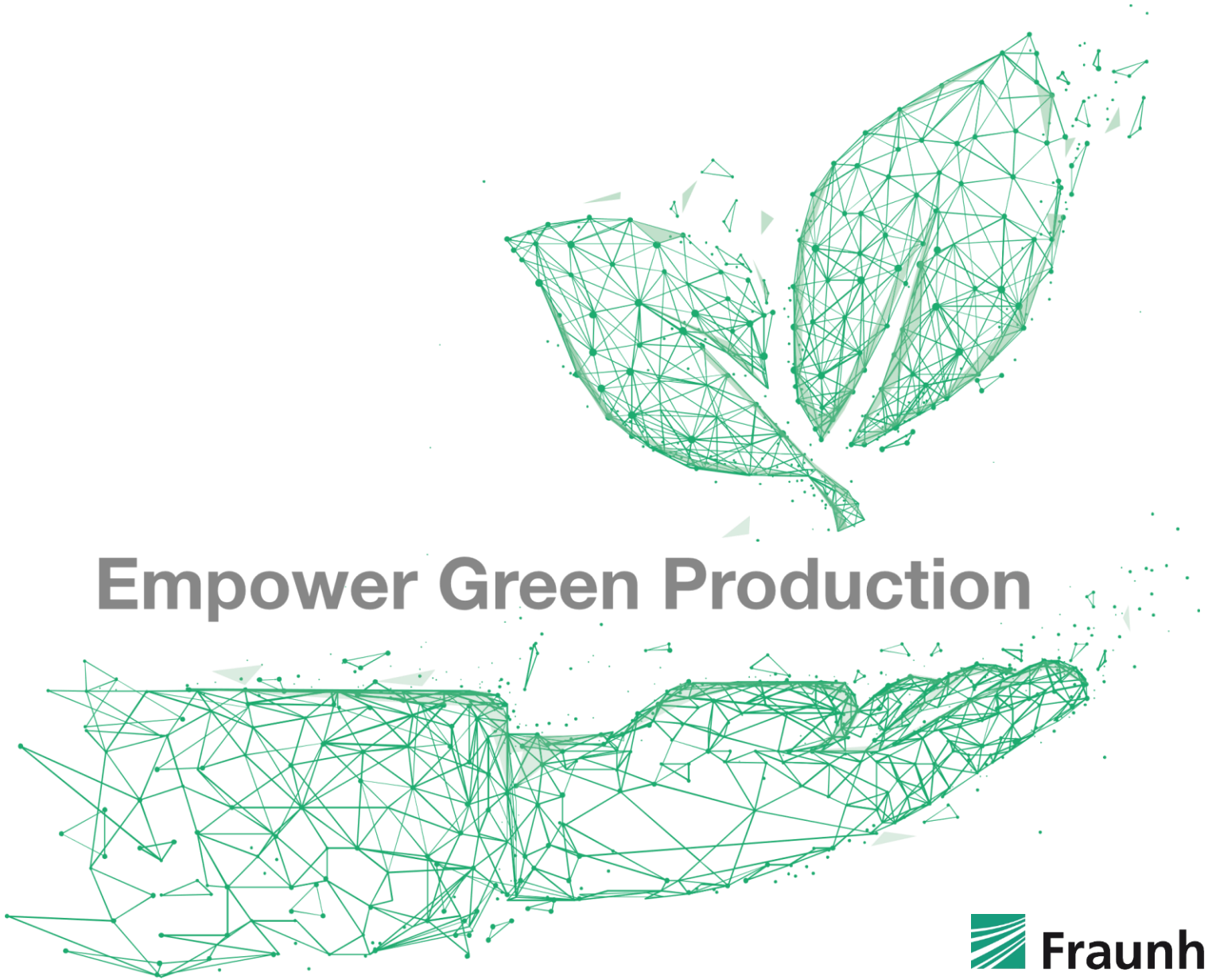
AWK'23

WWW.AWK-AACHEN.DE 11. / 12. MAI 2023

Manufacturing for a Circular Economy



Keynote – Session 2

Prof. Dr.-Ing. Thomas Bergs

Dr.-Ing. Jens Brimmers
Philipp Niemietz
Dr.-Ing. Robin Day
Philipp Ganser
Dr.-Ing. Tim Herrig

Fraunhofer IPT

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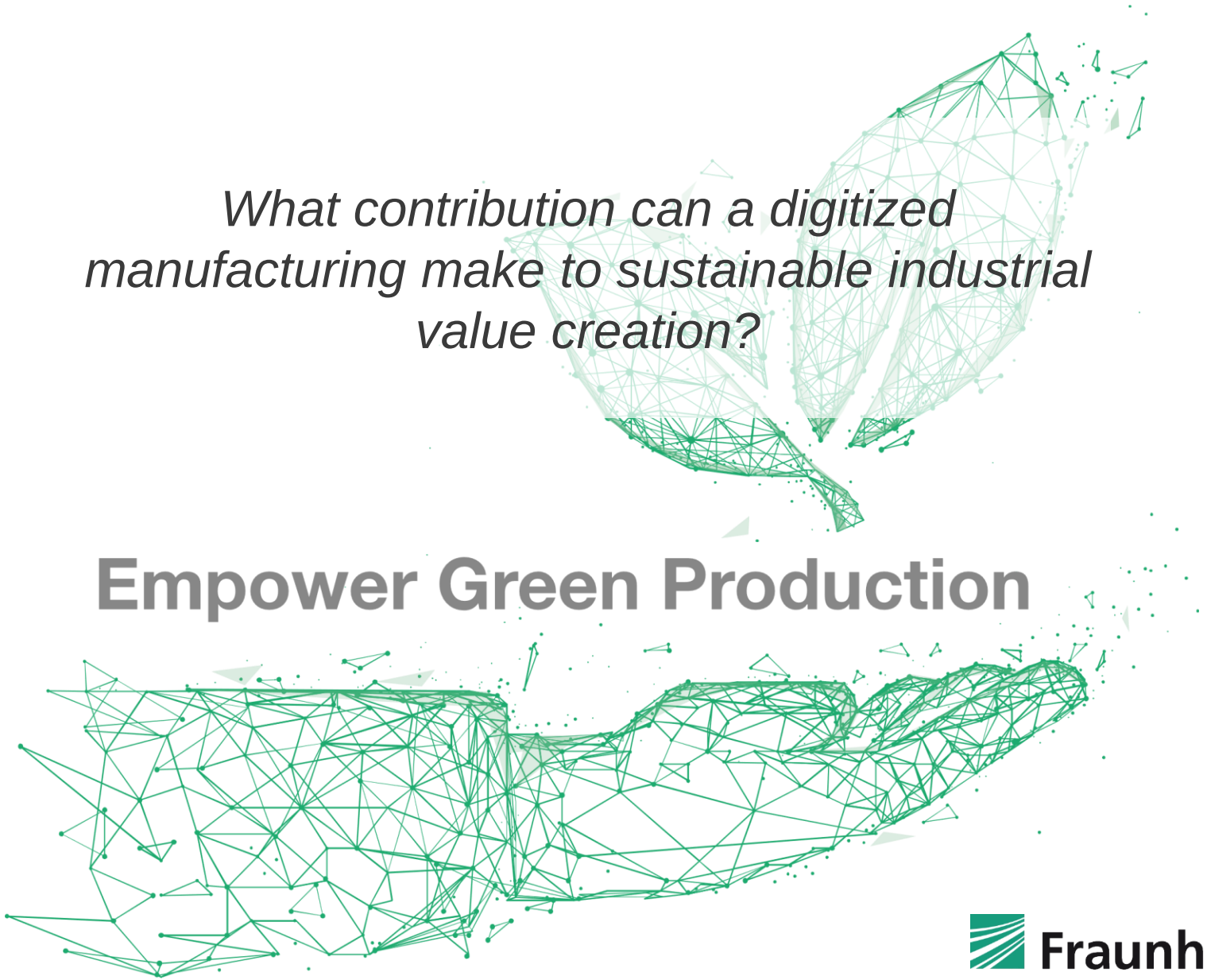
What contribution can a digitized manufacturing make to sustainable industrial value creation?

Manufacturing for a Circular Economy



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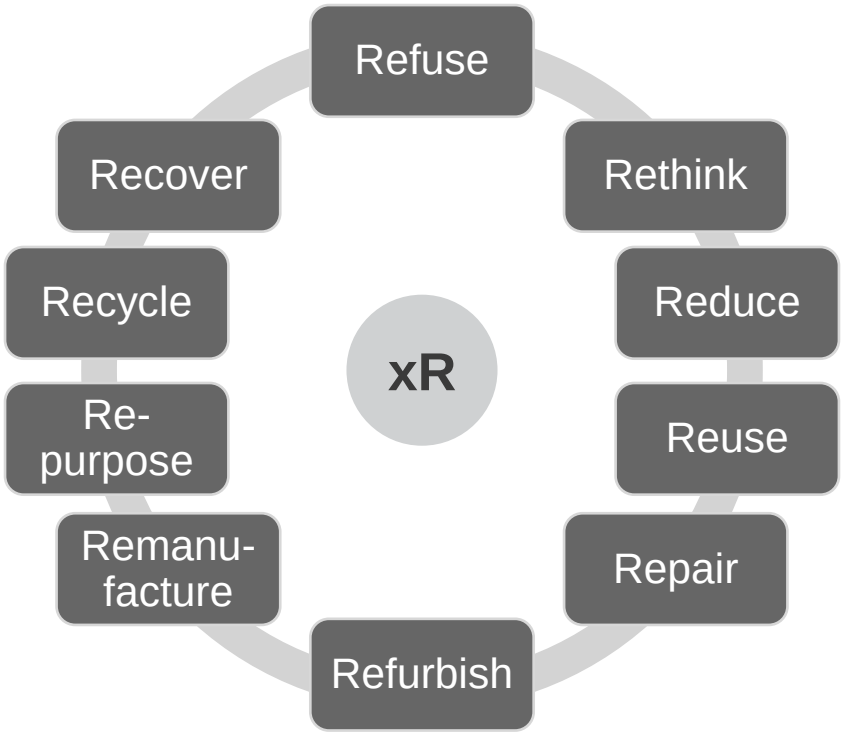
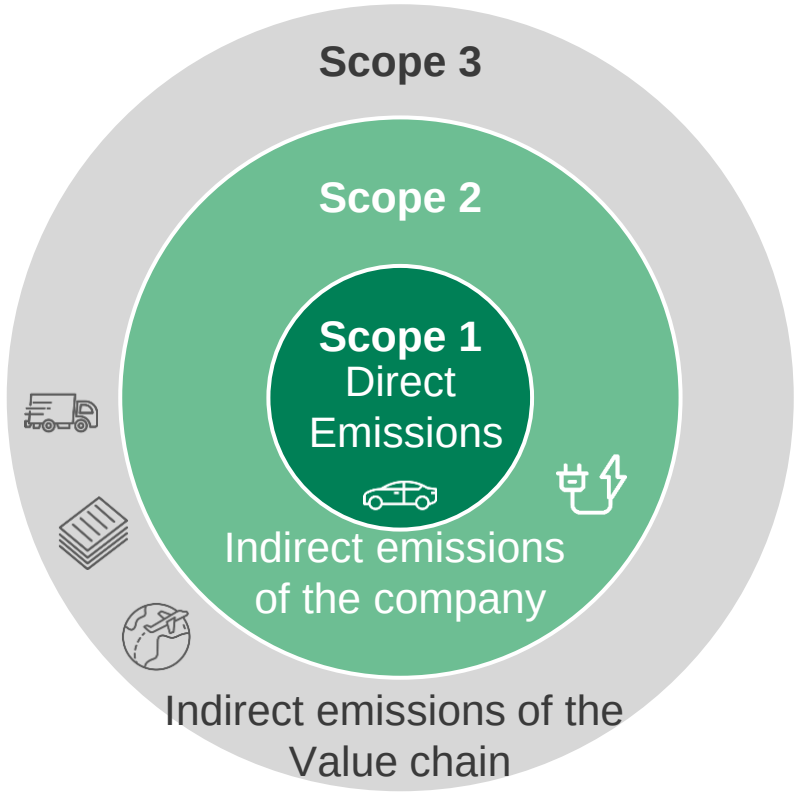
Established, methodical building blocks of the circular economy
Measures - Framework - Evaluation

