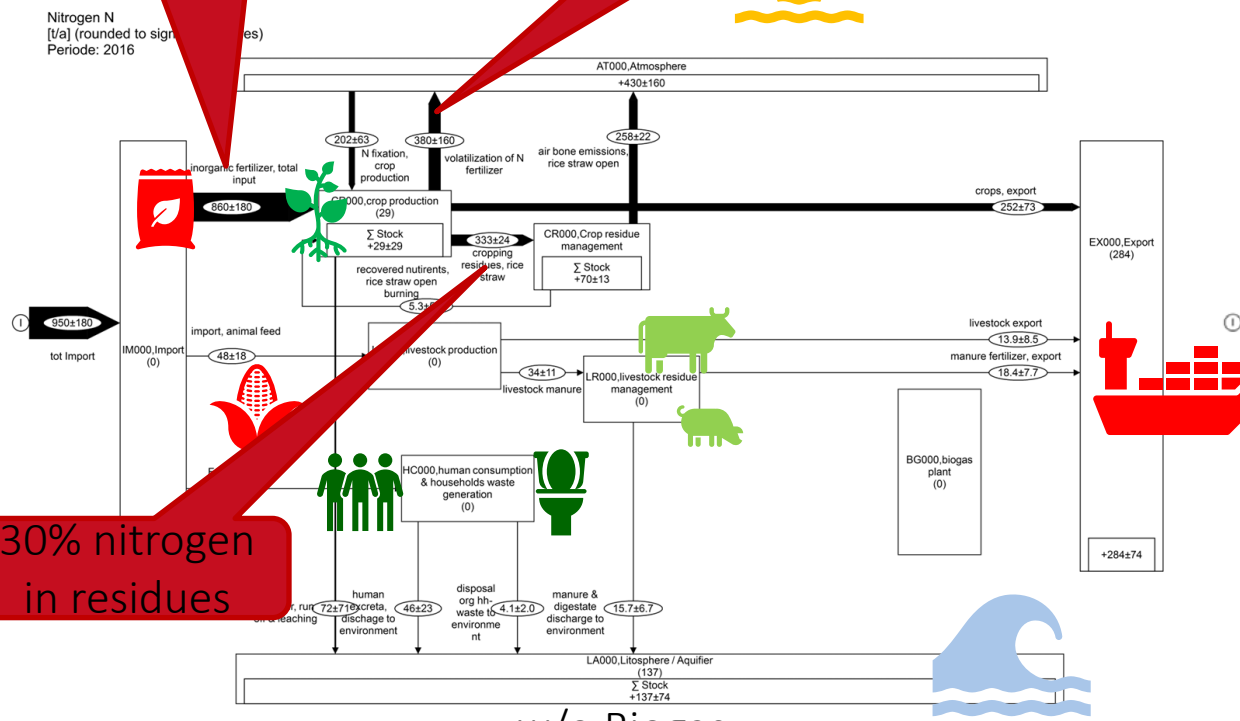
Alternative feedstock – are Bioplastics circular?

