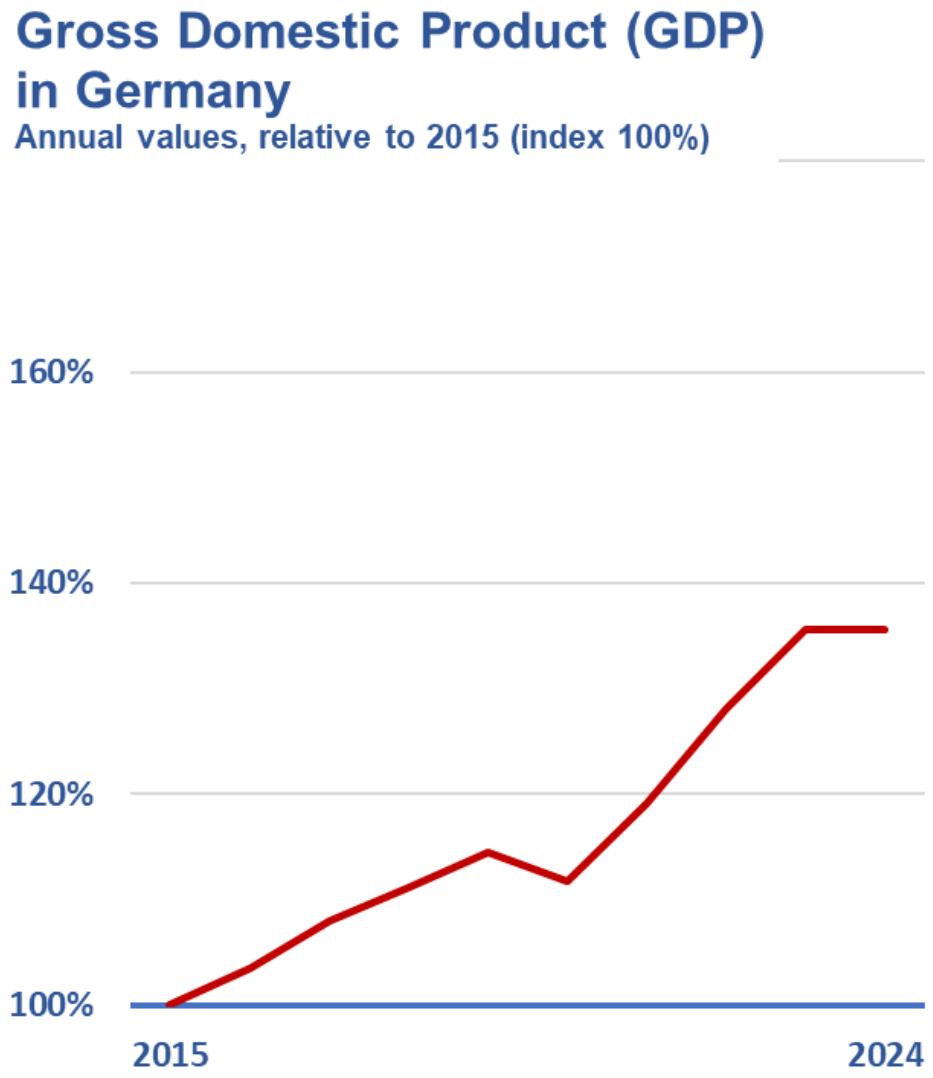
# Decarbonization as Driver for the Transformation of Metrology Markets