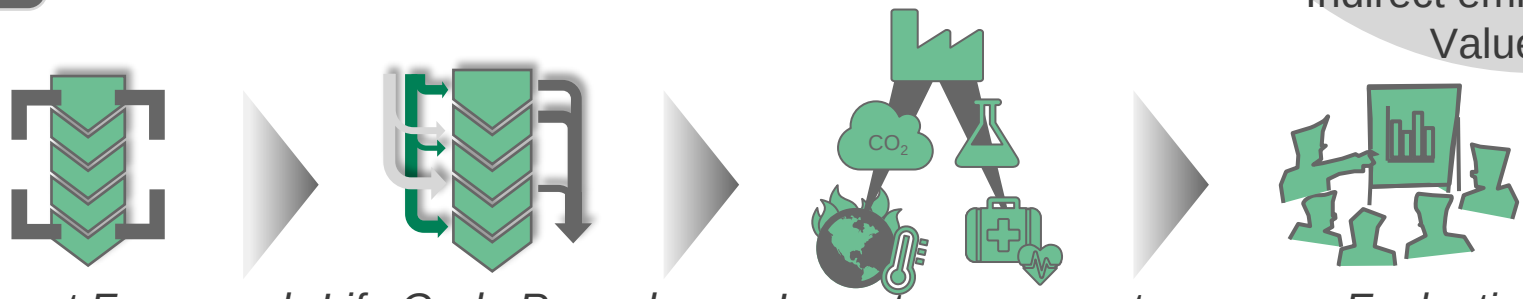


R-cycles for the Circular economy

Greenhouse Gas Protocol[1)]



Life Cycle Assessment according to DIN EN ISO 14044



Goal & Impact Framework *Life Cycle Record* *Impact assessment* *Evaluation*

1): https://ghgprotocol.org/

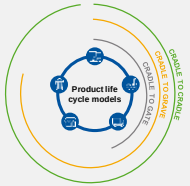
Sustainable production
Four design stages from the perspective of manufacturing

Product perspective | *Production perspective*

New value creation models

- Realization of circular economy potentials ("R-scenarios")

Reuse | Repair | Refurbish | Remanufacture | Recycle | ...



Manufacturing processes

- Transparency about resulting economic-ecological impact

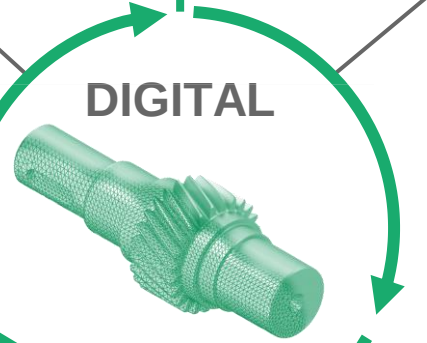
Life cycle assessment

- Transparency about the operational behavior of the manufactured components

Idea → Design → Production → Use

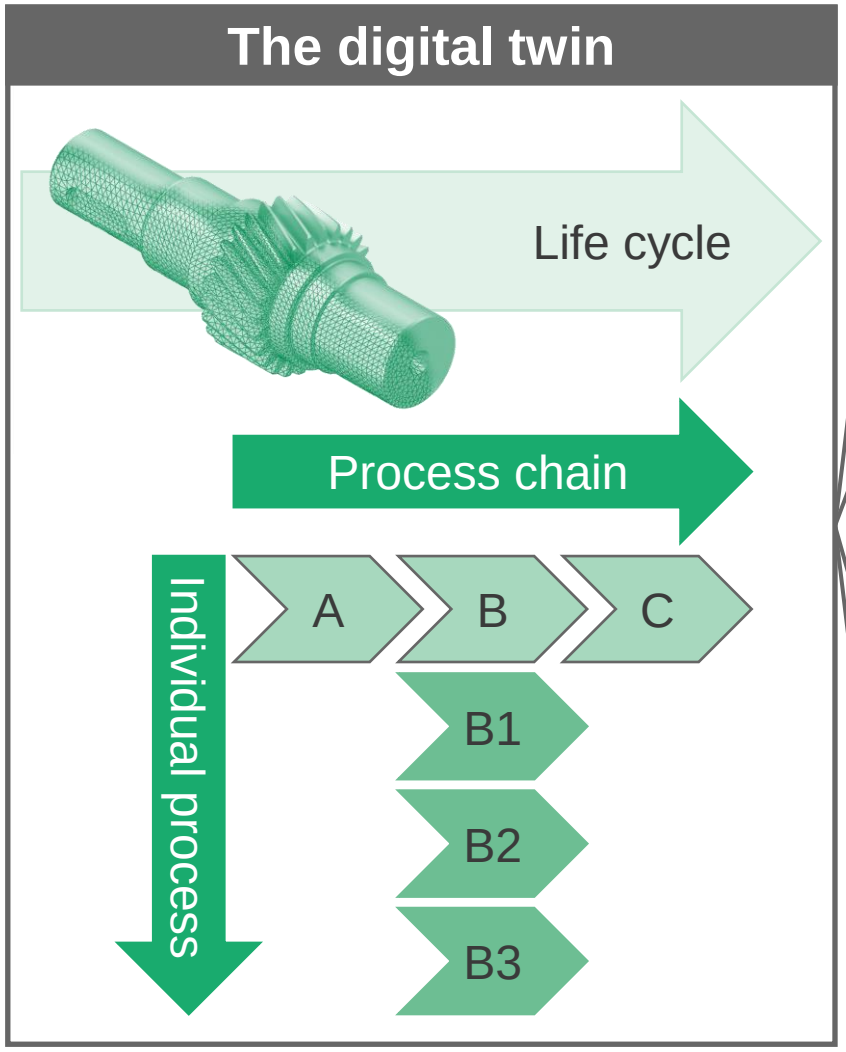
Functionally relevant properties

- Transparency about the production-related condition of the components



Icon Source: Flaticon

Enabler for the implementation of sustainable production
The digital twin



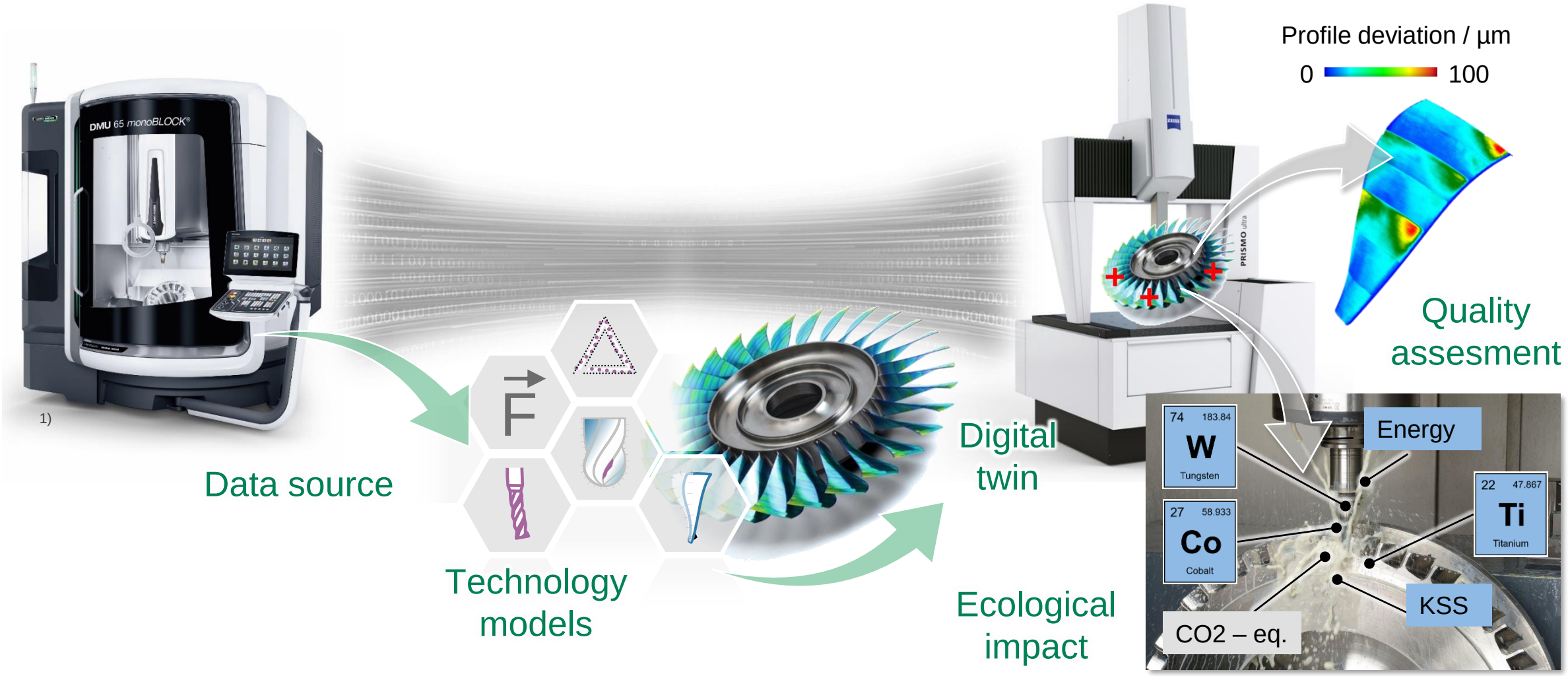
Data acquisition and connectivity
for the analysis of the individual processes and process chains as well as the operational behavior of the component

Standardized interfaces and IT architectures
for the exchange, recording and analysis of data in a heterogeneous manufacturing environment

Exchange platforms and data rooms
for "trusting" cross-company collaboration

Analysis and forecasting capability
*for the holistic evaluation and optimization of ecological value-added processes **and products***

Enabler for the implementation of sustainable production
The digital twin



Source: Fraunhofer IPT 1) Figure DMG MORI, 2) Figure Zeiss

Design of sustainable process chains
Production of a geared pinion shaft for electromobility

