Messung von Zirkularität –
Status quo, Herausforderungen, Perspektiven

Prof. Dr. Kathrin Greiff

RWTH Aachen University

Institut für Anthropogene Stoffkreisläufe (ANTS)

Recy & Depo Tech 2022

Leoben, 09.11.2022

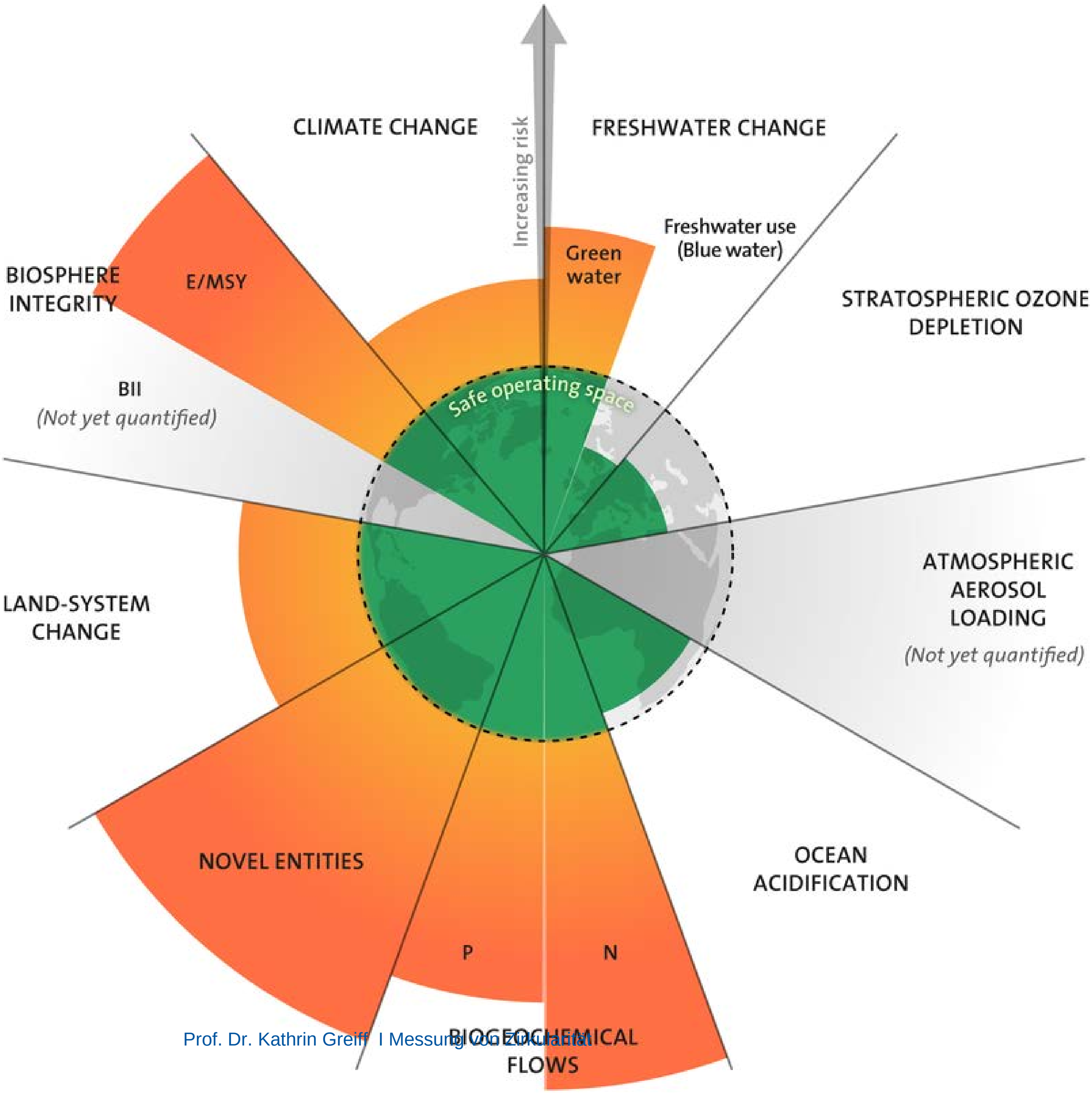
Agenda

- Globale Herausforderungen
- Das Konzept Circular Economy & Anforderungen an die Messung von Zirkularität
- Beispiele zu Reduce, Repurpose, Recycle
- Fazit und Perspektiven

„Wir brachen auf, um den Mond zu erkunden, aber tatsächlich entdeckten wir die Erde.“

Eugene Cernan, Kommandant Apollo 17, letzter Astronaut auf dem Mond (1972)

Quelle: https://pixabay.com/de/photos/erde-blauer-planet-erdkugel-planet-11008/



"The **planetary boundaries** framework defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth System. […] Two core boundaries—climate change and biosphere integrity—have been identified, each of which has the potential on its own to drive the Earth System into a new state should they be substantially and persistently transgressed."
Steffen et al. 2015