MFA of agro-food systems case Hậu Mỹ Bắc B - Tiền Giang province, VN

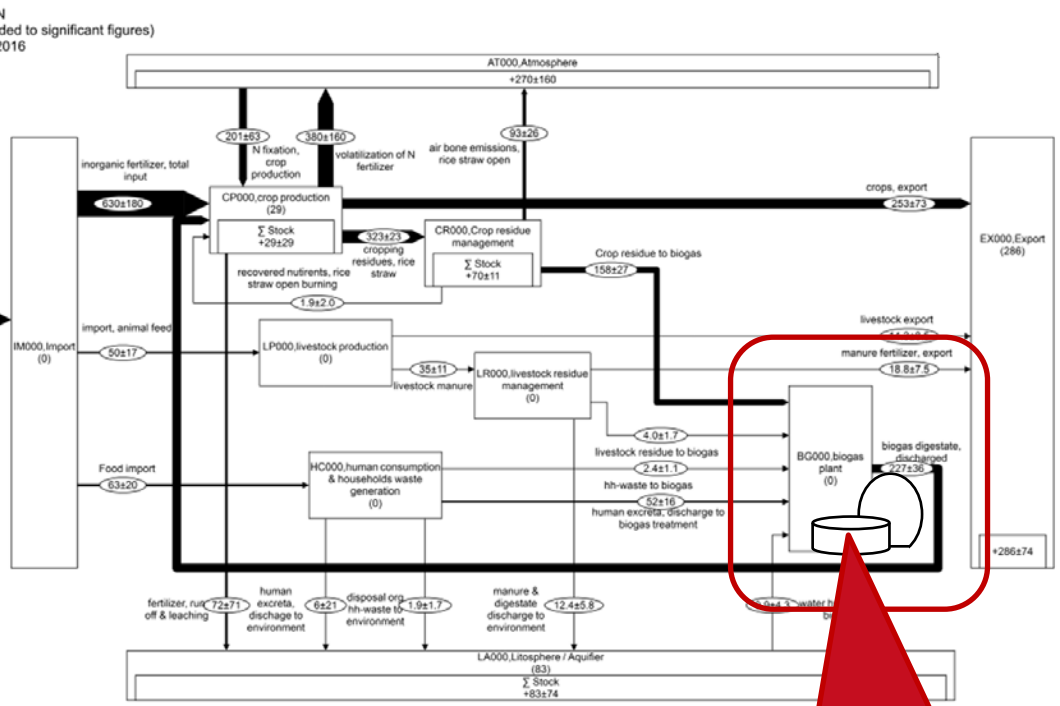
Nitrogen imported as mineral fertilizer

~ 40% nitrogen lost to atmosphere

30% nitrogen in residues



w/o Biogas



w Biogas

Biogas contributes to N 20 % recirculation

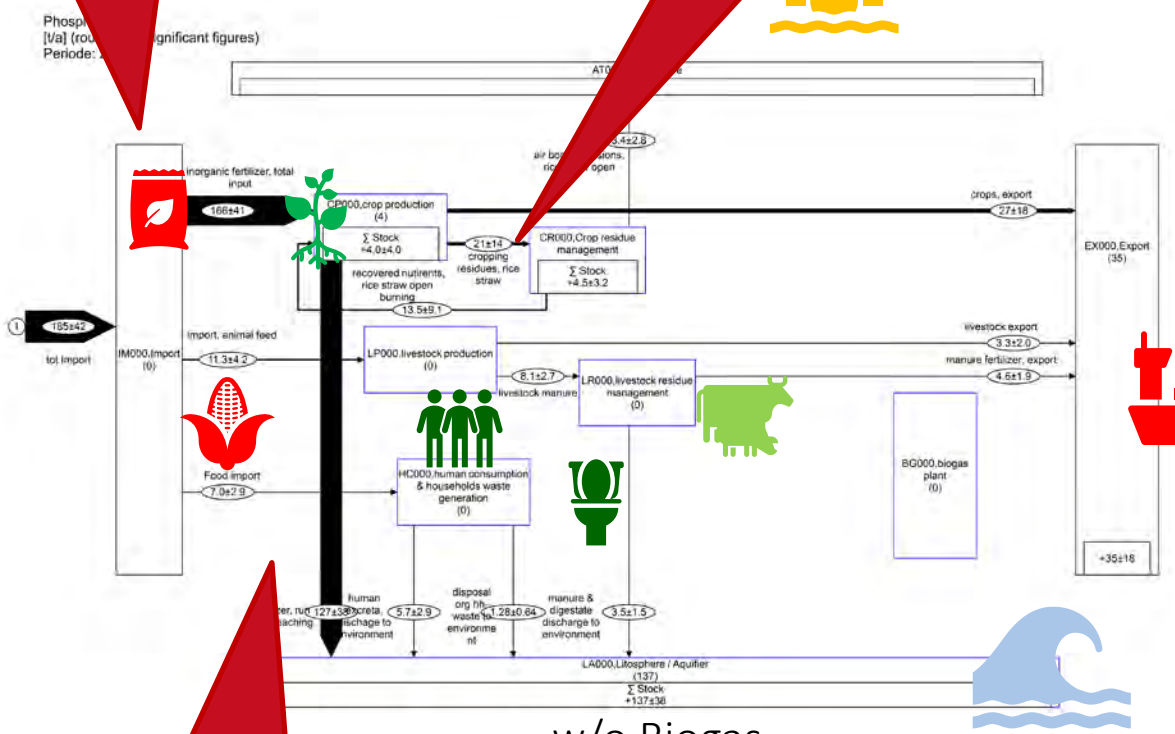
Alternative feedstock – are Bioplastics circular?