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Specifications

Material:	16MnCr5
Heat treatment:	case hardening
Quantity:	> 1000 pcs.
Length:	140.7 mm
Diameter:	49.0 mm
Face width:	22.4 mm
Module:	1.7 mm
Number of teeth:	24
Helix angle:	21.2°

Process chain

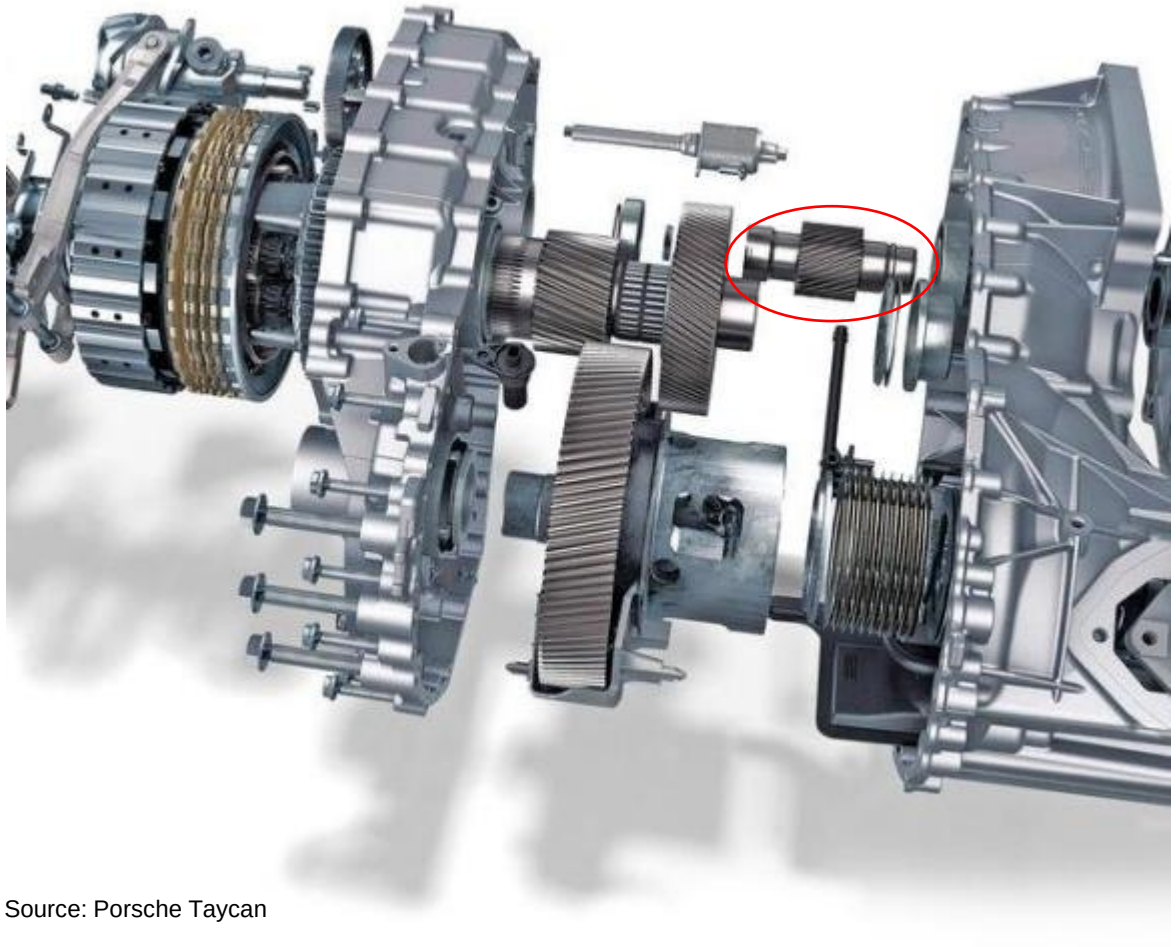
Soft turning

Gear hobbing

Cylindrical grinding

Gear-grinding

Use case



Source: Porsche Taycan

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Design of sustainable process chains
Process chains for the series production of geared pinion shafts



Material → Soft turning → Gear hobbing → Heat treatm. → Round grinding → Profile grinding → Usage → End-of-Life

Hard turning → Generating grinding




DMG NZX 1500 **Liebherr LC180** **Studer S41** **Klingelnberg 500KW**

Digital twin

Production, quality and usage data

Life cycle assessment

Influence analysis and data-driven optimization

Digital twin

Challenge: Heterogeneous machinery and linking of individual process data

Design of sustainable process chains
Recording of the component-related use of resources for the digital twin

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Microoptical wear monitoring

DMG NZX 1500

Edge-Gateway

Celos Control
Fanuc Focas
Library

AE sensor system

Insitu Process-sensory

Recording of cutting force & coolant use

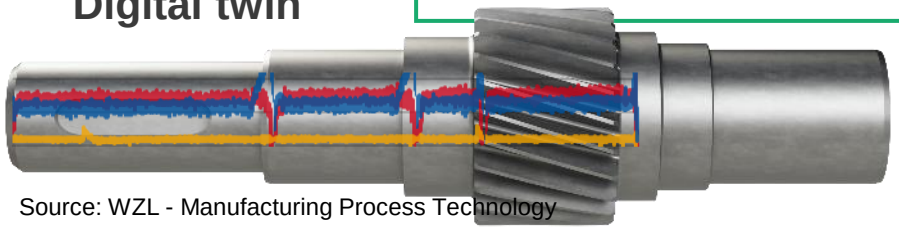
Machine Cloud

Liebherr LC180

Studer S41

Klingelnberg Viper 500KW

Digital twin



Meta Data

Source: WZL - Manufacturing Process Technology

Fraunhofer IPT

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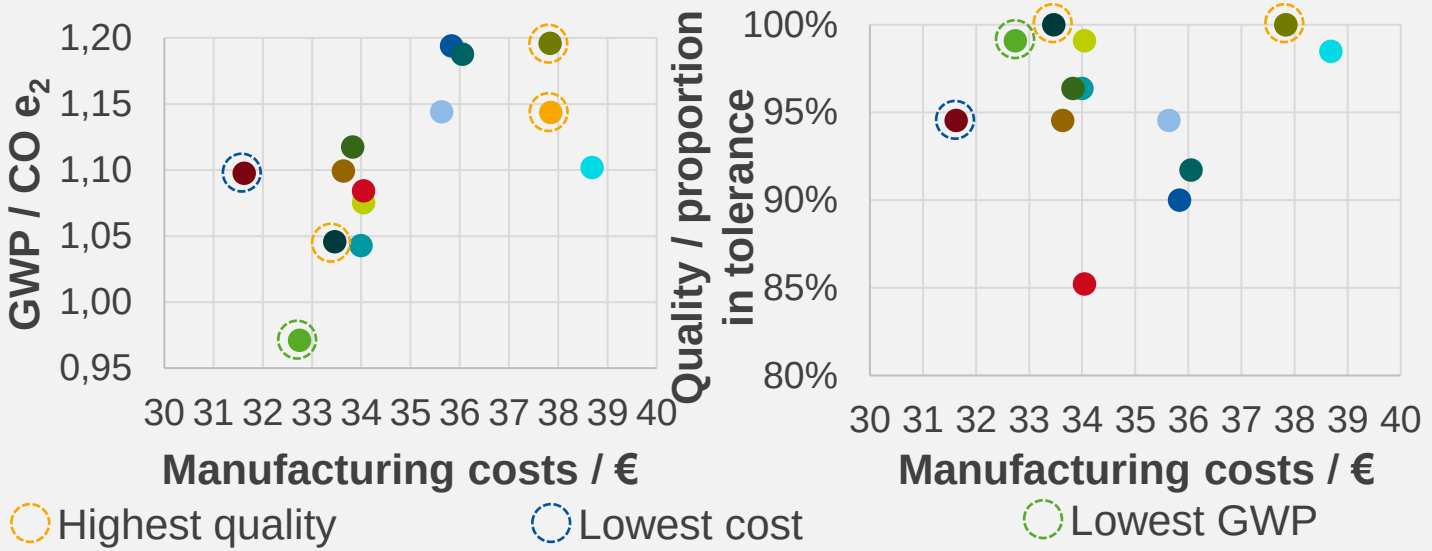
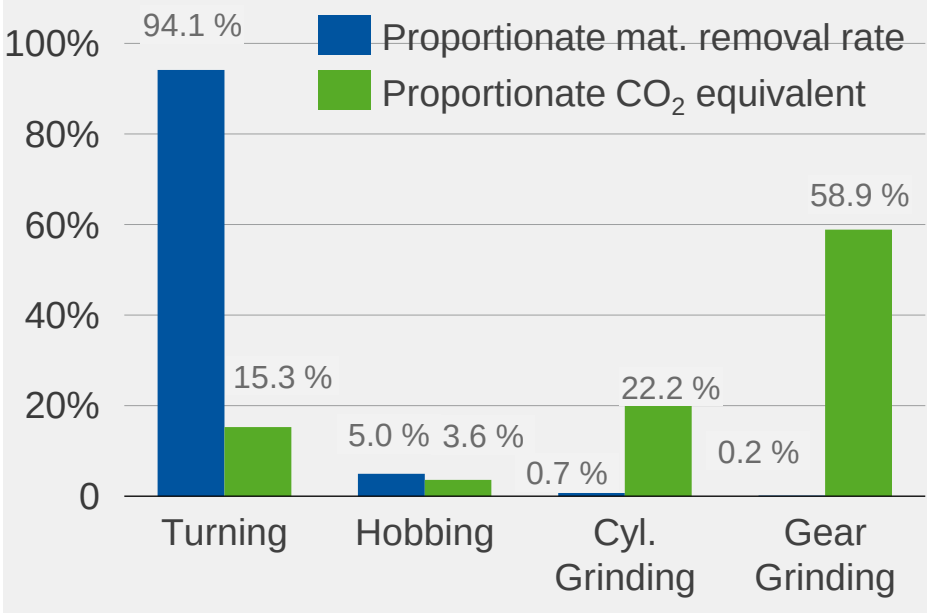
Economic-ecological evaluation and optimization of production

Results



Experiments: Variation of process designs and process parameters



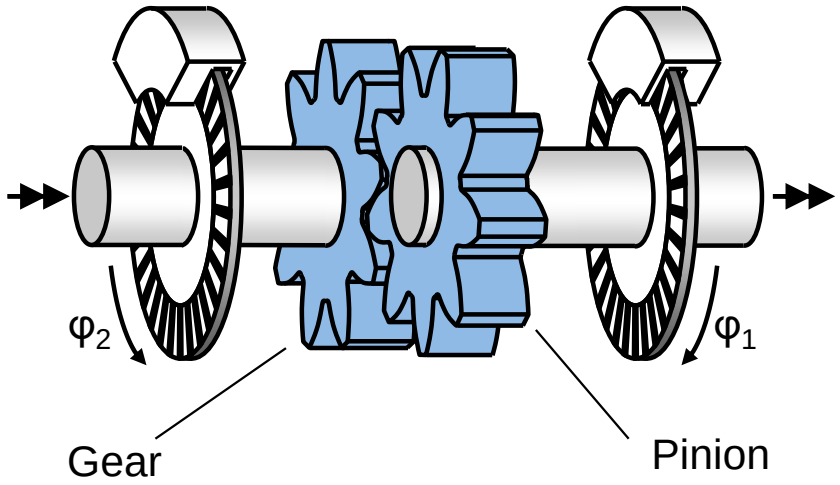
Optimization approaches can be identified through the identification of cross-process correlations and through data-based analyses.