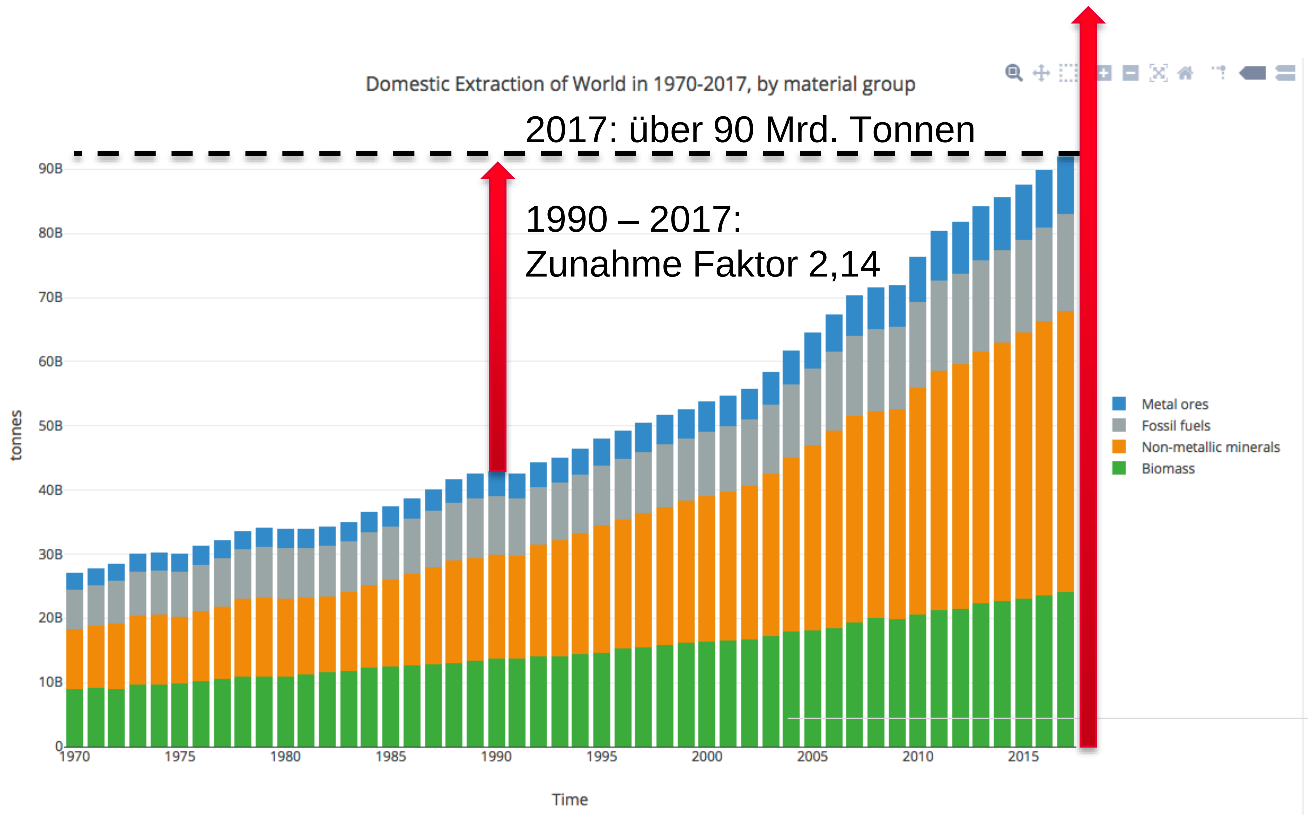
Aktualisierung der planetaren Grenzen. (Abbildung entwickelt von Azote für das Stockholm Resilience Centre, basierend auf Analysen in Wang-Erlandsson et al. 2022, Persson et al 2022, und Steffen et al 2015)

Weltweite Rohstoffgewinnung

- Gewinnung und Produktion von abiotischen Rohstoffen und Materialien: 23% globaler THG Emissionen (2015)

Metalle (Fe, Al, Cu etc.)	4.8 Gt CO_2eq
Nicht-metallische Mineralien	4.4 Gt CO_2eq
Kunststoffe	1.5 Gt CO_2eq
Holz Produktion	0.9 Gt CO_2eq

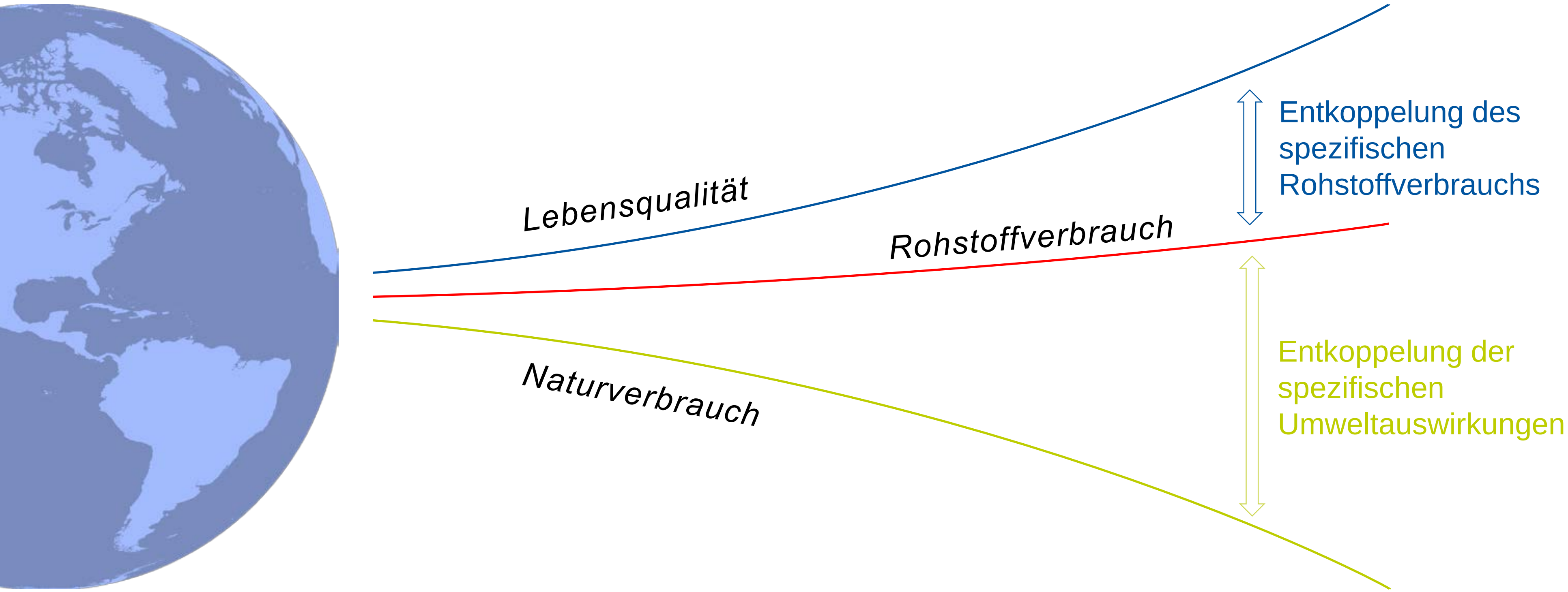
International Resource Panel 2019



http://www.materialflows.net/visualisation-centre/

Nachhaltige Entwicklung

- Zweifache Entkopplung von Ressourcenverbrauch und Lebensqualität bzw. Wohlstand



