AACHEN CENTER FOR ADDITIVE MANUFACTURING

dap Digital Additive Production | RWTH AACHEN UNIVERSITY


# On the way to green production
# How additive manufacturing can contribute to green production in the future and what challenges still need to be overcome?

Pauline Pletzer-Zelgert M. Sc. | 29.09.2022

# Paradigm Shift in Industrial Production
## **Green Manufacturing - Choice or Urge?**

"The frequency and intensity of **heavy precipitation events** have **increased** since the 1950s over most land area […] and **human-induced climate change** is likely the main driver."

IPCC - Sixth Assessment Report (2021)

* https://www.apotheke-adhoc.de/nachrichten/detail/apothekenpraxis/wassermassen-fluten-apotheken-unwetter-in-nordrhein-westfalen/

Paradigm Shift in Industrial Production

# Green Manufacturing - Choice or Urge?

## Political goals

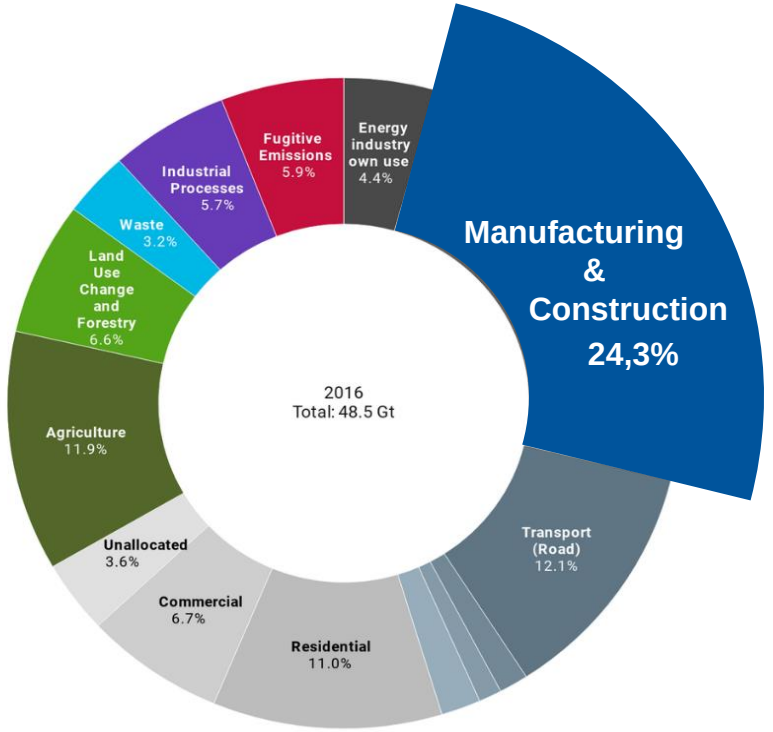
### Paris Agreement (2015)