Abbreviations: EG - Experimental group with variation of process sequence and process parameters GWP - Global warming potential

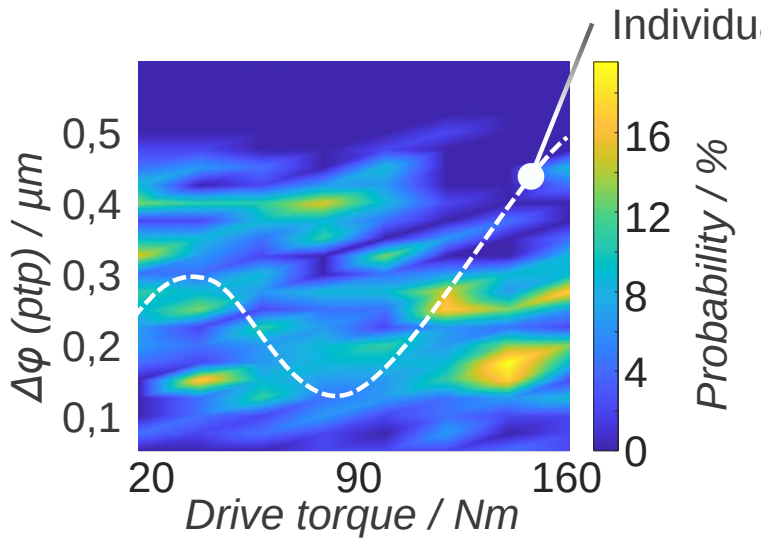
Correlation of manufacturing variation with functionally relevant effects

Analysis of the excitation behavior

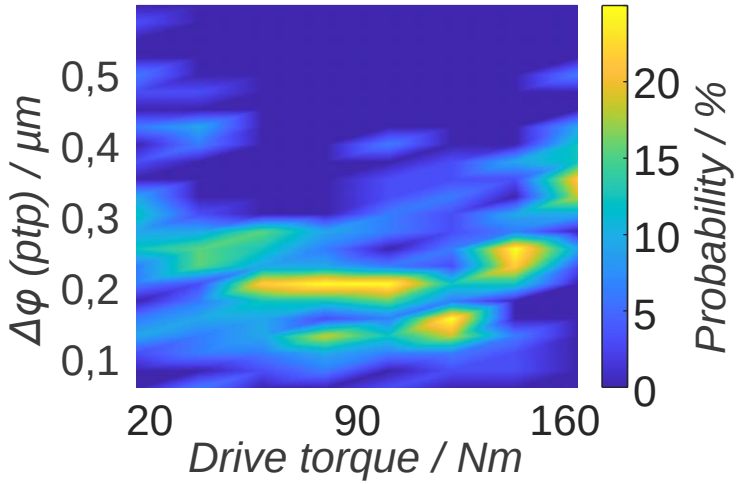
$$\Delta\varphi(t) = \varphi_2(t) - \frac{z_1}{z_2} \cdot \varphi_1(t)$$



Batch 1: n = 27 shafts



Batch 2: n = 45 shafts



All the shafts examined have a high and comparable geometric manufacturing quality

Influence of production on the use phase clearly visible and currently not fully explained by classic manufacturing tolerances

Rapid realization of sustainable products
The role of manufacturing using the example of mobility applications

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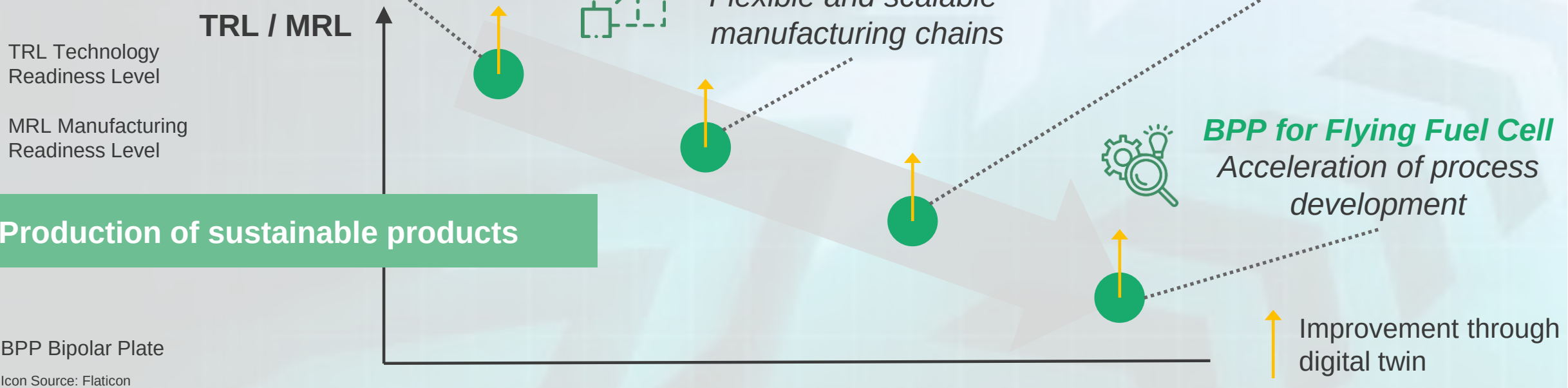
Sustainable production

Cooling plates for battery modules
Safeguarding of series processes & digital ramp up

Nozzle module for H_2
Flexible and scalable manufacturing chains

Fan BLISK for Rig-Tests
Acceleration of product development

BPP for Flying Fuel Cell
Acceleration of process development



Icon Source: Flaticon

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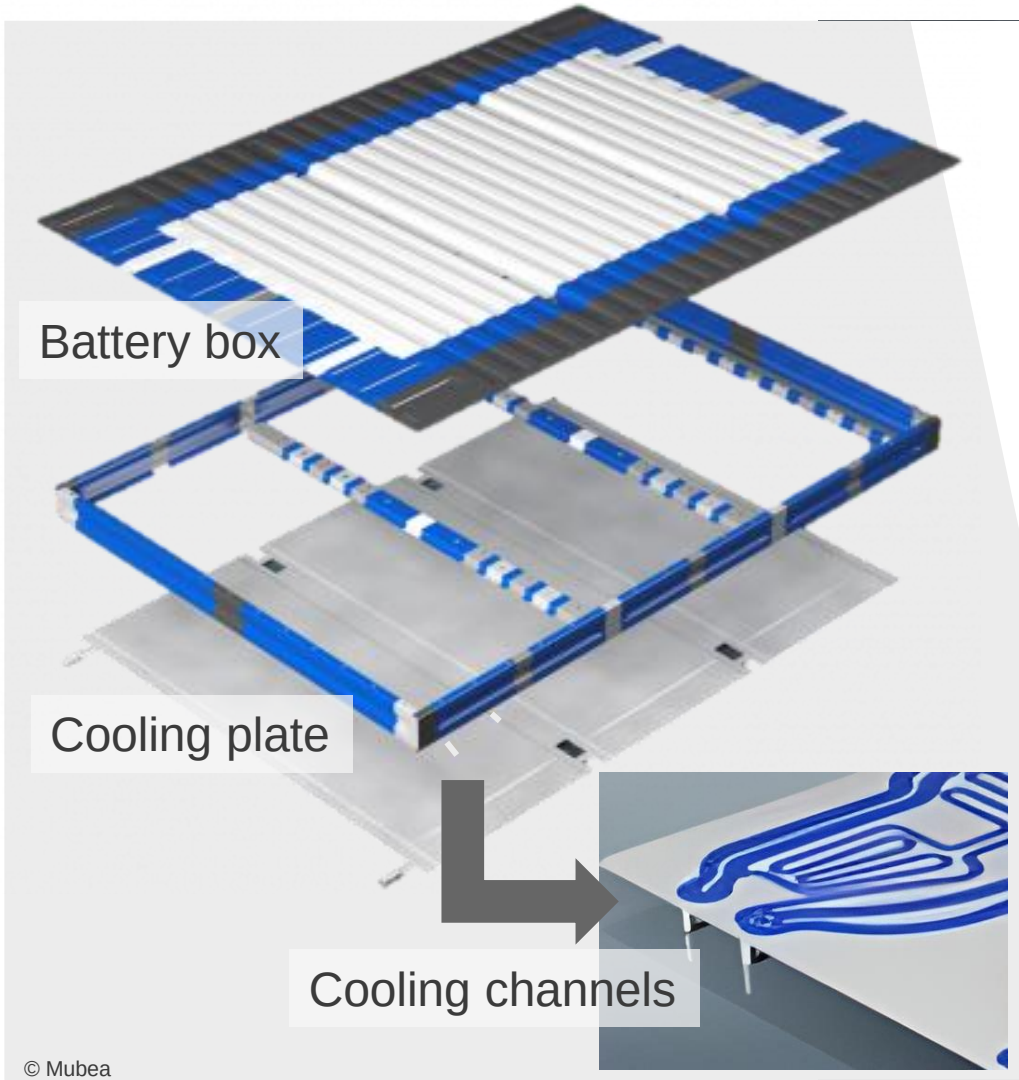
Cooling plates for battery modules in electromobility
Series production via roll bonding