Effizienz

- Geringerer Aufwand bei gleicher Funktion

Konsistenz

- Kreisläufe schließen

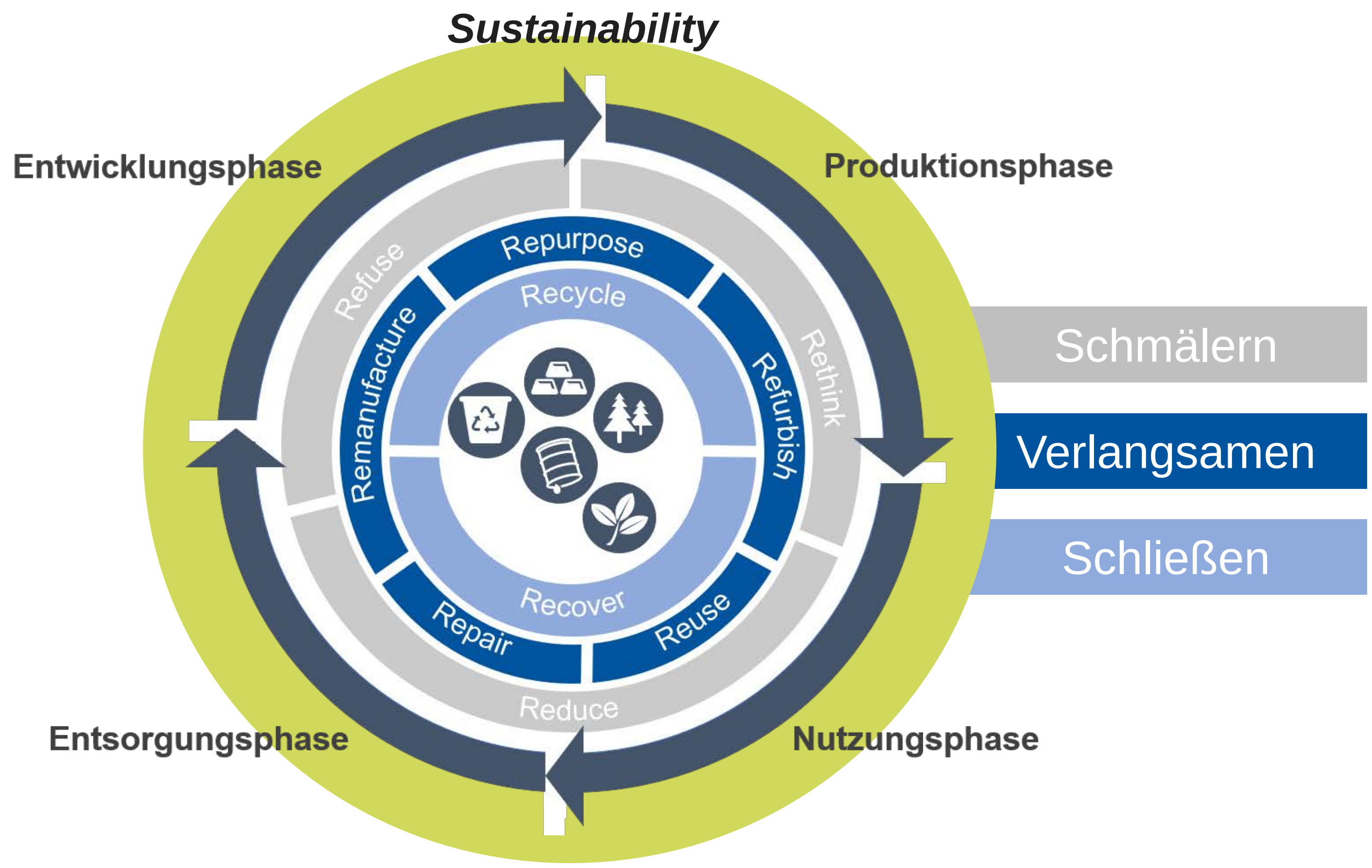
Suffizienz

- weniger
  anders
  besser

changed after Wuppertal Institute; Fischer-Kowalski et al./UNEP, IRP 2011: „impact decoupling“

Circular Economy = Kreislaufwirtschaft

» Definition



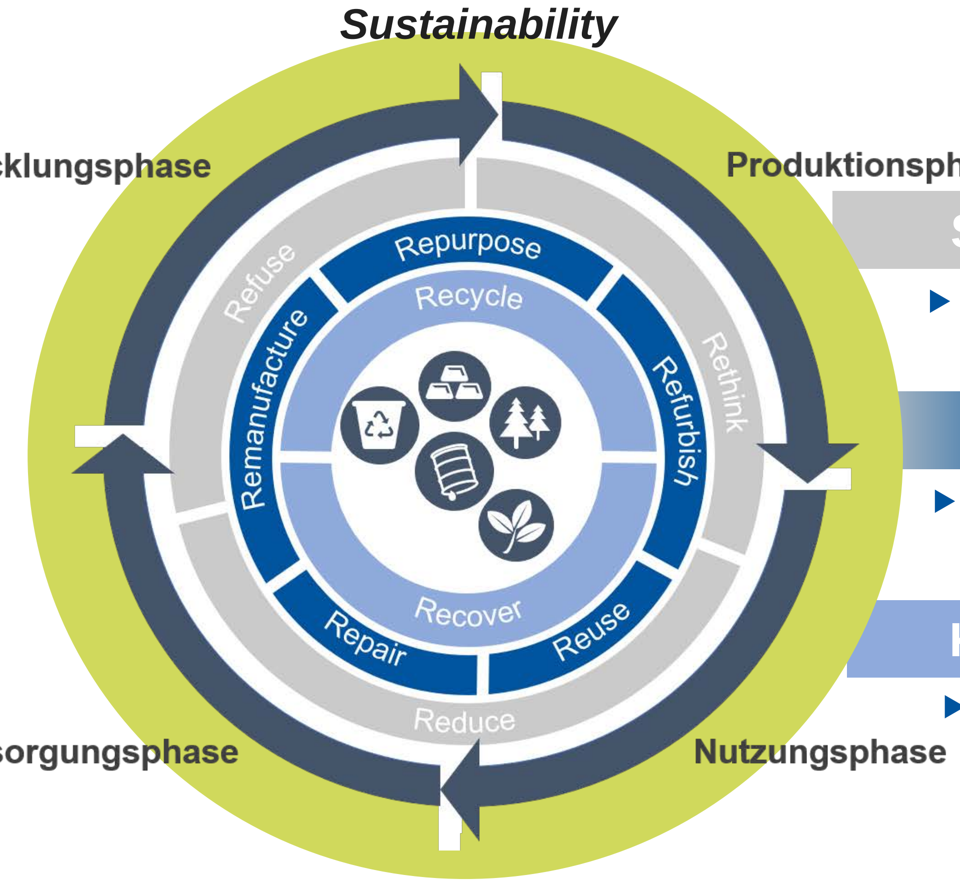
Circular Economy:

„(…)The value of products, materials and resources is ***maintained*** *in the economy for* ***as long as possible****, and the generation of* ***waste is minimised*** *(…), to develop a* ***sustainable, slow carbon, resource efficient and competitive*** *economy.“*
(EC, 2015)

ANTS Anthropogene Stoffkreisläufe | RWTH AACHEN UNIVERSITY

Circular Economy = Kreislaufwirtschaft

» Definition



Suffizienz

- Weniger, anders, besser

Effizienz

- Geringerer Aufwand bei gleicher Funktion

Konsistenz

- Kreisläufe schließen

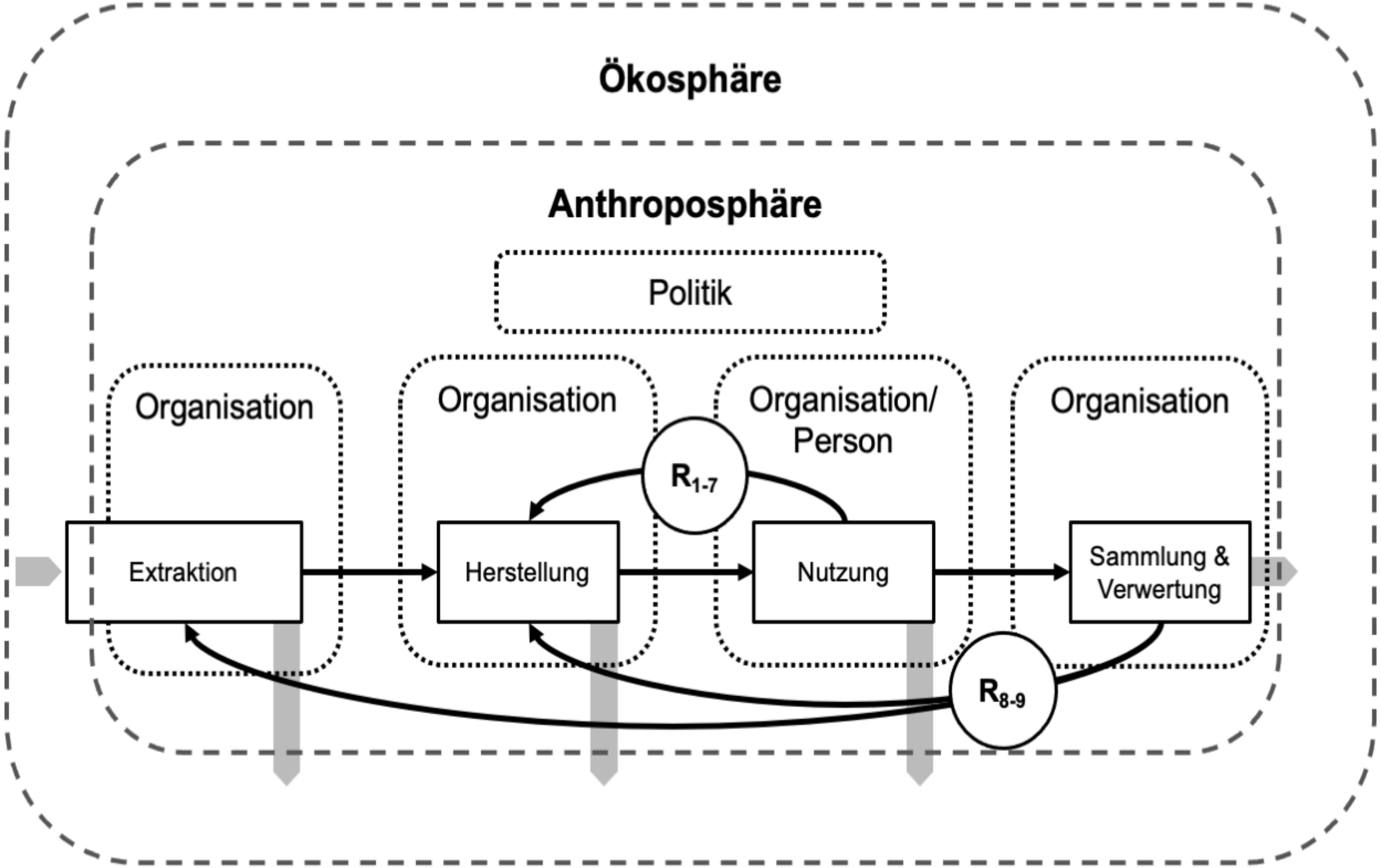
Circular Economy:

*„(…)The value of products, materials and resources is **maintained** in the economy for **as long as possible**, and the generation of **waste is minimised** (…), to develop a **sustainable, slow carbon, resource efficient and competitive** economy.“ (EC, 2015)*