PARIS2015
COP21·CMP11

Limiting global warming to below 2 °C,
**preferably below 1.5 °C**

### European Green Deal (2020)

Reduction of net greenhouse gas emissions to zero in 2050 in the European Union




**Global greenhouse gas emissions by sector[1] (2016)**

**Manufacturing has high impact on total greenhouse gas emission**

Sources:[1]earhcharts.org

Paradigm Shift in Industrial Production

# Green Manufacturing - Choice or Urge?

Political goals

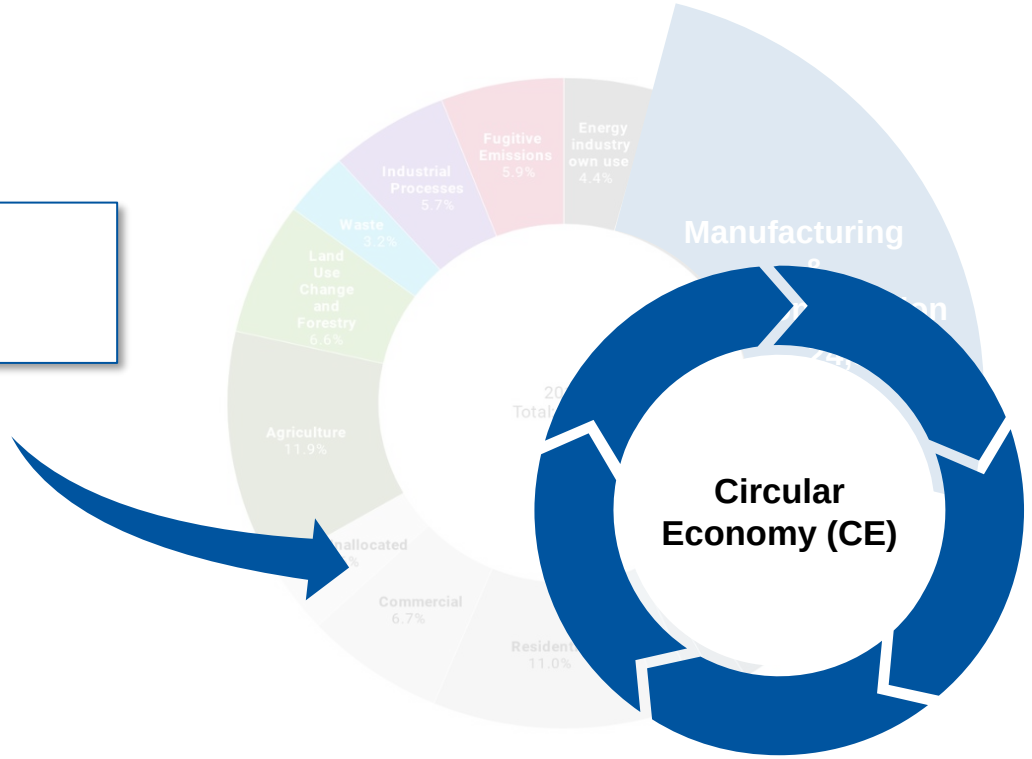
**How can we reach these goals?**

**Paris Agreement (2015)**

below 2 °C,
**preferably below 1.5 °C**

**European Green Deal (2020)**

Reduction of net greenhouse gas emissions to zero in 2050 in the European Union

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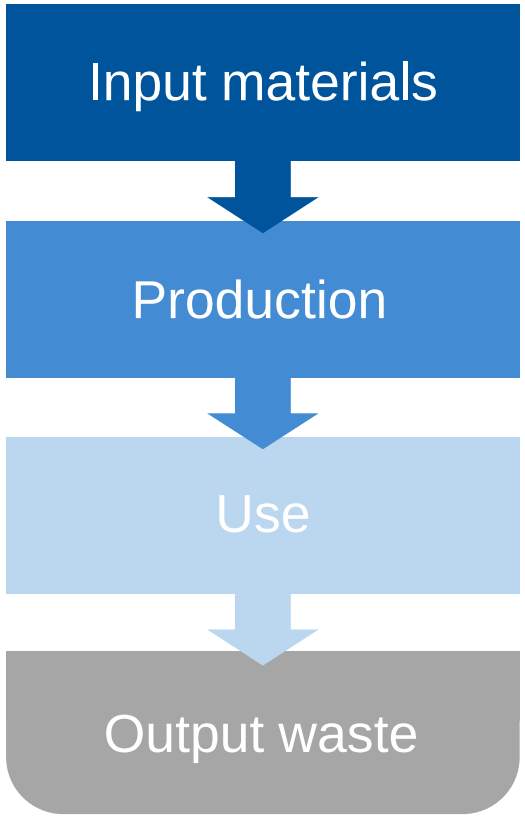
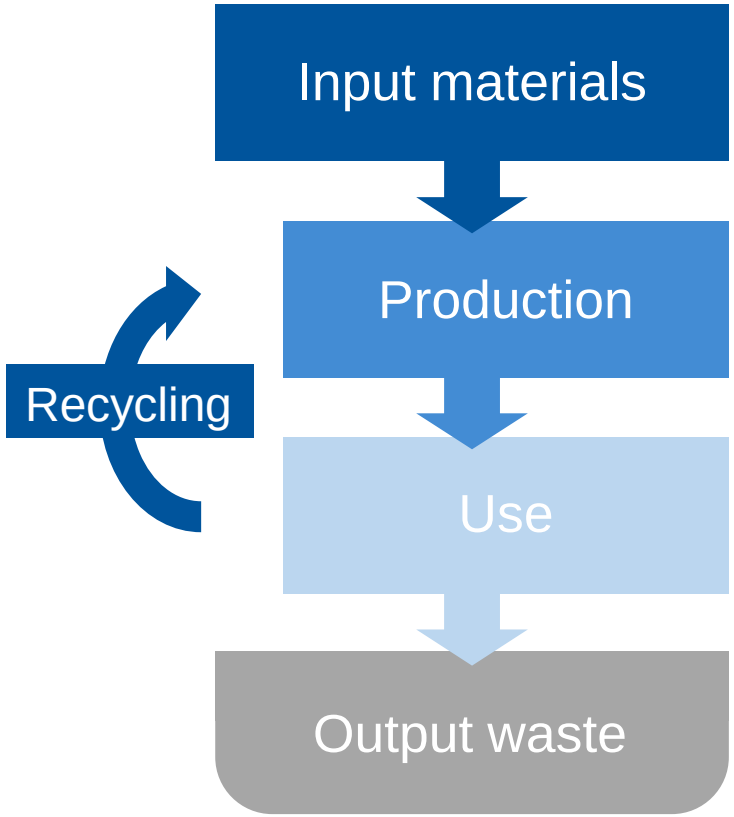
# From linear to circular