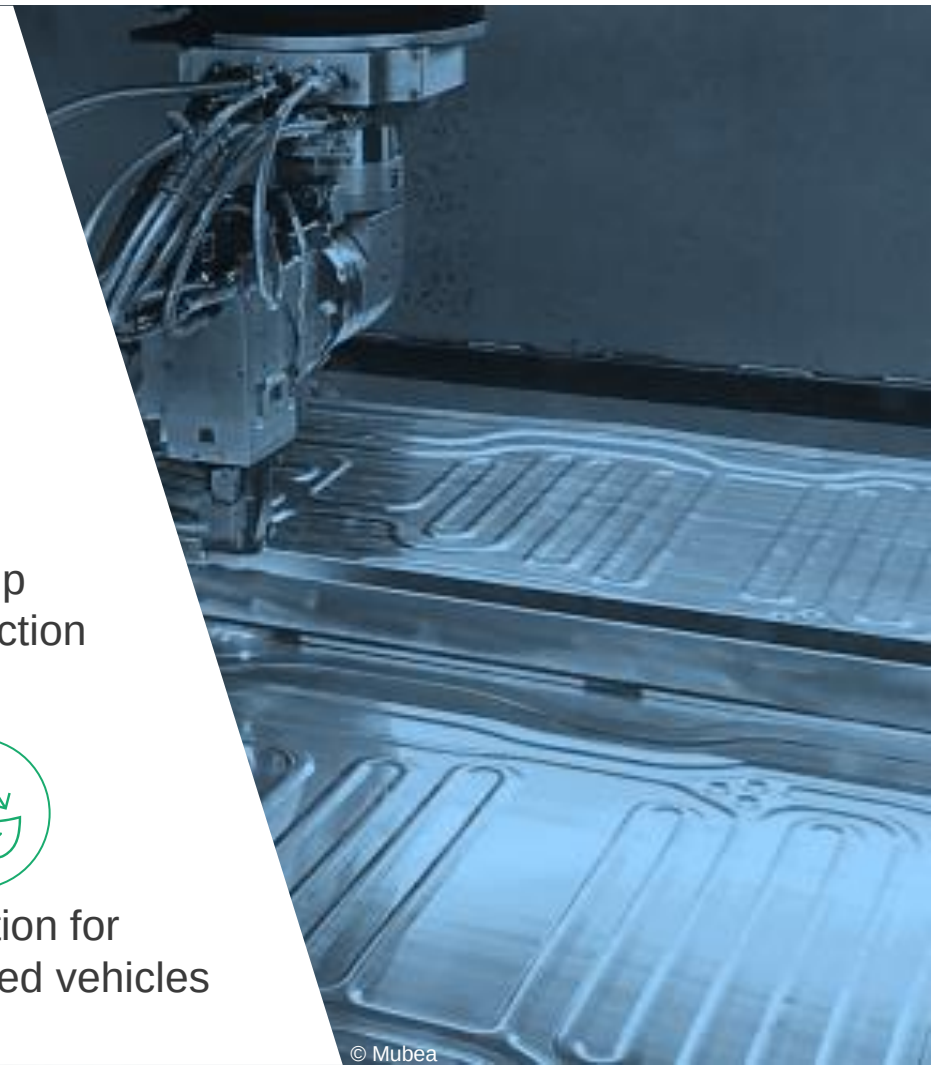
© Mubea

Cooling plates from aluminum or steel

Efficient Ramp-Up of large-scale production

Contribution for battery powered vehicles

Icon Source: Flaticon



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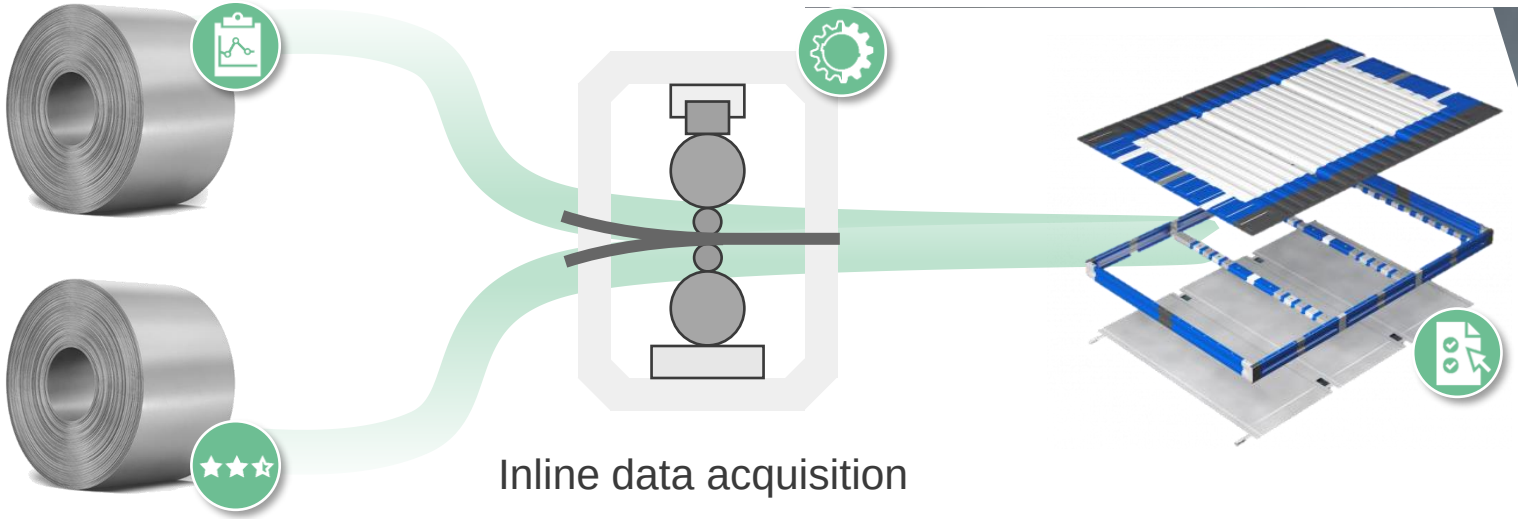
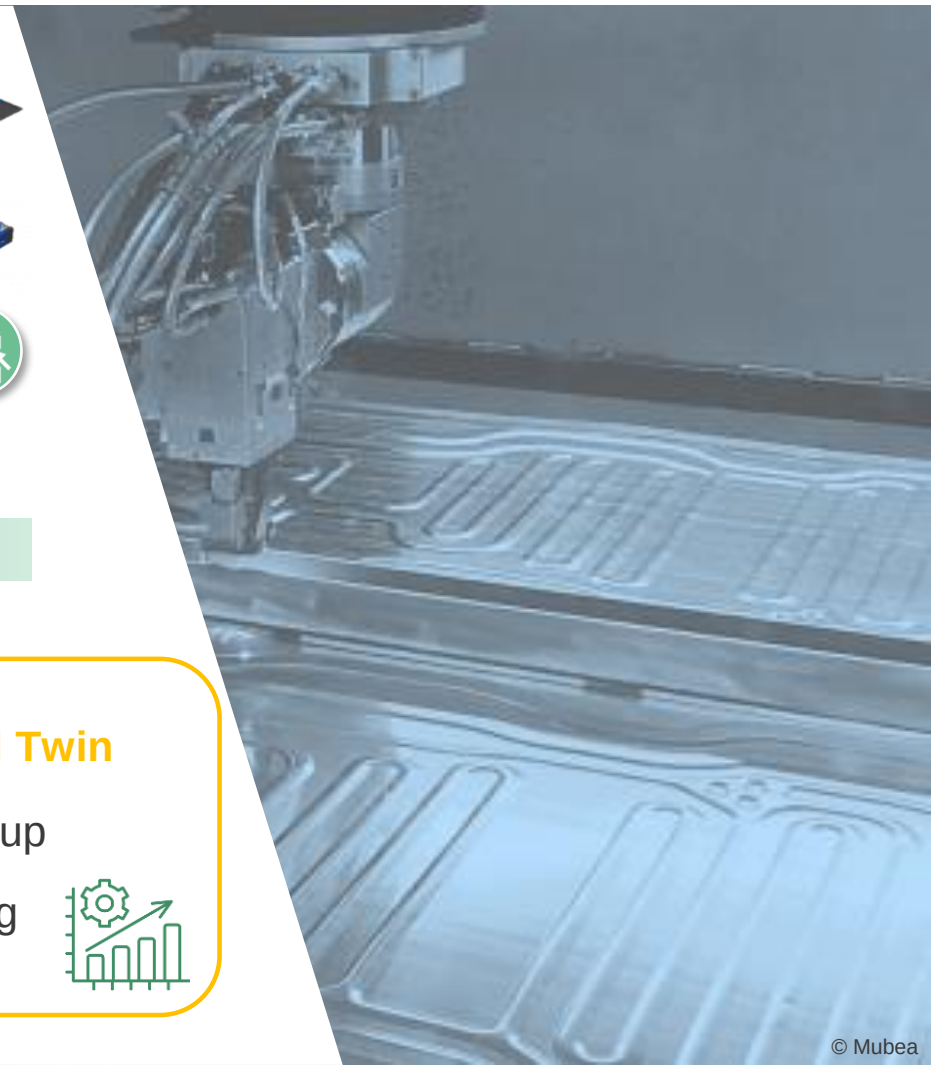
Cooling plates for battery modules in electromobility
Digitization to accelerate the start of series production

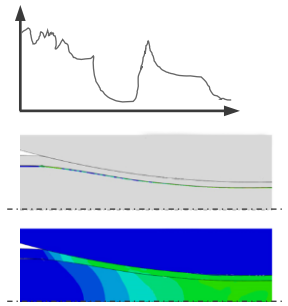




Sensor data

Simulation data

Technical expertise



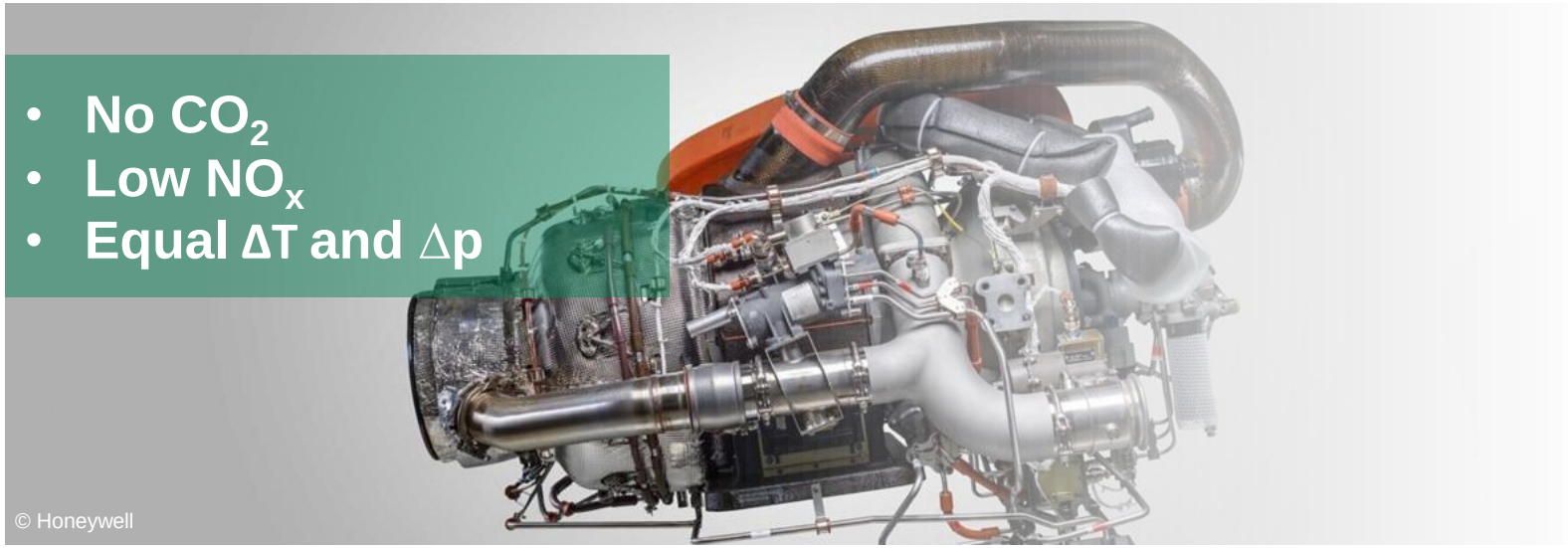
Use of the Digital Twin

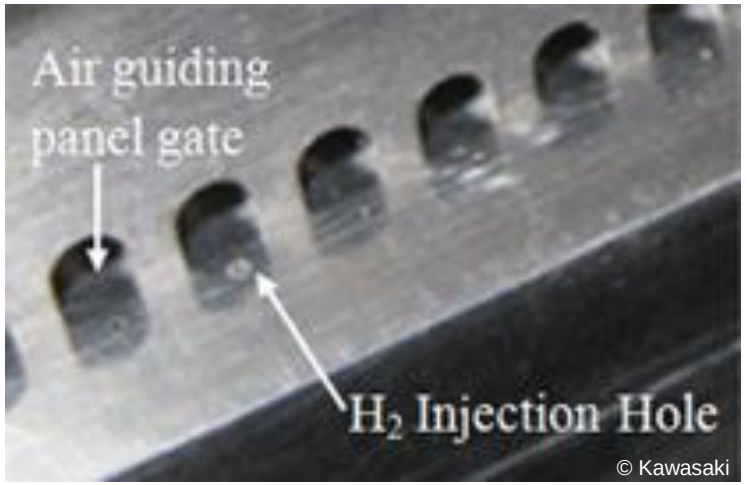
- Accelerated ramp up
- Process monitoring