Anforderungen an die Messung von Zirkularität

» Mehrebenenmodell – für ein systemisches Monitoring einer CE

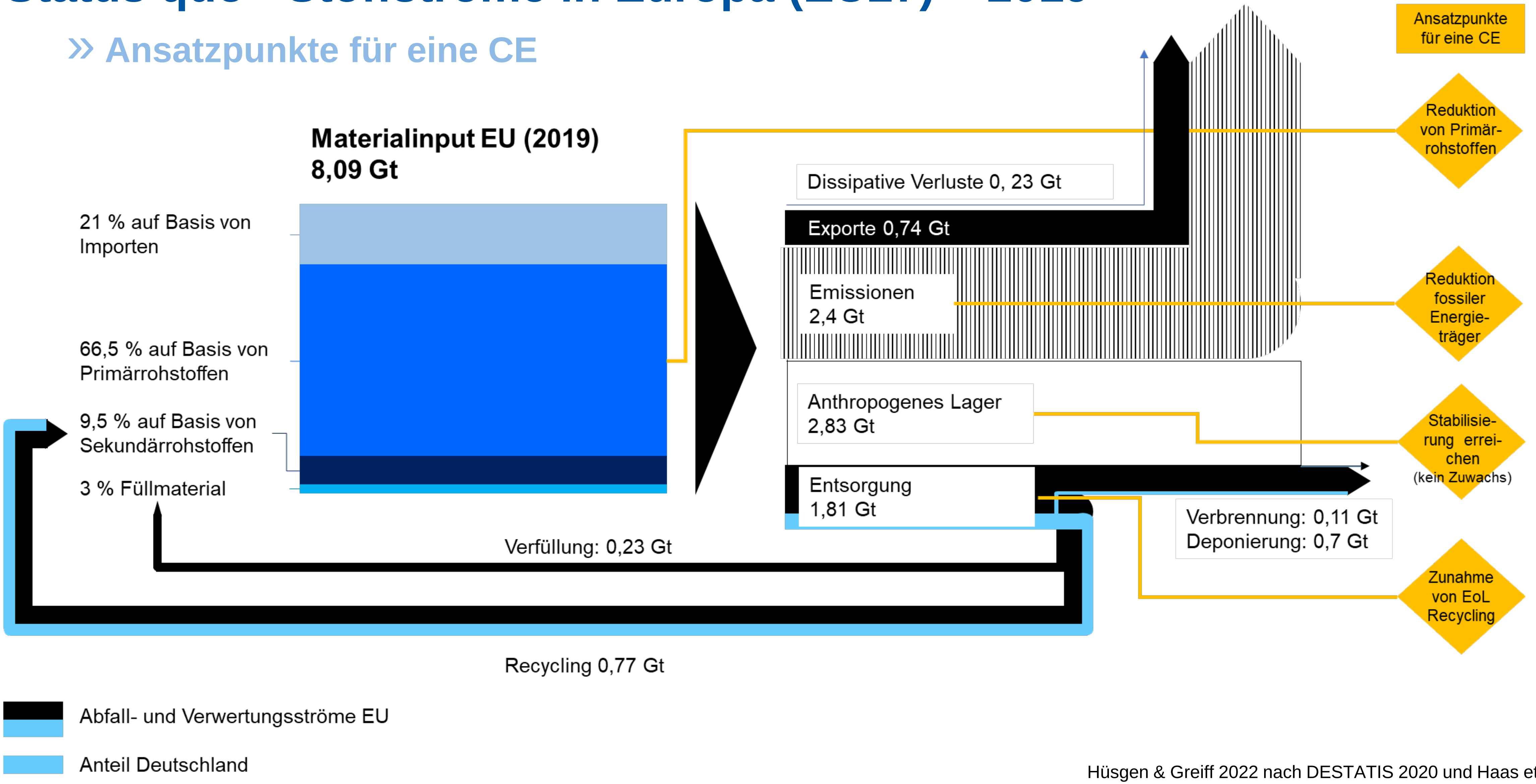
- **Mikro-Ebene –**
  Produkte, Unternehmen, Organisationen
- **Meso-Ebene –**
  Industrieparks
- **Makro-Ebene –**
  Regionen, Städte, Länder, Welt



Hagedorn & Greiff 2022

Status quo - Stoffströme in Europa (EU27) – 2019

» Ansatzpunkte für eine CE



Hüsgen & Greiff 2022 nach DESTATIS 2020 und Haas et al. 2017

Anforderungen an die Messung von Zirkularität

» Monitoring level

Monitoring levels:

(I) resource inputs

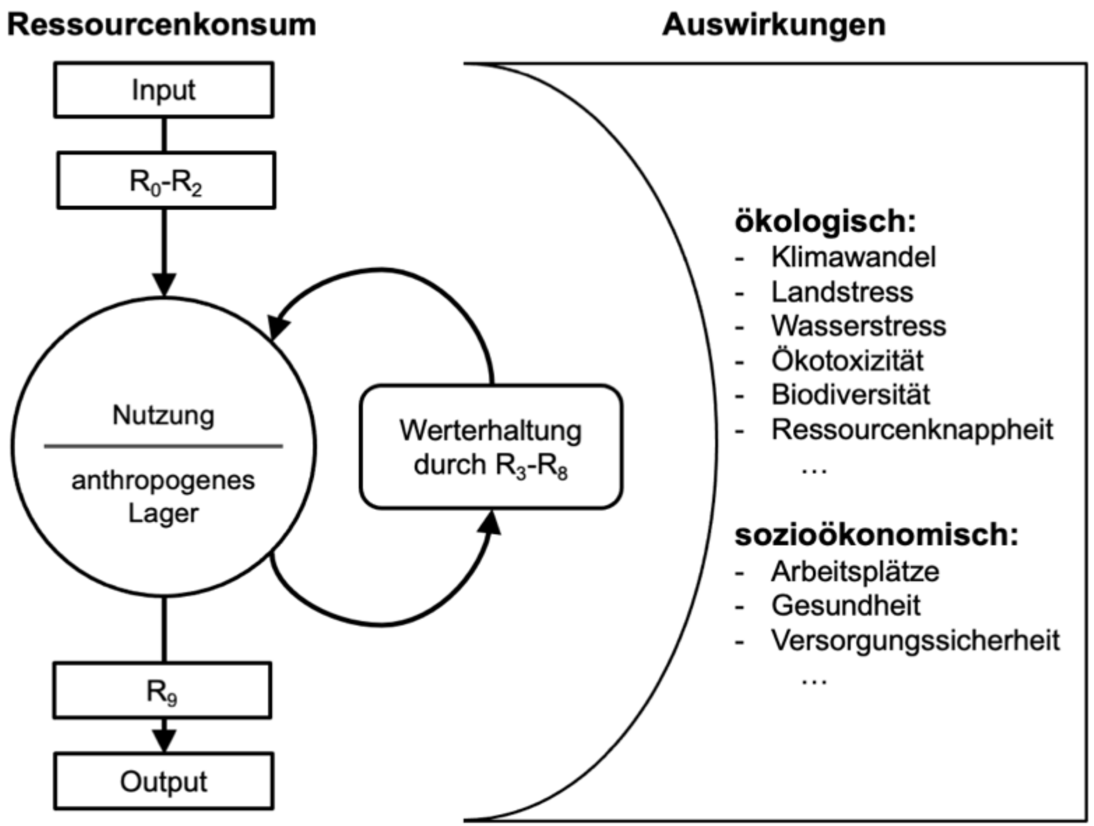
(II) resource use (throughput)

(III) resource outputs and

(IV) effects of a CE

(Koch & Coelho, 2020)

(V) CE Network



(Hagedorn und Greiff 2022 nach Kick et al. 2021)

Circular Economy

Zunahme an Nachhaltigkeit?