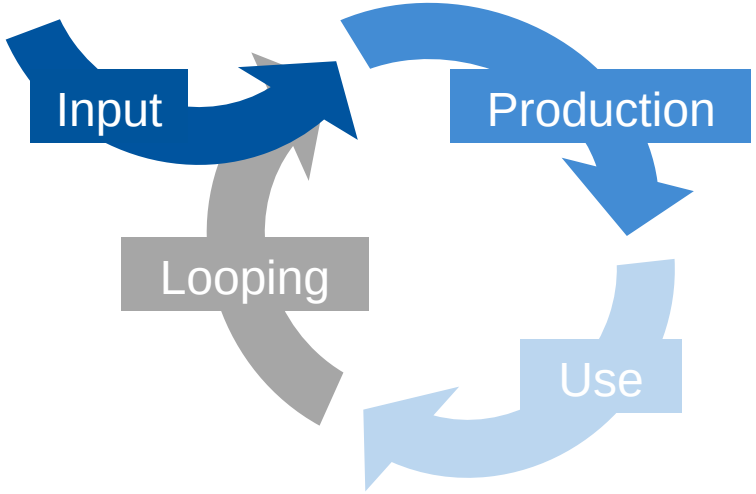
## Linear economy




## Recycling economy




## Circular economy




Sources: to be added

# The Path towards a Circular Economy
## From linear to circular

**Prioritize environment recovery**

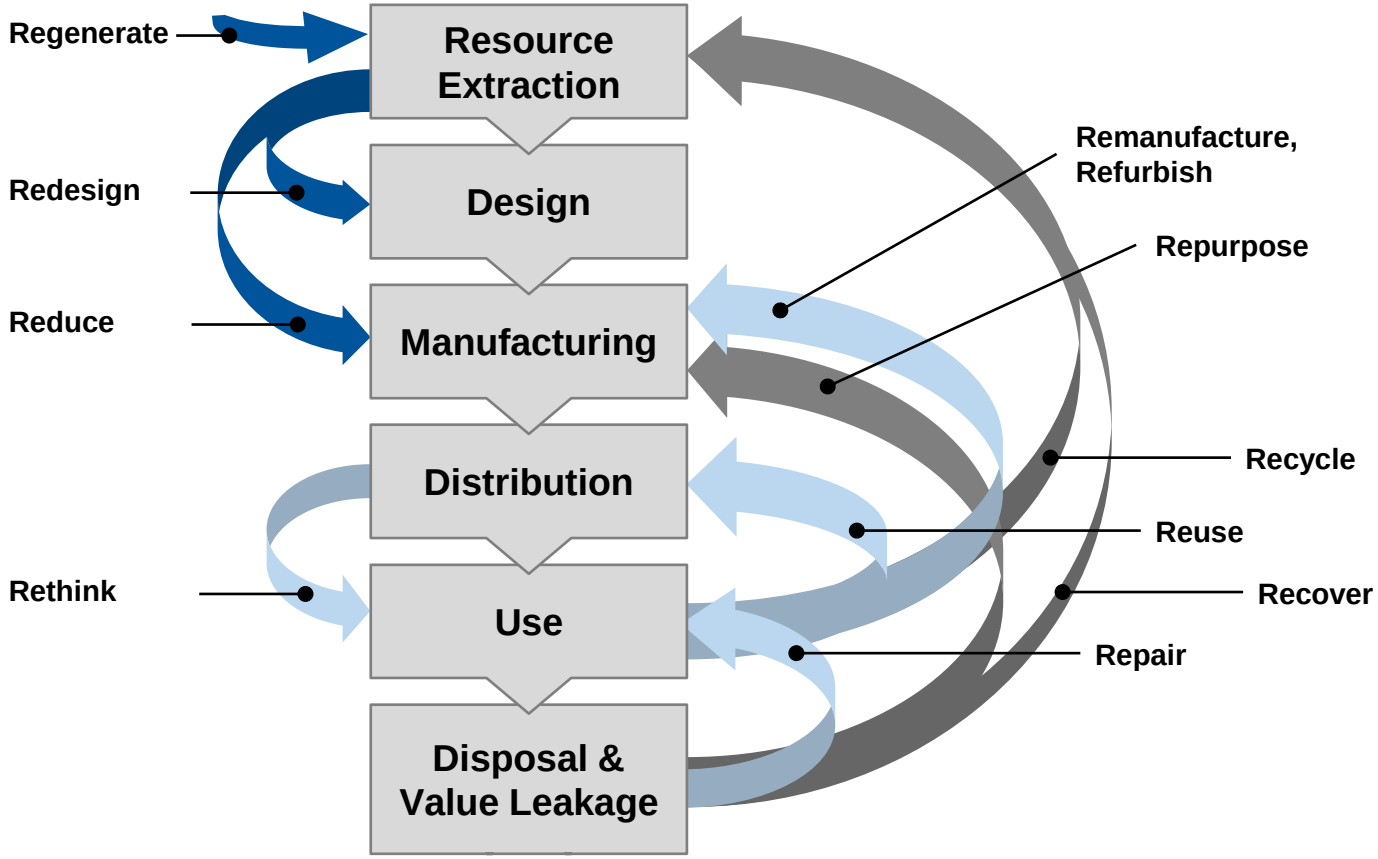
- $R_0$: Regenerate
- $R_1$: Redesign
- $R_2$: Reduce

**Maximize product use & lifespan**

- $R_3$: Rethink
- $R_4$: Reuse
- $R_5$: Repair
- $R_6$: Refurbish
- $R_7$: Remanufacture