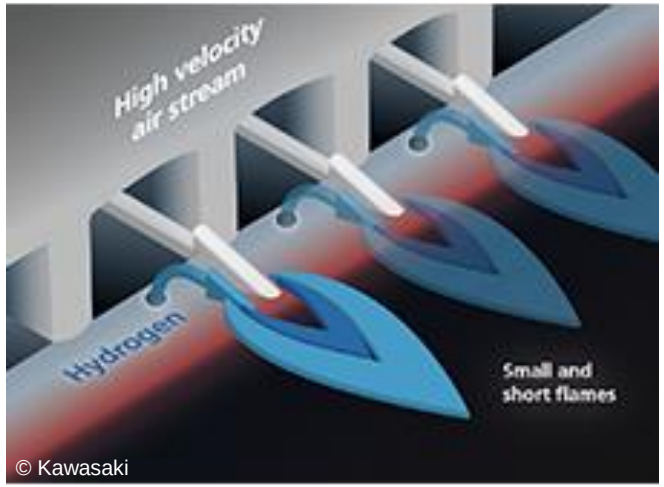
Icon Source: Flaticon

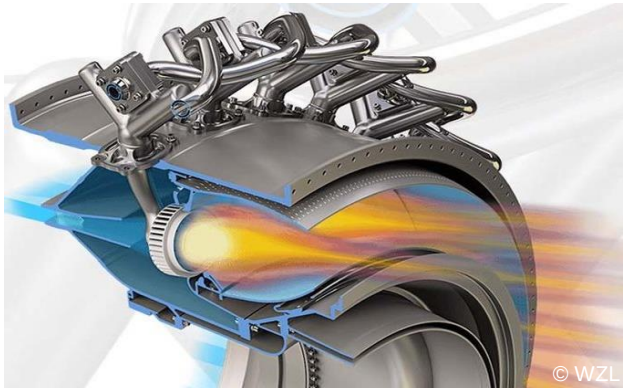
Direct combustion of hydrogen in gas turbines
Combustion chamber retrofit for an Auxiliary Power Unit (APU)

- No CO_2
- Low NO_x
- Equal ΔT and Δp









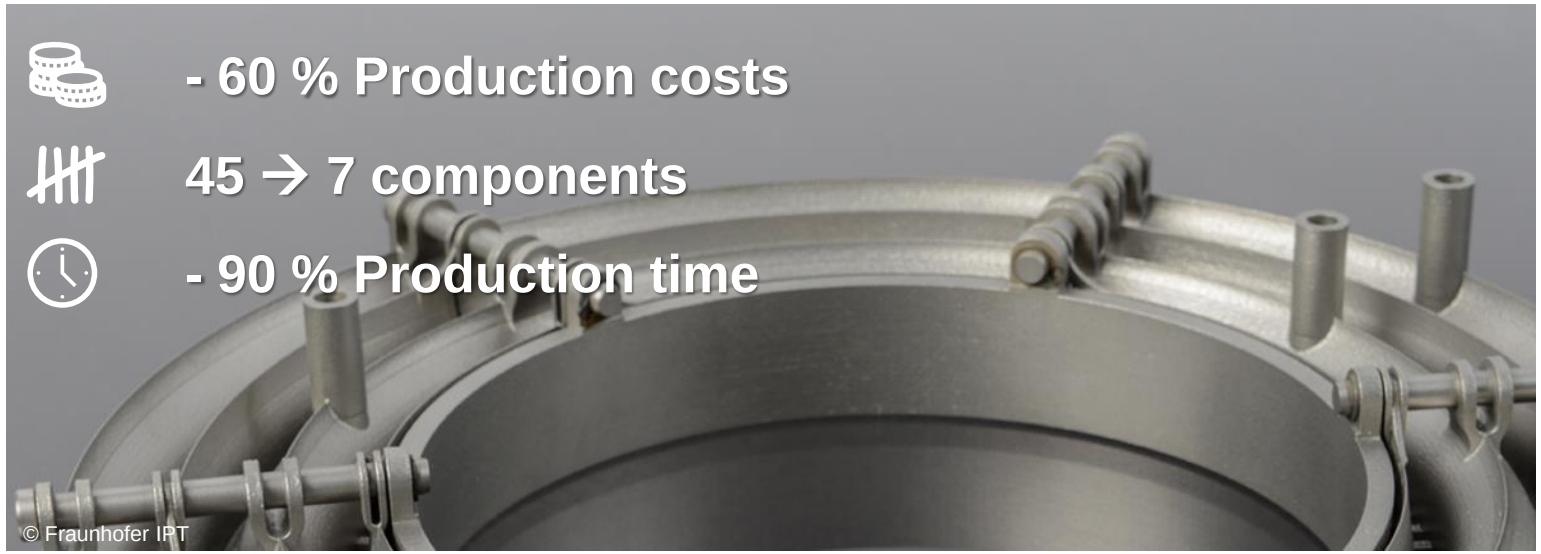
6 injectors - flame length (dm)

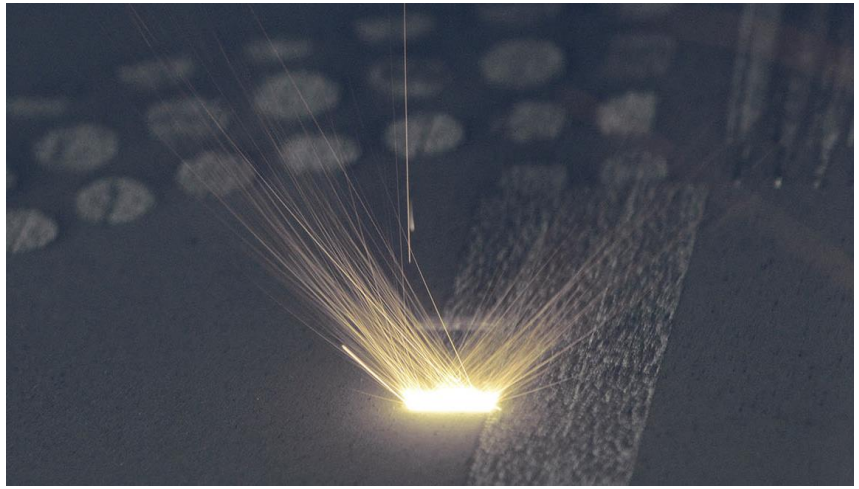
Plug in

300 Injectors - flame length (mm)

100 % Jet A1 → H_2 in same turbomachine

Direct combustion of hydrogen in gas turbines
Use of additive manufacturing for the series process





Fully digitized process chain

Semi-finished product production
- Laser Powder Bed Fusion (material characteristics, function, leak proof)

Postprocessing
- Heat treatment (distortion)
- Spoke drilling (centering)
- Separation (reference loss)

Subtractive machining
- Milling (clamping, reference, oscillation)
- Erosion (position, tolerance)

Sustainable aerospace propulsion
Design principle of a high bypass turbofan

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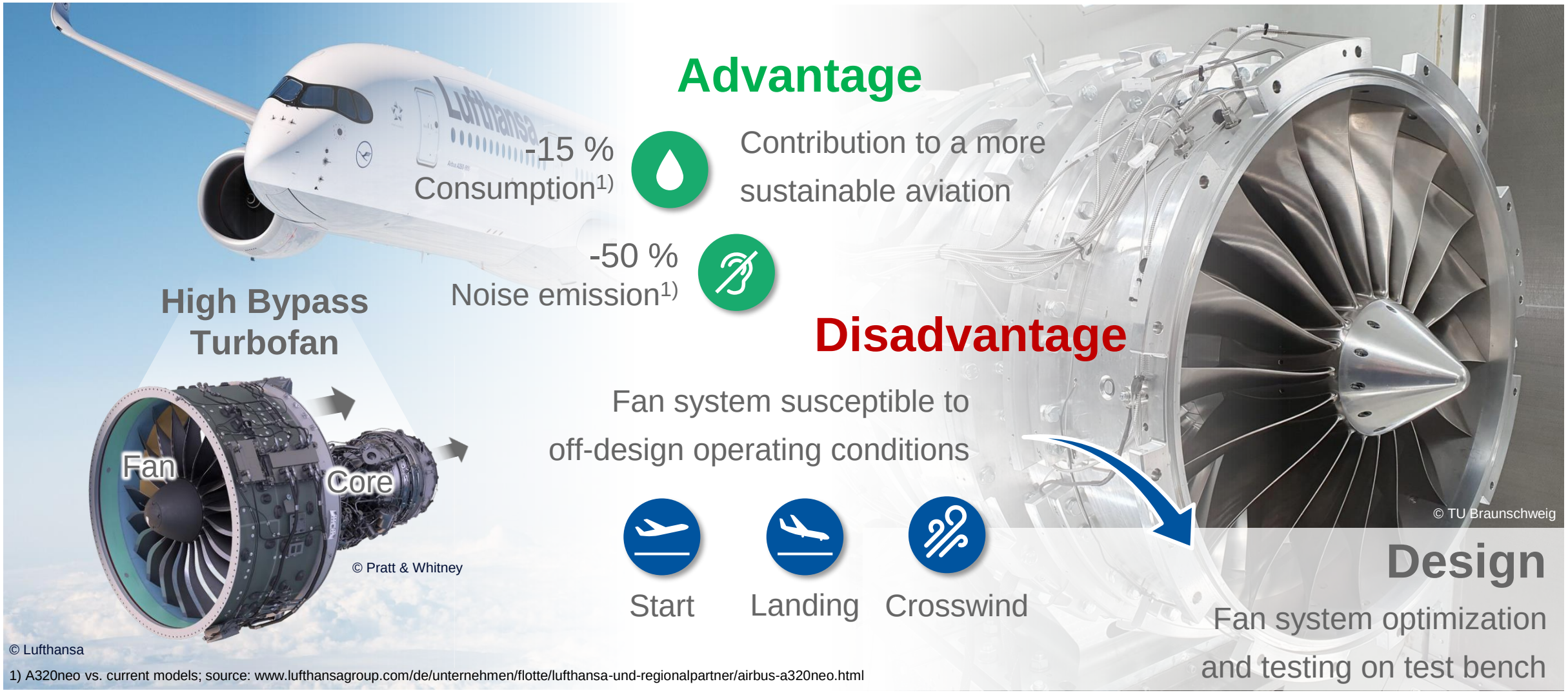