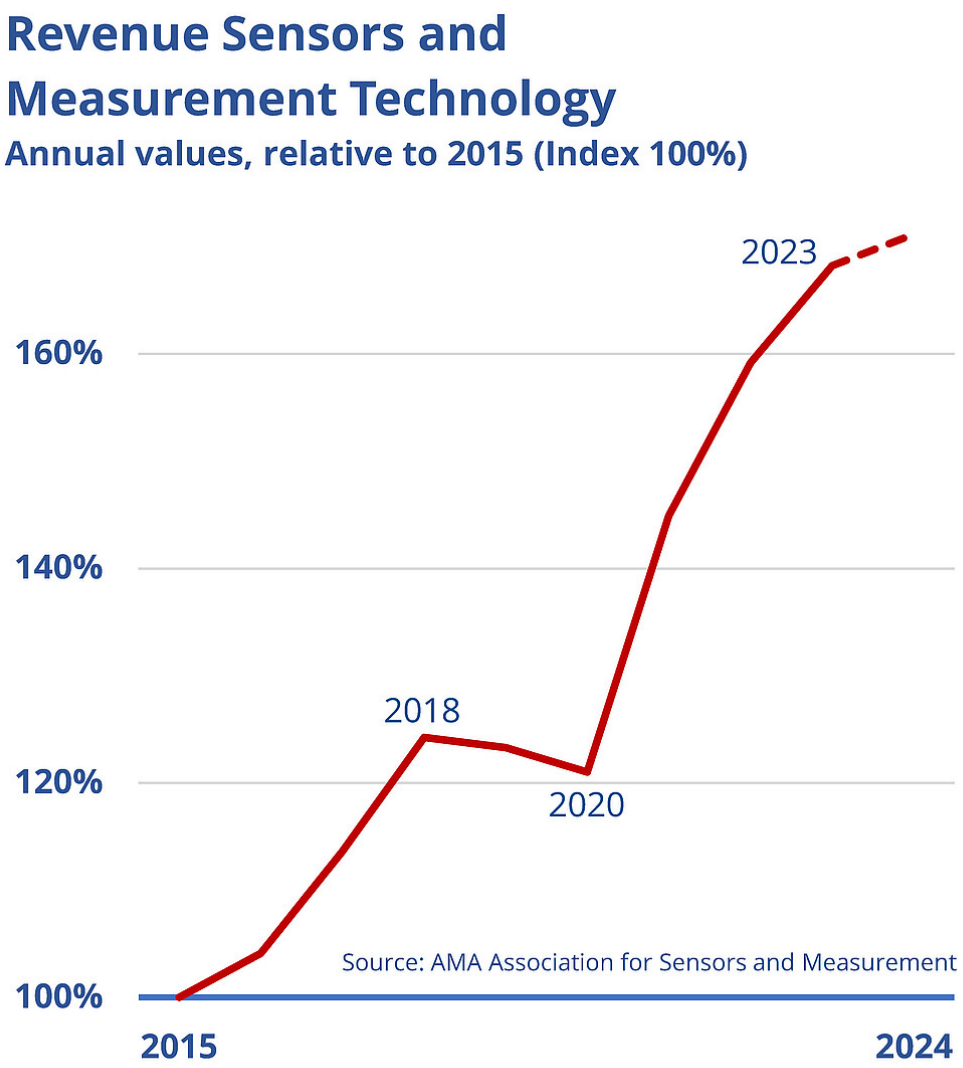
Dietrich Imkamp



# Revenue of Sensor and Measurement Technology Companies in comparison to GDP in Germany




Source: https://www.destatis.de/ own graphic




Source: https://www.ama-sensorik.de/fileadmin/_processed_/6/8/csm_AMA2024_RevenueRel2015_5a935cedbe.jpg

# Decarbonization

[CO2 neutrality: innovation as a driving force (zeiss.com)]

*“The current market transformation requires a clear commitment to greater eco-efficiency. Decarbonization will be one of the key success factors.”*

**Dr. Marc Wawerla**

CEO ZEISS Industrial Quality Solutions (IQS)



# Eco-Efficiency as Driver for Metrology Market Transformation




- Improving Performance of (existing) Metrology/Inspection Equipment for **greater Metrology/Inspection Efficiency**
- Life Cyle Assessment of Metrology/Inspection Equipment for **greater Carbon Emission Efficiency**
- New Measurement/Inspection Tasks coming from new Products for **greater Product Efficiency**
- Evaluation, Representation and Correlation of Result Data for **greater Production Efficiency**