MFA of agro-food systems case Hậu Mỹ Bắc B - Tiền Giang province, VN

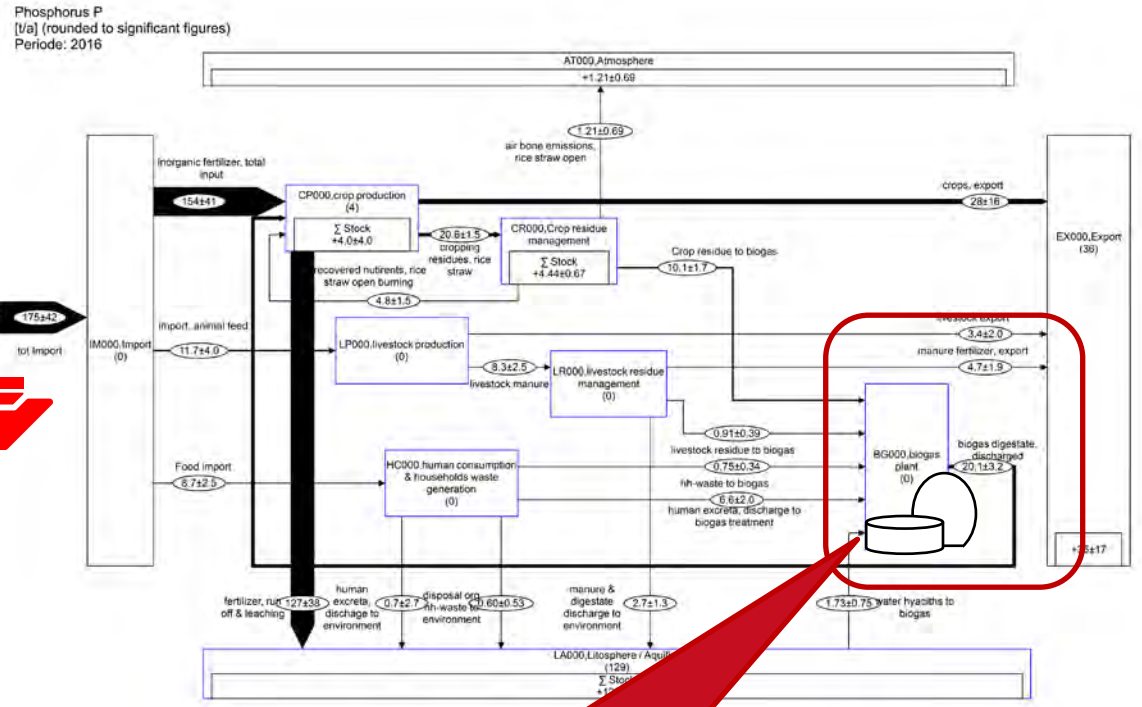
Phosphorous imported as mineral fertilizer

~10% P in crop residues

P horous N [Mg/a]



w/o Biogas



90% P loss to water

Biogas contributes to 10 % P recirculation

Alternative feedstock – are bioplastics scalable?