Advantage

-15 % Consumption[1)]

Contribution to a more sustainable aviation

-50 % Noise emission[1)]

High Bypass Turbofan

© Pratt & Whitney

© Lufthansa

Disadvantage

Fan system susceptible to off-design operating conditions

Start Landing Crosswind

© TU Braunschweig

Design

Fan system optimization and testing on test bench

1) A320neo vs. current models; source: www.lufthansagroup.com/de/unternehmen/flotte/lufthansa-und-regionalpartner/airbus-a320neo.html

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Prototyping of a Fan-BLISK – first part right

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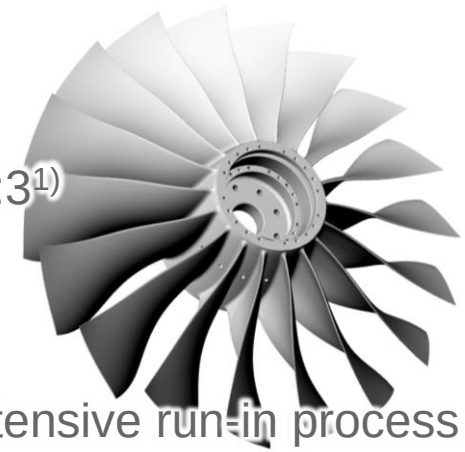
Prototype

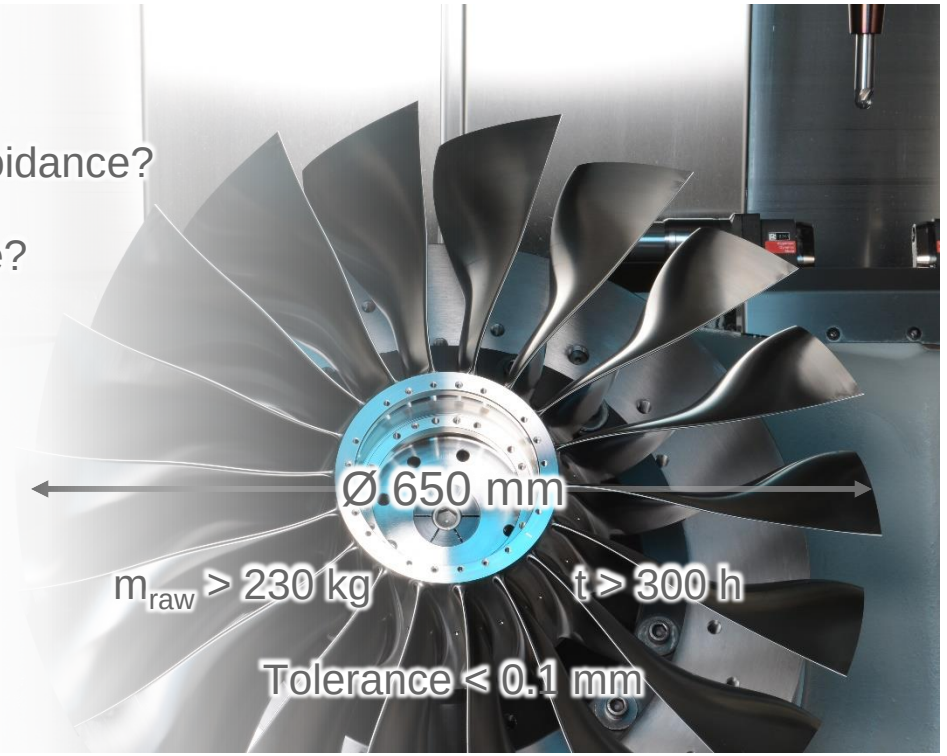
Integral titanium fan in scale 1:3[1)]



Tool life?

Vibration avoidance?

Production time?



Challenge

Highly iterative, resource-intensive run-in process

Process design → Run-in *(approx. 2 parts)* → Manufacturing *(1 part)* → Quality

First-Part-Right

Completely virtual process design

based on the digital twin


Turning


Milling


Quality

1) Deutsches Zentrum für Luft- und Raumfahrttechnik – Institut für Antriebstechnik

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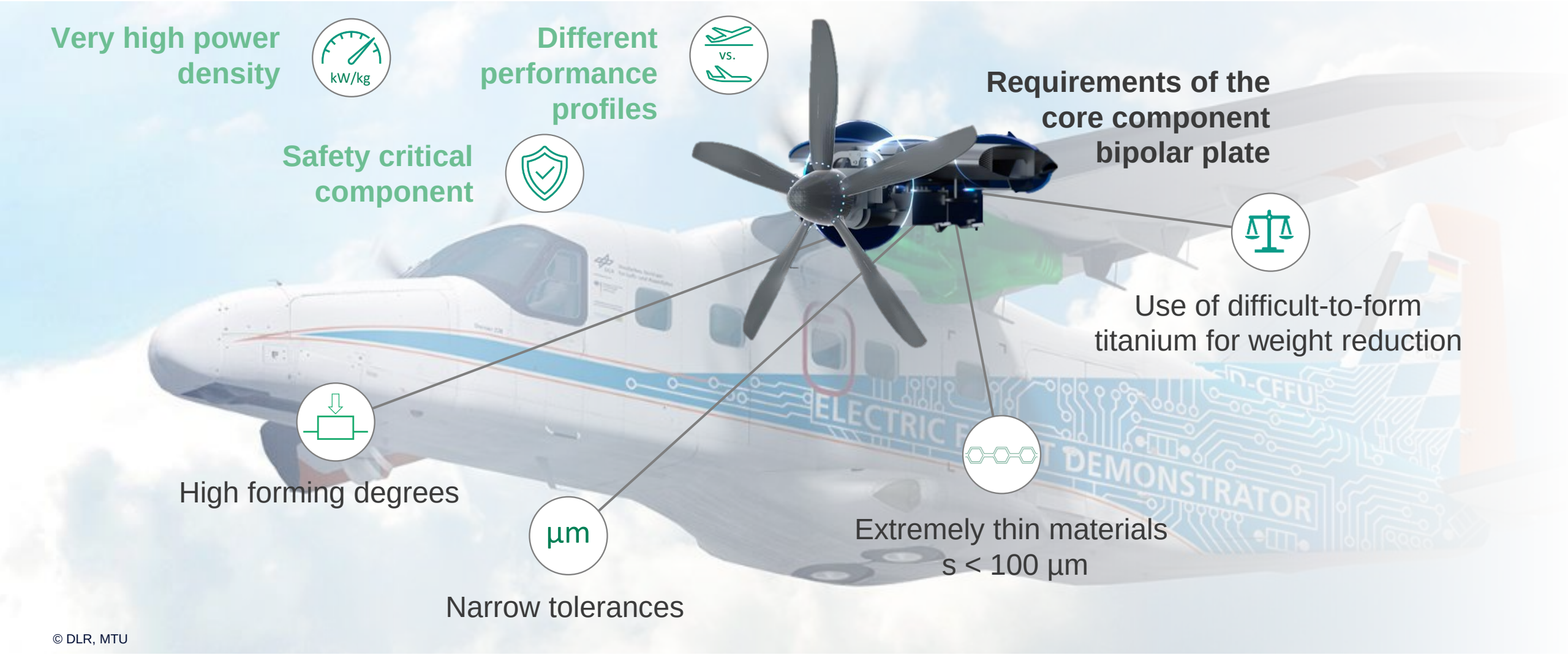
Emission-free flying
"Flying Fuel Cell" for electric aircraft propulsion systems



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Emission-free flying
Process development for demanding forming processes

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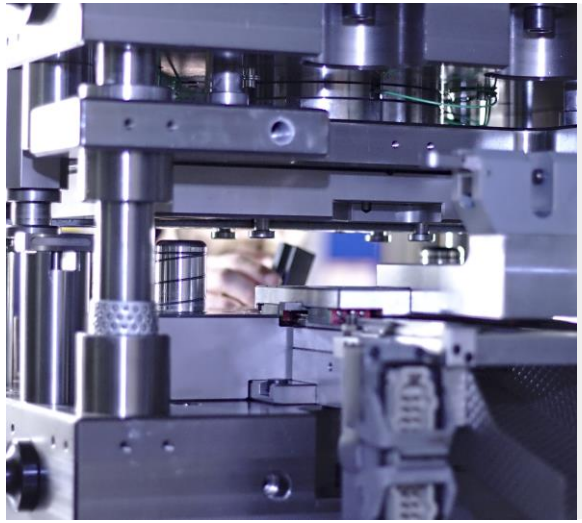
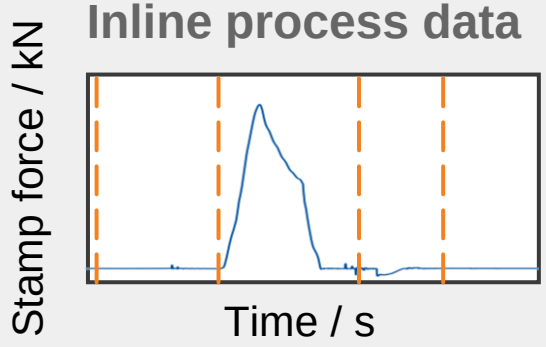
Black Box