**Minimize pollution & waste**

- $R_8$: Repurpose
- $R_9$: Recycle
- $R_{10}$: Recover



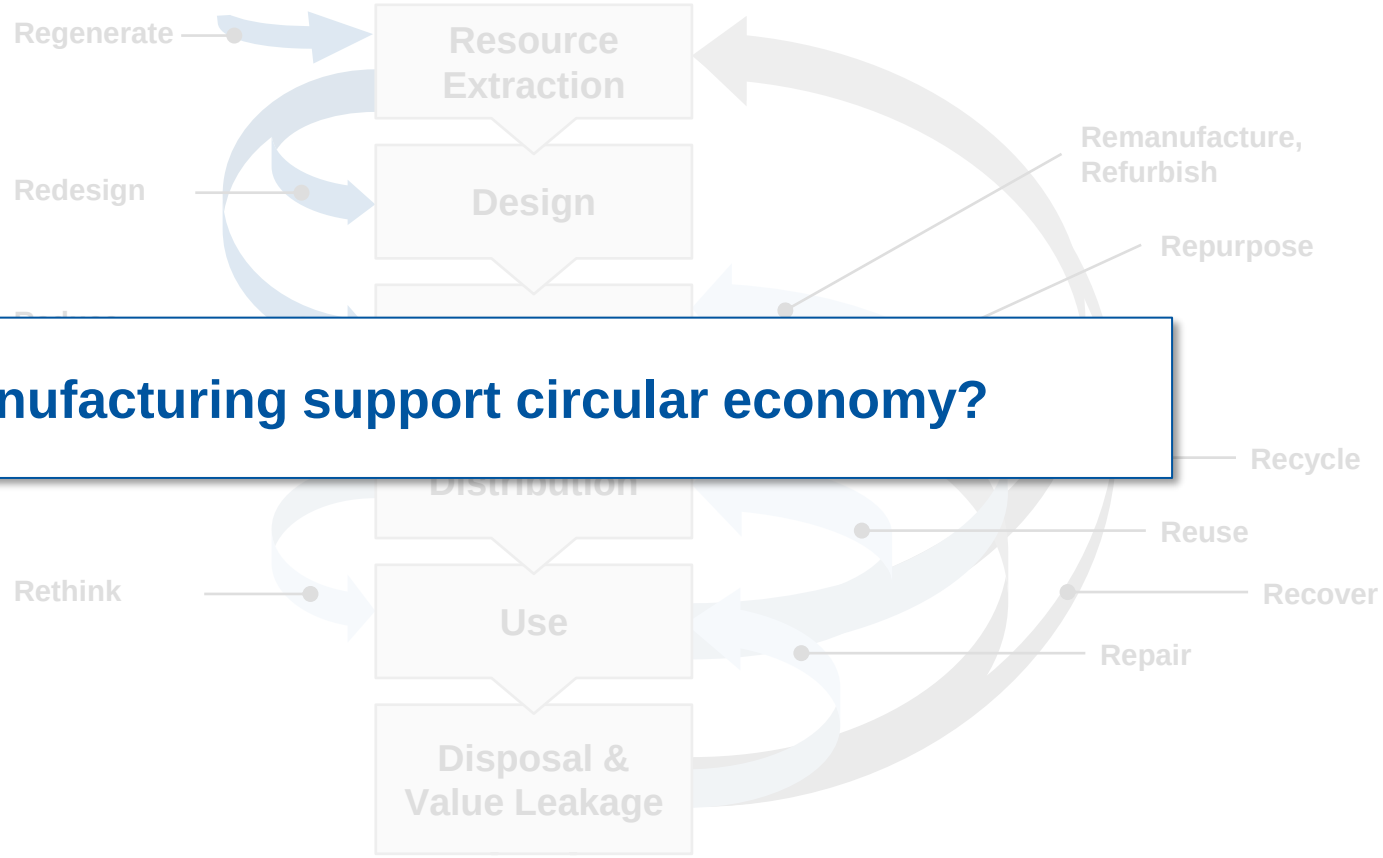

Sources: adapted from J.Potting, M. Hekkert, E. Worrell Circular economy strategies. Source: PBL (2017). Circular economy: measuring innovation in the product chain.

# The Path towards a Circular Economy
## From linear to circular

Prioritize environment recovery

Maxim… product … lifesp…

Minimize pollution & waste

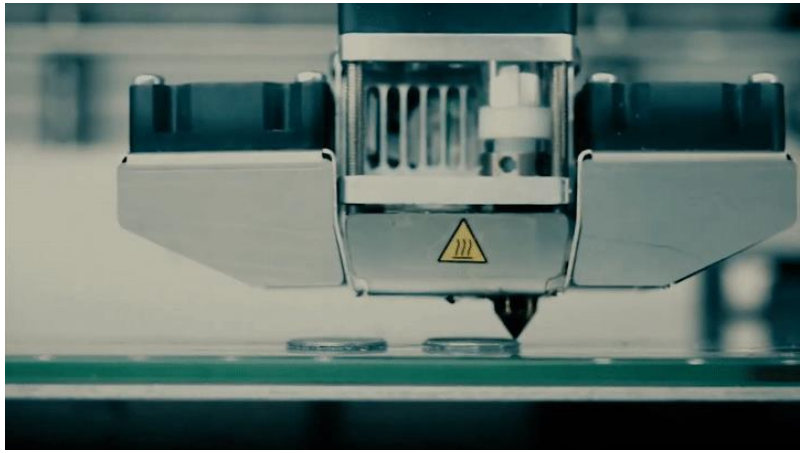



**How can additive manufacturing support circular economy?**

# Additive Manufacturing - Definition

## Definition (VDI 3405)

*“Manufacturing process in which the **workpiece is built up in successive layers or units**.”*