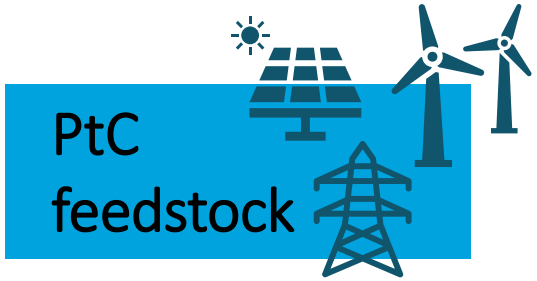
Substitution potential and resulting land use in Germany

Plastics produktion (virgin material)	in kt 1)	Theoretical land use in ha 2)				
	2017	Sugar cane	Sugar beet	Corn Maize	Potatoes	Wheat
PE-LD/LLD	1630	749,800	700,900	1,646,300	1,874,500	4,417,3
PE-HD/MD	1340	616,400	576,200	1,353,400	1,541,000	3,631,4
PP	2250	1,080,000	1,035,000	2,385,000	2,700,000	6,390,0
PS	135	64,800	62,100	143,100	162,000	383,4
PS-E	455	218,400	209,300	482,300	546,000	1,292,2
PVC	1640	287,000	270,600	615,000	697,000	1,656,4
PA	670	214,400	207,700	475,700	542,700	1,279,7
other Thermoplasts	1705	511,500	477,400	1,125,300	1,261,700	3,000,8
other plastics	1190					
Total	**11.015**	3,742,300	3,539,200	8,226,100	9,324,900	22,051,200
	Share of the total crops cultivation area 2017 3)	~	900%	1963%	3596%	748%

To substitute 100% of the todays plastics production requires 10% of the todays arable land

1) Plastics productionin 2017 in Germany according to Conversio, 2017 https://www.bvse.de/images/news/Kunststoff/2018/181011_Kurzfassung_Stoffstrombild_2017.pdf
2) Land use requirements per t of polymereaccording to IfBB – Institute for Bioplastics and Biocomposites
3) Area of cultivation 2017 according to Destatis Area under cultivation (field crops and grassland): Germany, years, types of crops https://www-genesis.destatis.de/genesis/online?language=en&sequenz=statistikTabellen&selectionname=41241#abreadcrumb

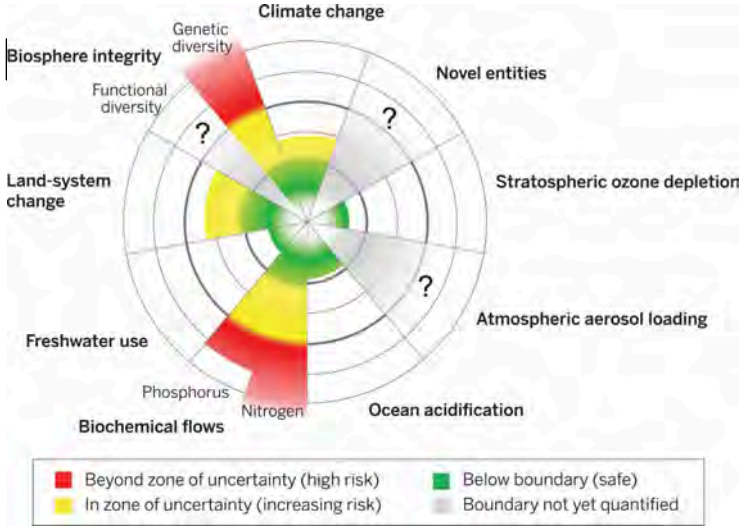
Alternative feedstock - Bioplastics



Resource scarcity

- Land
- Water
- Raw materials
- Biodiversity

Current status of the control variables for seven of the



The green zone is the safe operating space, the yellow represents the zone of uncertainty (increasing risk), and the red is a high-risk zone.