Zunahme an Zirkularität

Linear Economy

	R- Strategien		Wirkung
Smarte/ Innovative Herstellung und Nutzung von Produkten	Refuse	Ersatz bisheriger Produkte durch neuartige PDL Systeme	Schmälern
	Rethink	Intensivierung von Produktnutzung (z.B. durch Sharing)	
	Reduce	Steigerung der Materialeffizienz	
Erhöhte Lebensdauer von Produkten und Produkt-teilen	Reuse	Weiternutzung vorhandener Produkte durch andere Konsumenten	Verlangsamen
	Repair	Reparatur/Pflege von defekten Produkten und Weiternutzung	
	Refurbish	Aufarbeitung von defekten Produkten und Weiternutzung	
	Remanufacture	Nutzung von Modulen/Bauteilen eines defekten Produkts in einem neuen Produkt mit der gleichen Funktion	
	Repurpose	Nutzung von Modulen/Bauteilen eines defekten Produkts in einem neuen Produkt mit der geänderter Funktion	
Einsatz von Werkstoffen und Materialien	Recycle	Verfahren zur Herstellung von Materialien mit gleicher oder niedrigerer Qualität	Schließen
	Recover	Verbrennung von Materialien mit Energiegewinnung	

verändert nach Potting et al. 2017

Beispiel Reduce

» Material – Prozess – Produkt

Recyclingfähigkeit?
Dissipative Verluste?

Environmental Performance im Vergleich

Adaption	42CrMo4	33MnCrB5-2	LHD	Δ CF*	Δ CED*
Material Level				-	↑ 11-13%
Process Level				↓ 17-22%	↓ 16-19%
Product Level				↓ 29-32%	↓ 29-32%

*LHD im Vergleich zu Szenarien mit 42CrMo4 und 33MnCrB5-2

Hagedorn et al. 2022

Beispiel Reduce, Repurpose, Recycle

» More Than Recycling
The potential of the circular economy by a case study of the metal working industry

- The case study shows the **diverse possibilities to design production processes** of steel products besides the well-established recycling route.
- It can achieve a considerable reduction of environmental impacts but is not per se environmentally beneficial.

Hagedorn, W., S. Jäger, L. Wieczorek, P. Kronenberg, K. Greiff, S. Weber, und A. Roettger. 2022. „More than Recycling – The Potential of the Circular Economy Shown by a Case Study of the Metal Working Industry“. *Journal of Cleaner Production* 377:134439. doi: 10.1016/j.jclepro.2022.134439.

Wuppertal Institut

ANTS Anthropogene Stoffkreisläufe

RWTH AACHEN UNIVERSITY

BERGISCHE UNIVERSITÄT WUPPERTAL

Industry Partners:

TKM

freund

Funding:

FONA Ressourceneffizienz BMBF

ReziProK Ressourceneffiziente Kreislaufwirtschaft – Innovative Produktkreisläufe

Bundesministerium für Bildung und Forschung

EUROPEAN UNION
Investing in our Future
European Regional Development Fund

Journal of Cleaner Production 377 (2022) 134439

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

ELSEVIER

More than recycling – The potential of the circular economy shown by a case study of the metal working industry

W. Hagedorn [a,b,d,*], S. Jäger [b], L. Wieczorek [b], P. Kronenberg [b], K. Greiff [d], S. Weber [c], A. Roettger [b]

[a] Wuppertal Institut für Klima, Umwelt, Energie gGmbH, Germany
[b] Lehrstuhl für Neue Fertigungstechnologien und Werkstoffe, Bergische Universität Wuppertal, Germany
[c] Lehrstuhl für Werkstofftechnik, Ruhr-Universität Bochum, Germany
[d] Department of Anthropogenic Material Cycles, RWTH Aachen University, Germany

ARTICLE INFO

Keywords:
Circular economy
Steel
Circular products
Case study
Environmental assessment
Material efficiency

ABSTRACT

The steel industry is responsible for a quarter of all industrial greenhouse gas emissions. So far, the environmental savings are mainly due to steel recycling. Besides recycling, the circular economy offers strategies to increase material efficiency and thus decrease the primary raw material demand. However, the potentials remain unexploited because circular economy concepts with a higher degree of circularity are not considered. The presented case study of an industrial machining knife illustrates how the production process can be improved by implementing various circular strategies. The environmental performance is analyzed by calculating and comparing the carbon footprint, the cumulative energy demand and the material footprint, and the material efficiency indicator. The results show that the implementation of the three overarching strategies of the circular economy - narrowing, closing, and slowing – contributes to a significant increase in material efficiency. The implementation also has a positive effect on the overall environmental performance. The circular production processes require less energy and resources and cause fewer emissions. Auxiliary processes such as additional transport routes are relevant, as they can reduce or even overcompensate for savings. These processes must be adequately considered and designed.

1. Introduction

The climate crisis continues uninhibited, and the steel industry has a significant contribution. It is half-time to achieve climate neutrality by 2050 to tackle the climate crisis. Moreover, research shows that previous measures are insufficient to meet this target (UNEP, 2021). The steel industry is of great importance regarding the climate crisis as it is responsible for a quarter of all industrial greenhouse gas (GHG) emissions (Allwood et al., 2011; Ito et al., 2020). In 2018, the global steel use counted 1.8 billion t (worldsteel, 2019a). Thus, it forms the most significant mass flow of metallic resources. On average, one ton of steel causes 1.8 t CO_2 equivalent (CO_2 eq) (worldsteel, 2019b). With an annual production of approx. 41 Mt of crude steel in 2021, Germany belongs to the ten biggest steel producers in the world and is the largest in the European Union (26% of European crude steel production) and causes immense pollution (worldsteel, 2022).

Even though the secondary route for steel is well established and shows how to close anthropogenic material flows, it is not sufficient to meet climate targets. The reduction of environmental impact needs to be increased by extensive measures of both, energy, and material efficiency. The steel industry can look back on a long history of recycling, a core principle of the circular economy (CE), promoting and resulting in significant resource and emission savings: Secondary steel production is related to three times fewer emissions than primary steel production (Flint et al., 2020). Nevertheless, there are doubts if future steel production can be covered entirely by secondary material due to the limits of recycling, such as quality losses due to contamination by e.g., copper and stock dynamics (Daehn et al., 2017; Haupt et al., 2017; Xylia et al., 2018). Also, recycling will always require energy and primary material

* Corresponding author. Department of Anthropogenic Material Cycles, RWTH Aachen University, Bergische Universität Wuppertal, Lehrstuhl für Neue Fertigungstechnologien und Werkstoffe, and Wuppertal Institut für Klima, Umwelt, Energie gGmbH, Doeppersberg 19, 42103, Wuppertal, Germany.
E-mail addresses: wiebke.hagedorn@ants.rwth-aachen.de (W. Hagedorn), jaeger.fuw@uni-wuppertal.de (S. Jäger), wieczorek.fuw@uni-wuppertal.de (L. Wieczorek), kronenberg.fuw@uni-wuppertal.de (P. Kronenberg), kathrin.greiff@ants.rwth-aachen.de (K. Greiff), weber@wtech.rub.de (S. Weber), roettger.fuw@uni-wuppertal.de (A. Roettger).