### Additive


*Geometry is generated by adding material instead of removing or forming*

### Toolless

*Component geometry is independent from tool*

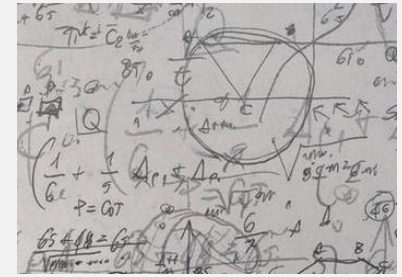

Aniwaa

### Digital

*Direct manufacturing based on digital 3D models*

### Complex

*Different technologies require specific expert knowledge*



Prioritize Environment Recovery

# Design Products with Circular Purposes in Mind

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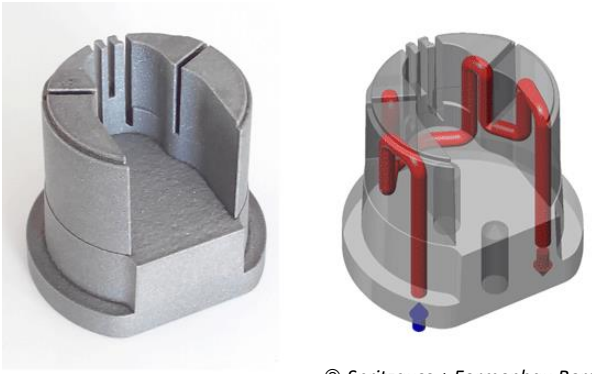
**Design products with circular purposes in mind.**

- **Greater lifetime**
- **Improve product development phase**
- **Individualization (better product use/longer lifespan via affection)**
- **Better efficiency of parts**

*© HPL Technology GmbH*



*© Spritzguss + Formenbau Bergmann*

Sources: tbd

## Maximize Product Use & Lifespan

# Apply Maintenance and restore old Products to recover Performance

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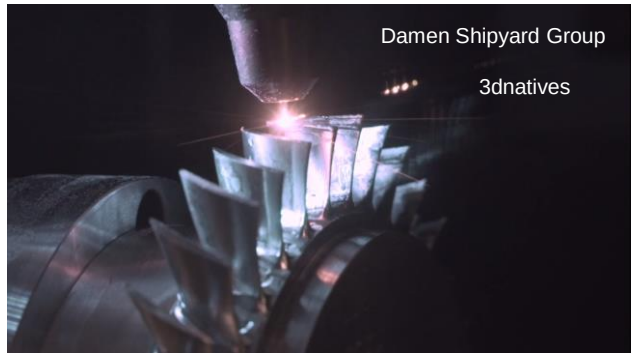
**Apply maintenance of defective products to recover performance and extend their lifetime**

**Repairing of previously discarded parts**




**Repair on site**

**Providing out of series Spare parts**

**Access to spare parts (Home)**

Hard-to-Find Parts for Classic Cars

Despite the many modern cars available in the market, we can still see a couple of rare and classics cruising along the streets. If a particular part gets damaged, looking for a replacement is difficult since they are not always being produced or found anymore.


Sources: tbd

Minimize Pollution & Waste

# Process and transform Waste or By-Products into new Raw Material Input

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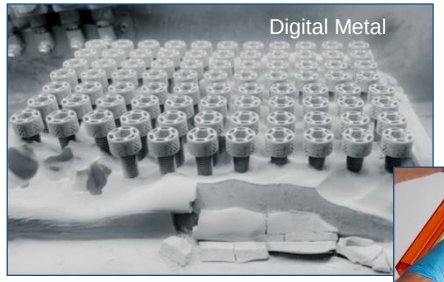
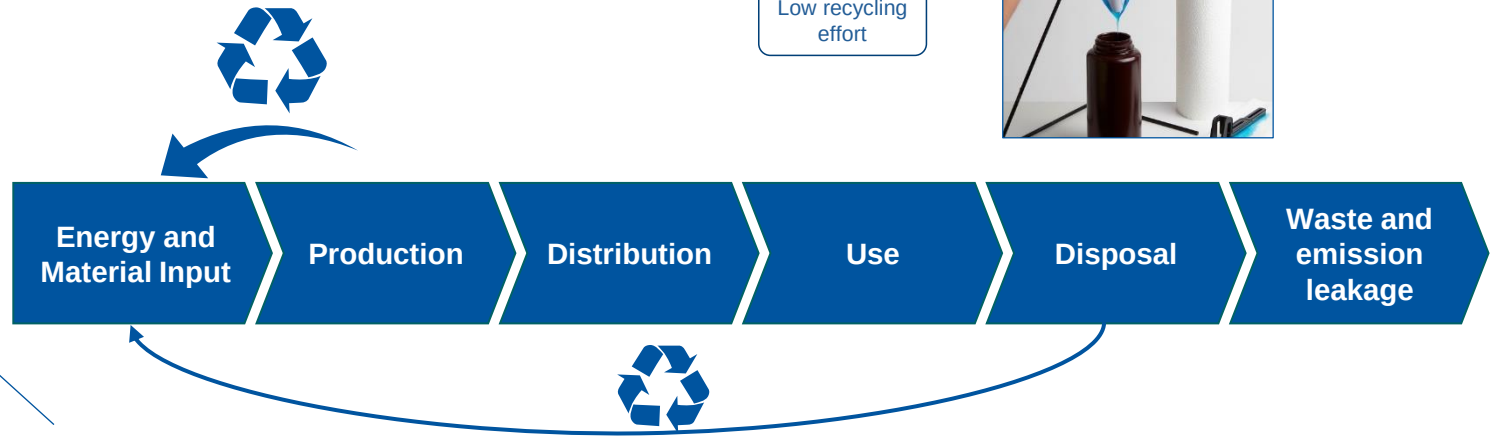
**Process and transform waste or by-products into new raw material input for a different product lifecycle**