W. Steffen et al .,Science347, 1259855 (2015). DOI: 10.1126/science.1259855

Opportunities and limits of a bio-economy - Plastics in the circular economy

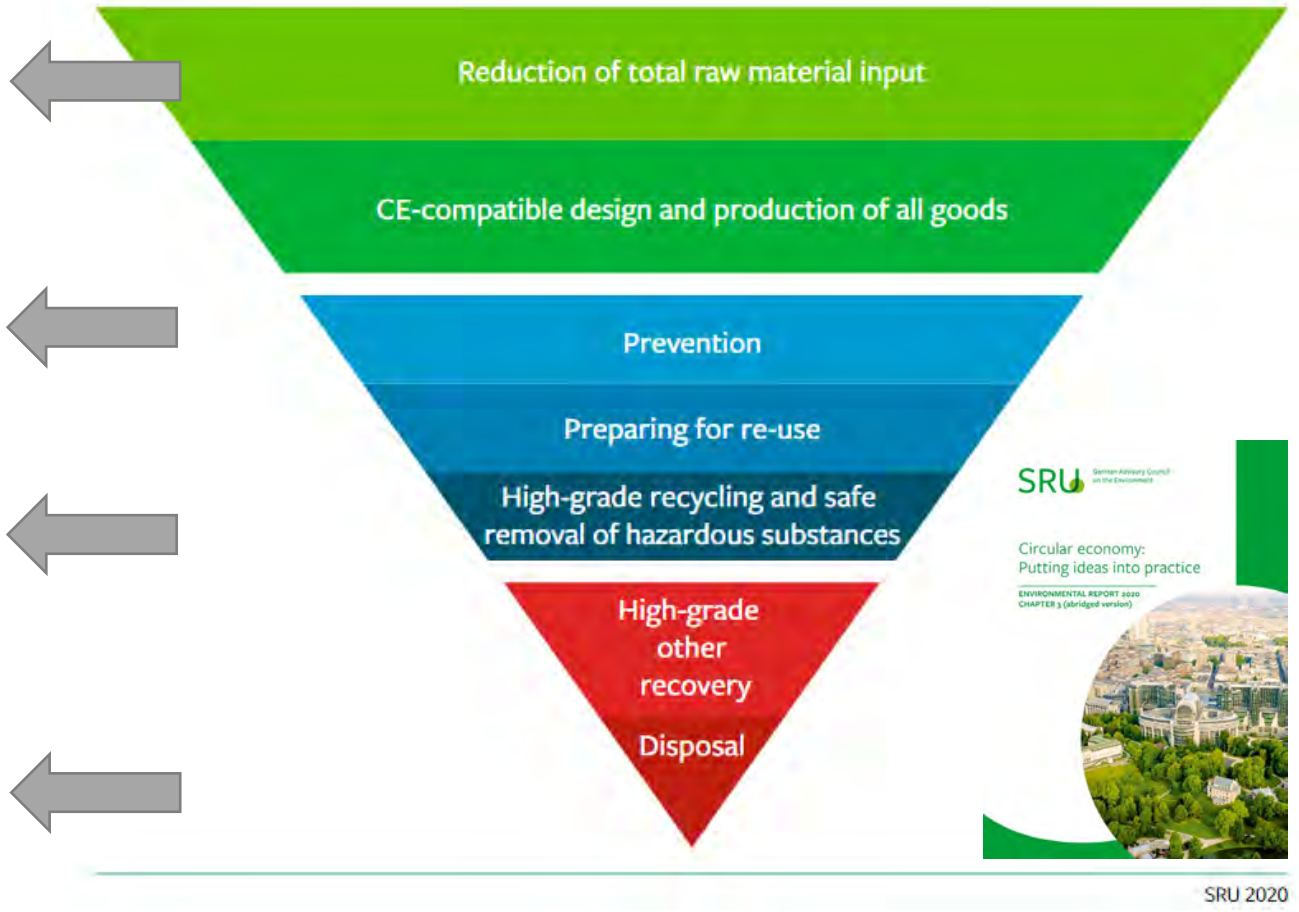
… or why less could be more

reduce (plastic) flows to enable cycles within planetary boundaries

implement CE compatible design and product policies

specify and enable “high-grade” recycling

assure safe removal of hazardous substances



SRU 2020

Towards the circular economy – the role of reduction

Author: Hiroshi TAKATSUKI (Pen-name: High Moon) *
emeritus professor, Kyoto University
Member, Japan Cartoonists Association

Thank you for your attention

勿体無い
Mottainai!

Foto: Maarten Siebel

Prof. Dr.-Ing. Vera Susanne Rotter
Technische Universität Berlin
Fachgebiet Kreislaufwirtschaft und Recyclingtechnologie -
Institut für Technischen Umweltschutz

www.circulareconomy.tu-berlin.de