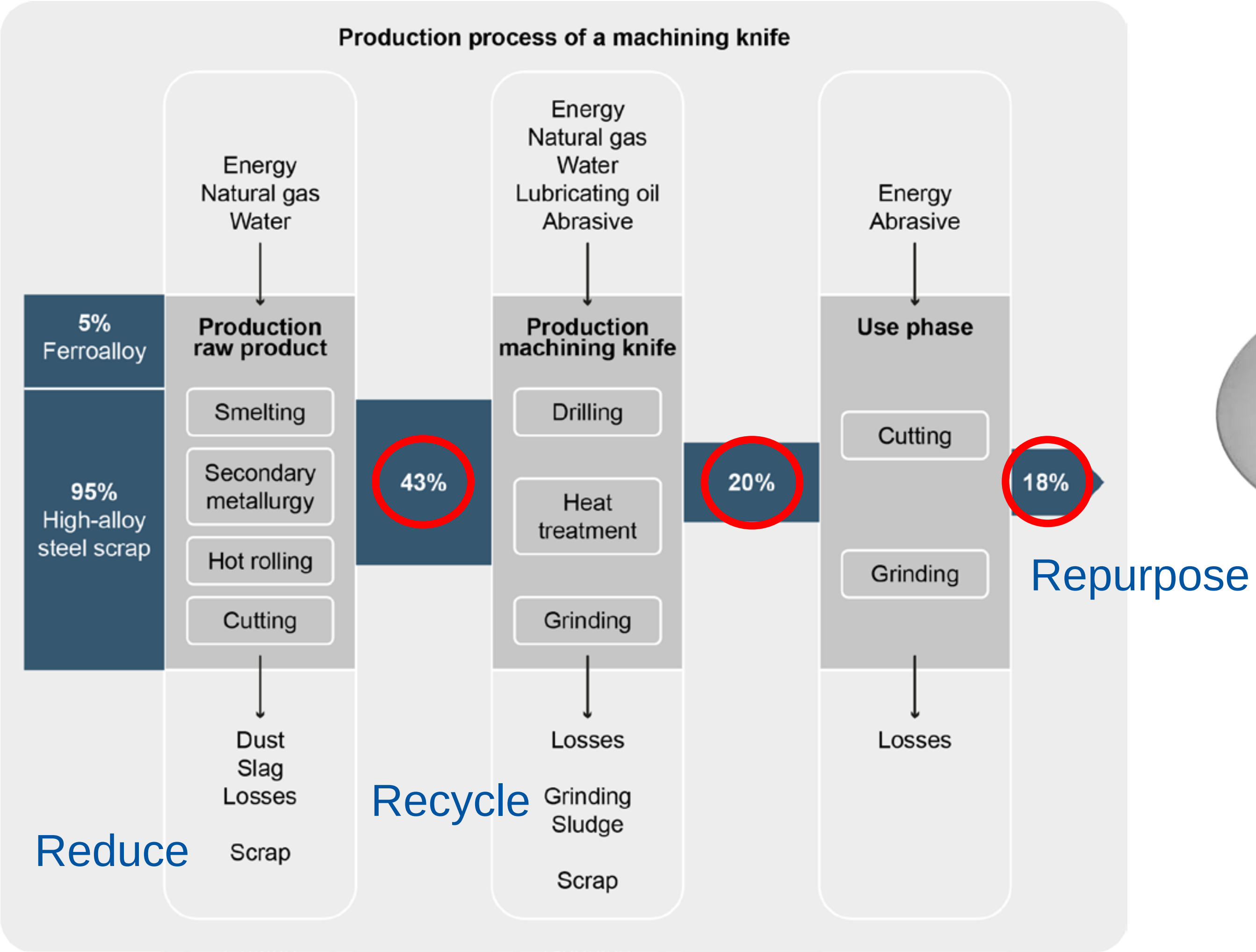
https://doi.org/10.1016/j.jclepro.2022.134439
Received 14 March 2022; Received in revised form 14 September 2022; Accepted 29 September 2022
Available online 4 October 2022