**Recycling processed materials**




Near net shape

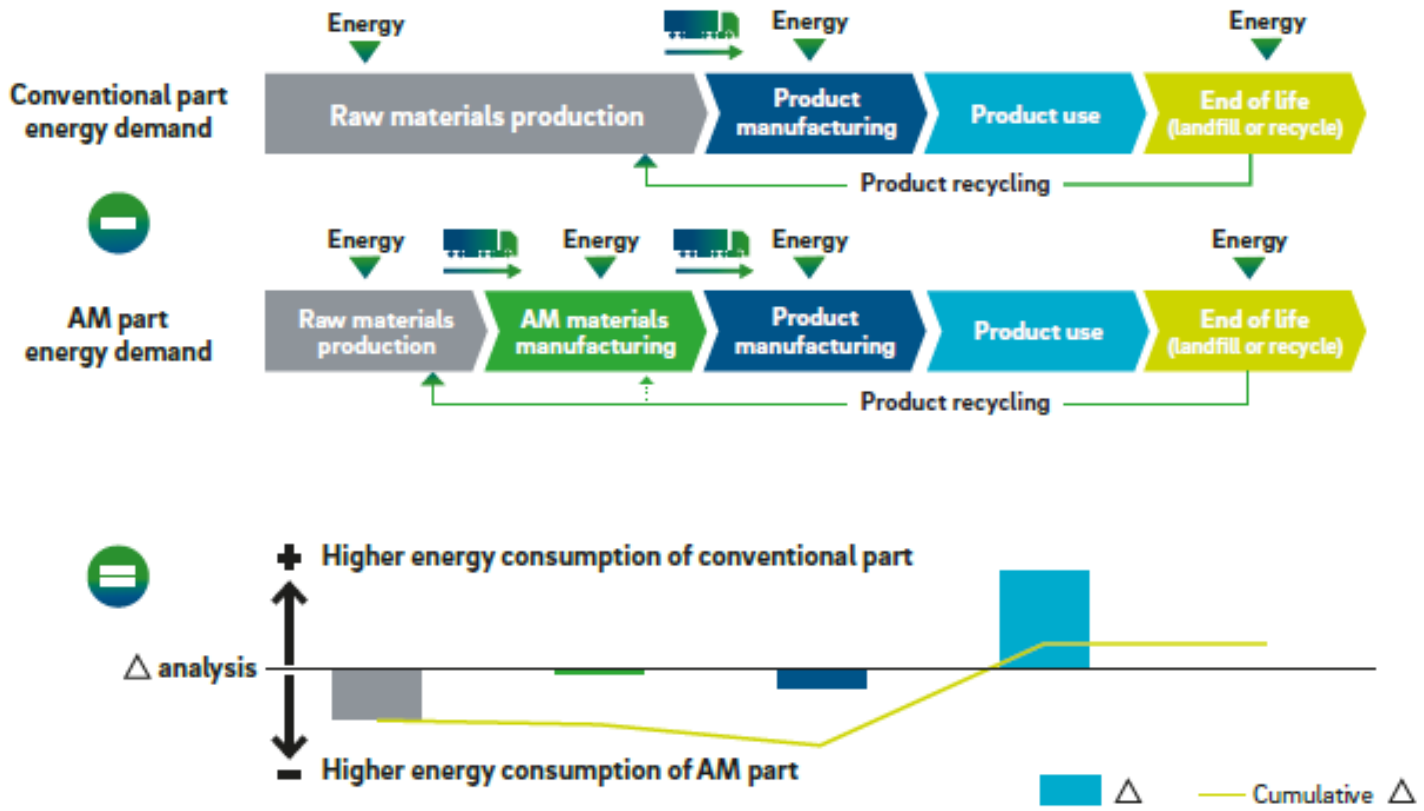

Low recycling effort




Sources: to be added

# Challenge for additive Manufacturing
# **Energy Consumption in the Process Route**

**Comparison with 1 kg of material in each process step**



# Challenge for additive Manufacturing
## Energy Consumption in the Process Route

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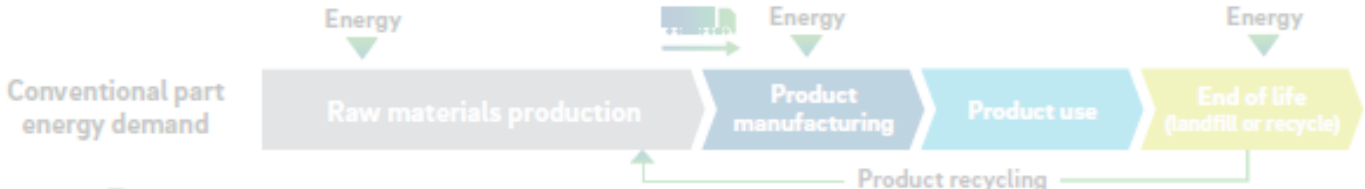
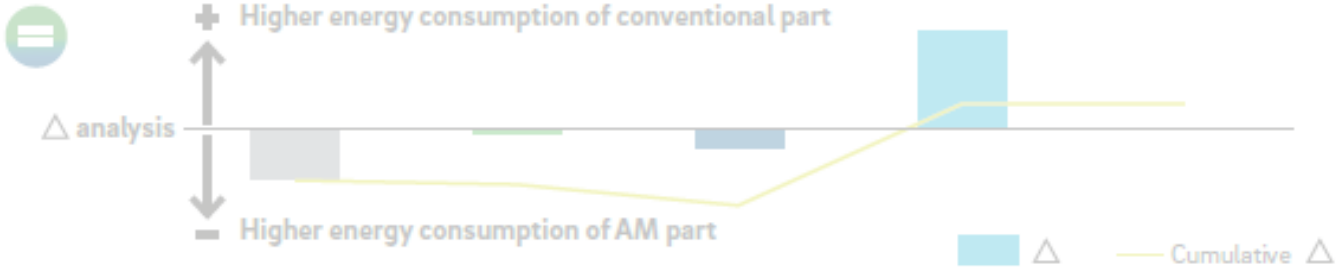
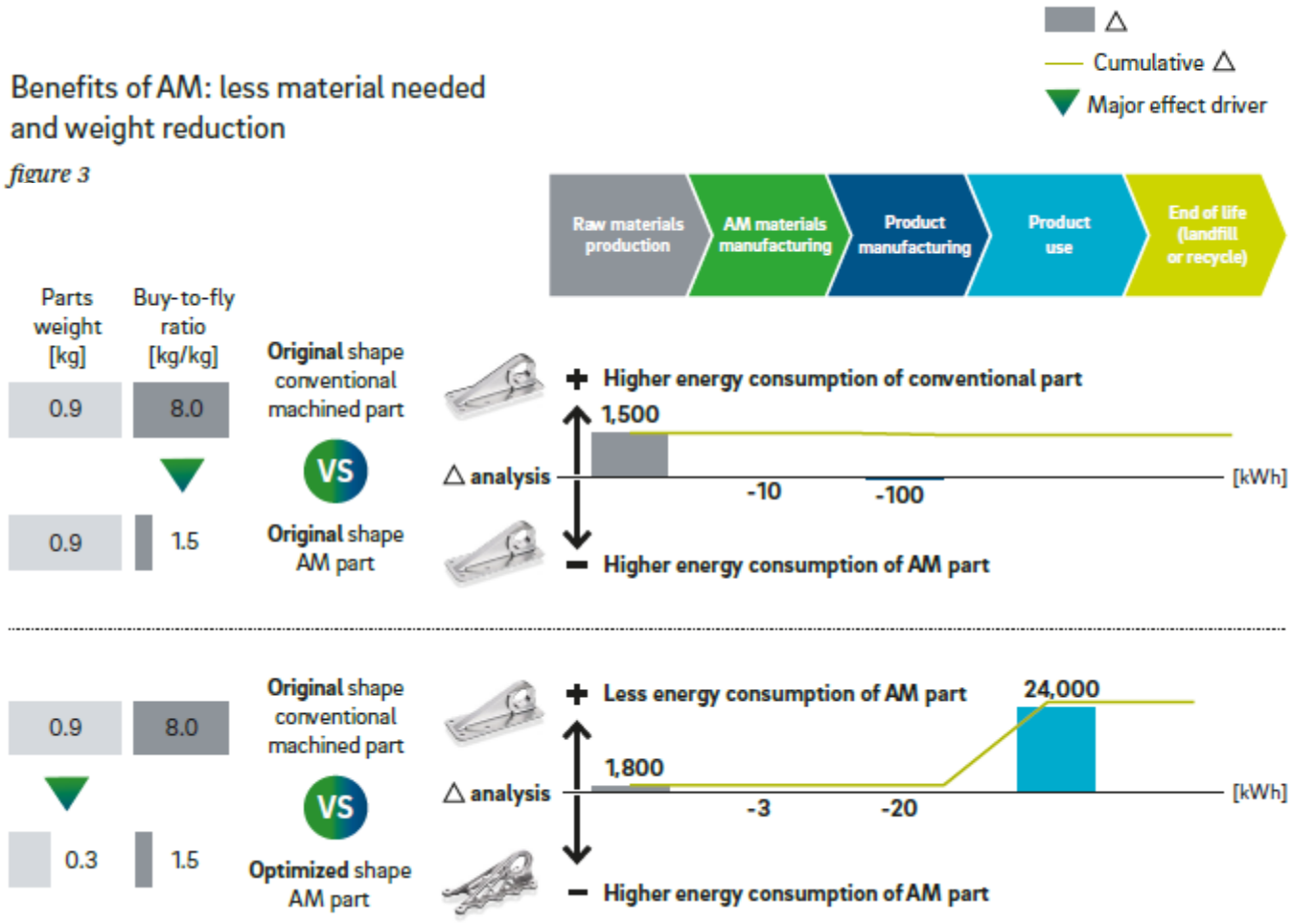