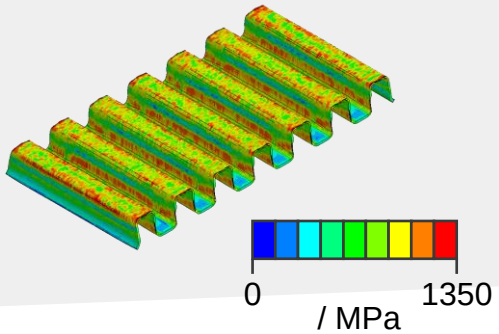
Inline process data



White Box

Material

Simulation



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Icon Source: Flaticon

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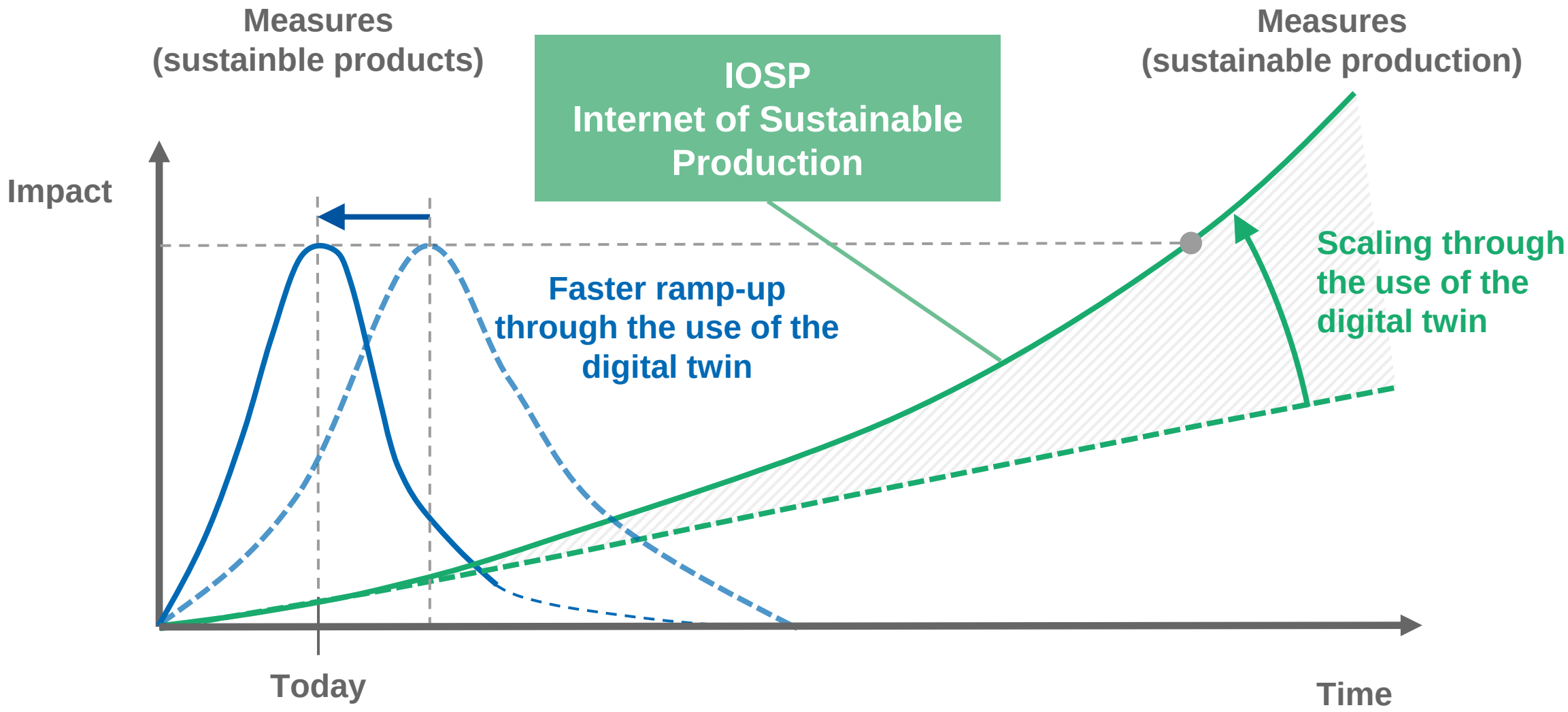
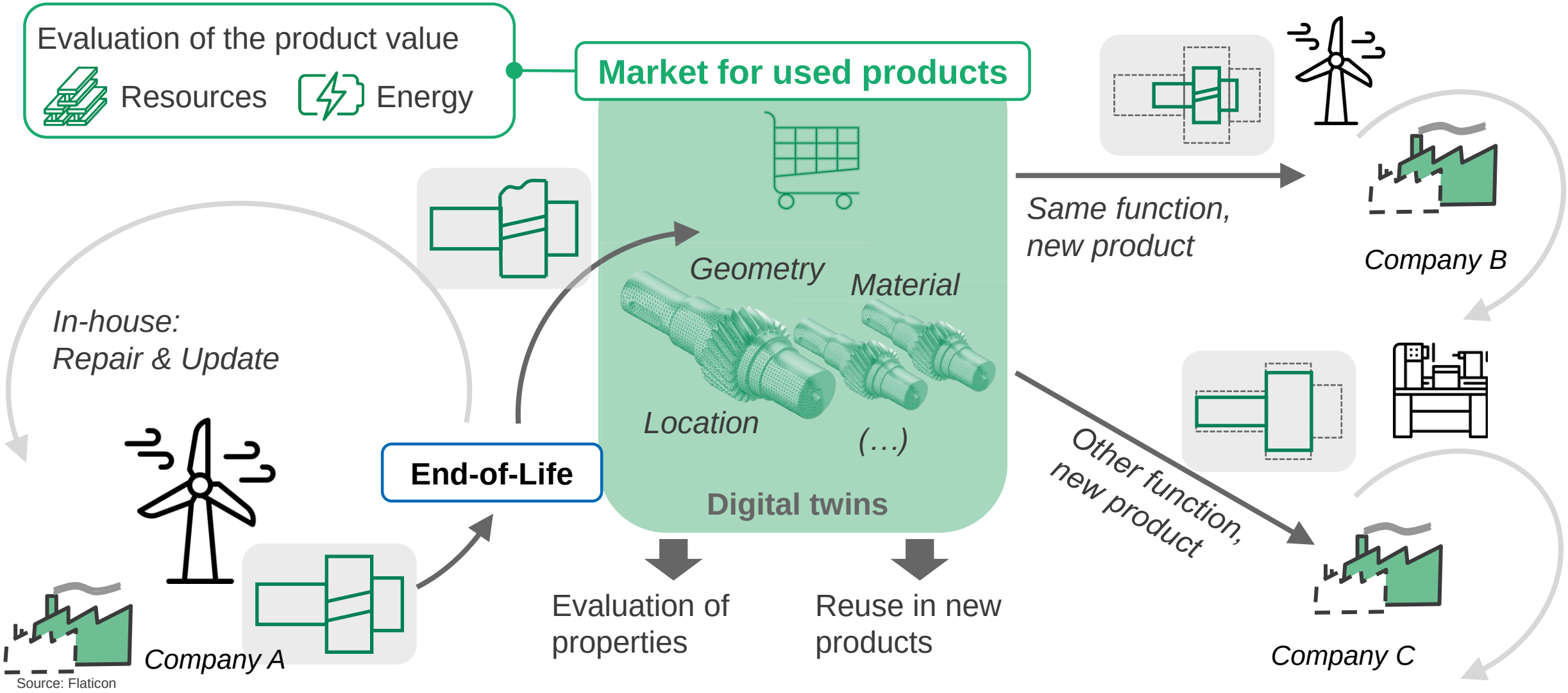
Positioning of production as a sustainability driver

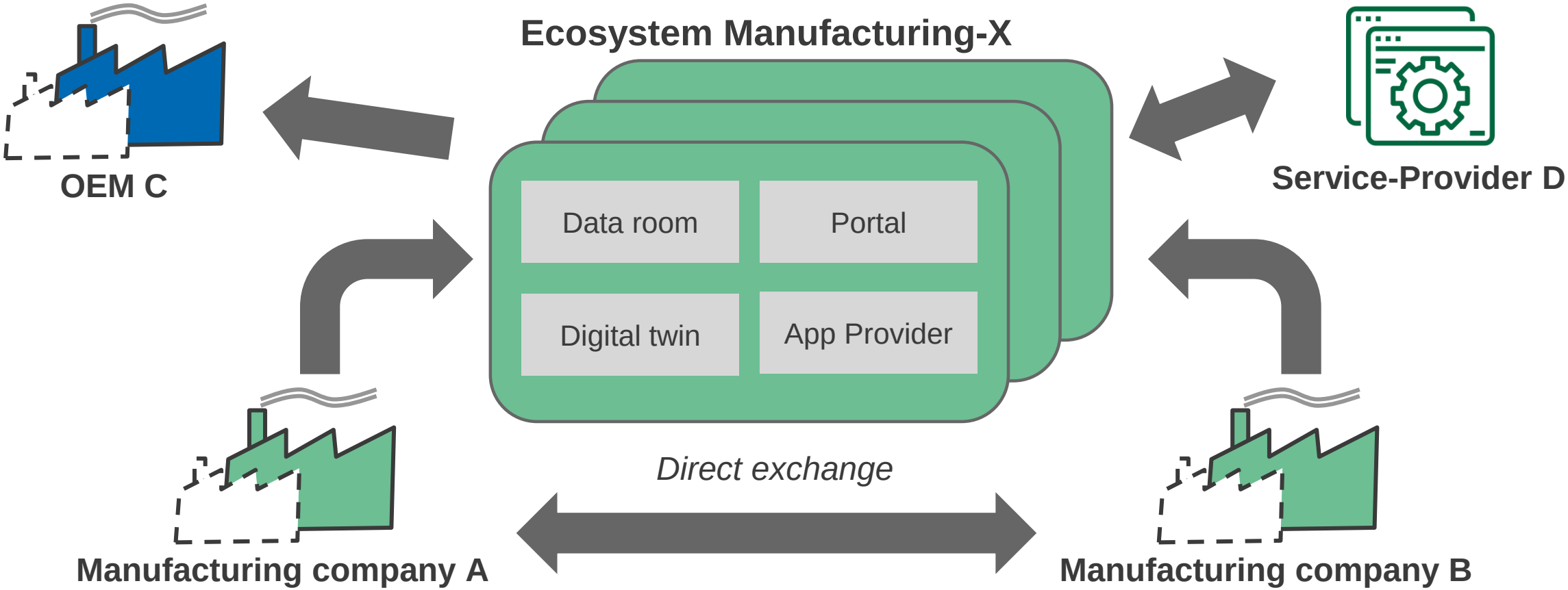


Our vision
Digital marketplace for used components as semi-finished products



Source: Flaticon

Manufacturing-X initiative based on the Catena-X model



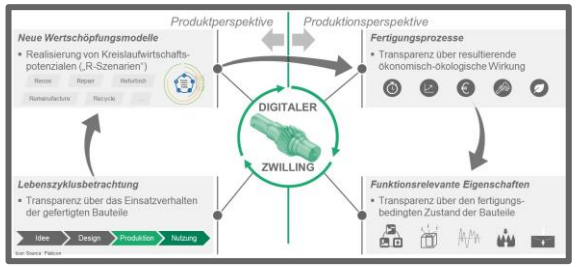
Source: https://www.plattform-i40.de/IP/Navigation/DE/Manufacturing-X/Initiative/initiative-manufacturing-x.html

Cross-company ecosystem Manufacturing-X for manufacturing using the example of Catena-X

Picture Source: Flaticon

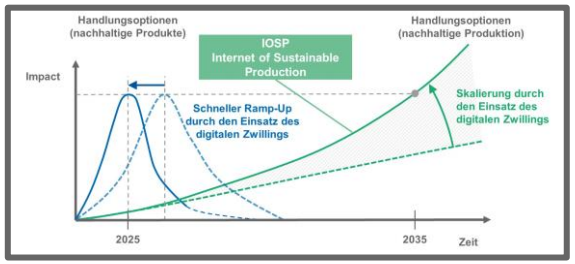
Summary and conclusion

What contribution can a digitized manufacturing make to sustainable industrial value creation?



Creates the prerequisite for minimal energy and resource use in the sense of a lifecycle-spanning circular economy!

Ensures the rapid availability of product innovations with a high sustainability effect!



Together with the concept of the digital twin and a data ecosystem, this forms the prerequisite for the
IOSP - *INTERNET OF SUSTAINABLE PRODUCTION*