ANTS Anthropogene Stoffkreisläufe

RWTH AACHEN UNIVERSITY

Beispiel Reduce, Repurpose, Recycle

» Case Study Kreismesser für die papierverarbeitende Industrie



Hagedorn et al. 2022, TKM GmbH

Beispiel Reduce, Repurpose, Recycle

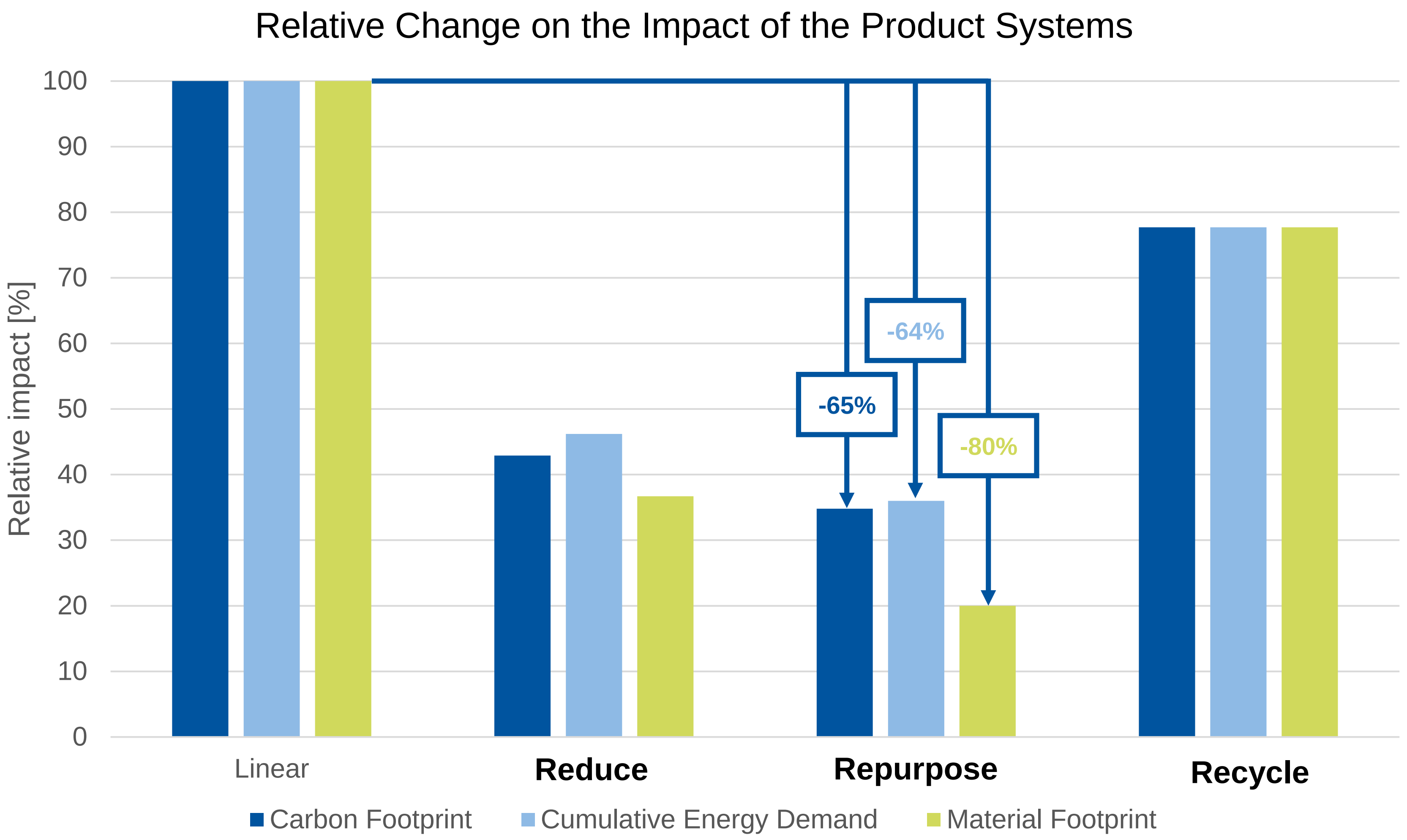
» Potentiale verschiedener R-Strategien

Absolute Impact of Reference System:

106 kg CO_2 eq

1.915 MJ-eq

1.068 kg

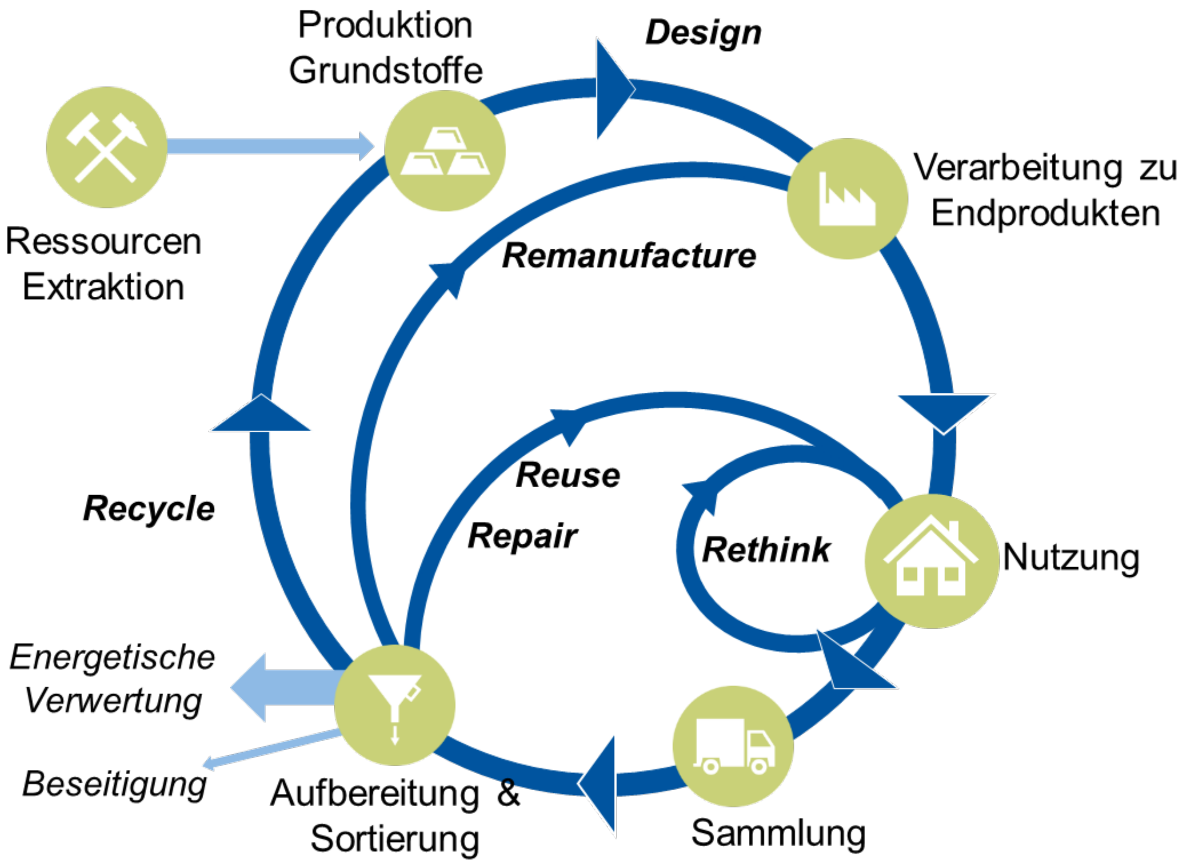


Hagedorn et al. 2022

Fazit & Perspektiven

» Messung von Zirkularität

- **Ziele**: klar formulieren
- Alle **R-Strategien** in den Blick nehmen
- **Indikatoren:** anhand der Ziele auswählen
  - **Transparenz & Datenverfügbarkeit**
  - **Mehrebenen**: Micro- Meso- Makro-Ebene
  - **Monitoring Level**: Input, Throughput, Output, Effekte
  - Gesamten **Lebenszyklus** betrachten
  - **CE Netzwerk:** Kreislauffähigkeit
- Ganzheitliches Monitoring System
  für **nachhaltiges und zirkuläres Wirtschaften**



Danke für die Aufmerksamkeit!

Prof. Dr. Kathrin Greiff
Institutsleiterin
Institut für Anthropogene Stoffkreisläufe (ANTS)
RWTH Aachen University

Wüllnerstr. 2
52062 Aachen
Tel: +49 241 80-95700
Fax: +49 241 - 80 92232
Kathrin.Greiff@ants.rwth-aachen.de
www.ants.rwth-aachen.de