**While most AM manufacturing techniques require additional energy during the material and production phase, the significant benefits of AM in the use phase result in improved overall energy consumption**



# Challenge for additive Manufacturing

## Material and weight reduction can outweigh the disadvantages in energy consumption



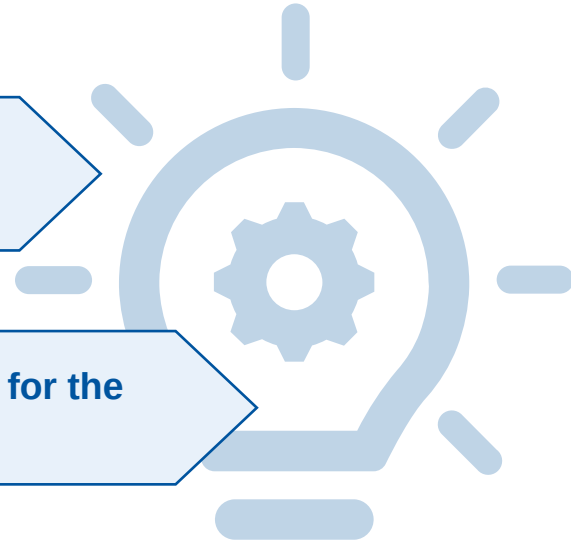

**Depending on the application, the reduction in material and weight can bring considerable advantages to the life cycle assessment for AM**

**How can we identify these use cases and how can we increase the sustainability of AM?**

# Challenge for additive Manufacturing

## The roadmap toward AM as a sustainable manufacturing technology

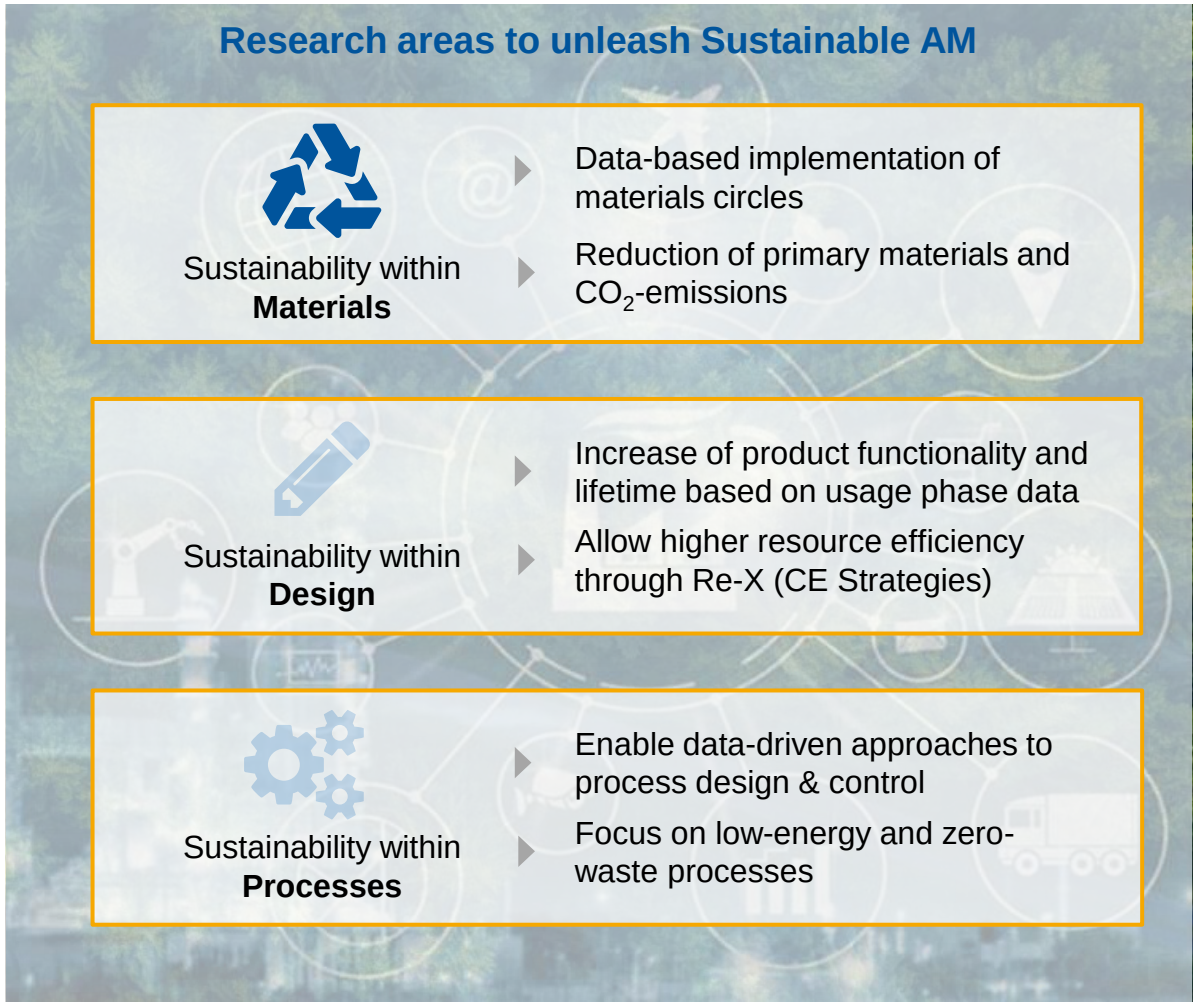
| Challenge | | Followed Roadmap |
|---|---|---|
| 1 | Lack of provided information which is provided for the users | Make the environmental footprint impact of AM materials, machines, and processes more transparent |
| 2 | Databases for life cycle assessment calculations for AM insufficient | Develop an LCA database, especially for the usage and recycling phases |
| 3 | No quick analyses are possible for the comparison of LCAs between CM and AM | Predict environmental impact before printing |
| 4 | Potential of AM is not yet exhausted regarding sustainability | Take action to reduce the environmental footprint of AM |



# Improving Sustainability of AM
## Key Message, Potentials & Outlook

**Key message:**

- AM plays a role in sustainability
- We should not optimize only one component
- Use the data to help this conflict
- AM as a key tech for sustainable production also
  due to its strong link to the digital world
- Increasing knowledge of the carbon footprint is essential to optimize technology and identify potential components.



# Your contact

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