# Agenda


**01** Metrology/Inspection Equipment Efficiency

**02** Carbon Emission Effiiency

**03** Product Efficiency

**04** Production Efficiency

**05** Summary

# Agenda


**01** Metrology/Inspection Equipment Efficiency

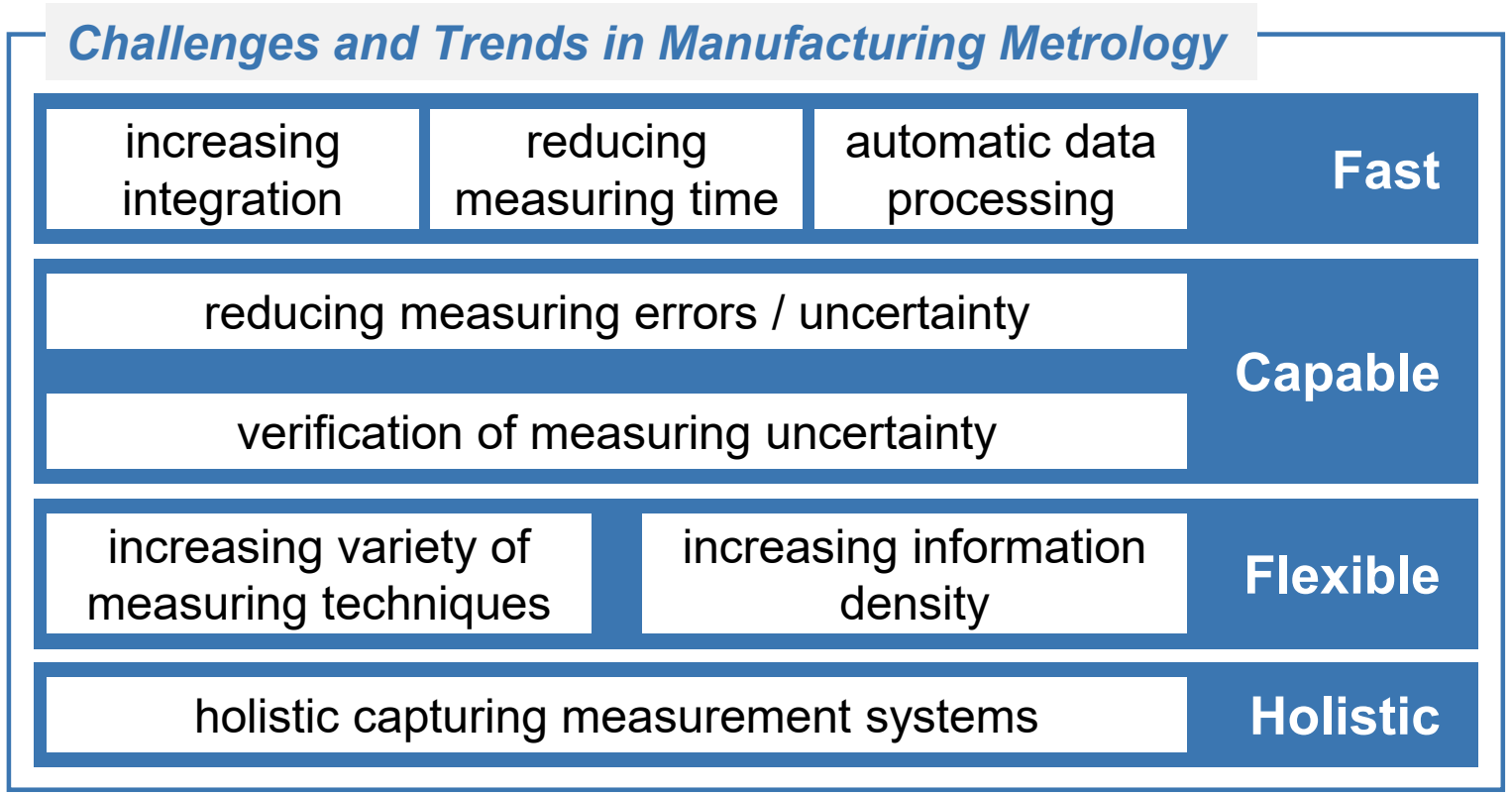
**02** Carbon Emission Effiiency

**03** Product Efficiency

**04** Production Efficiency

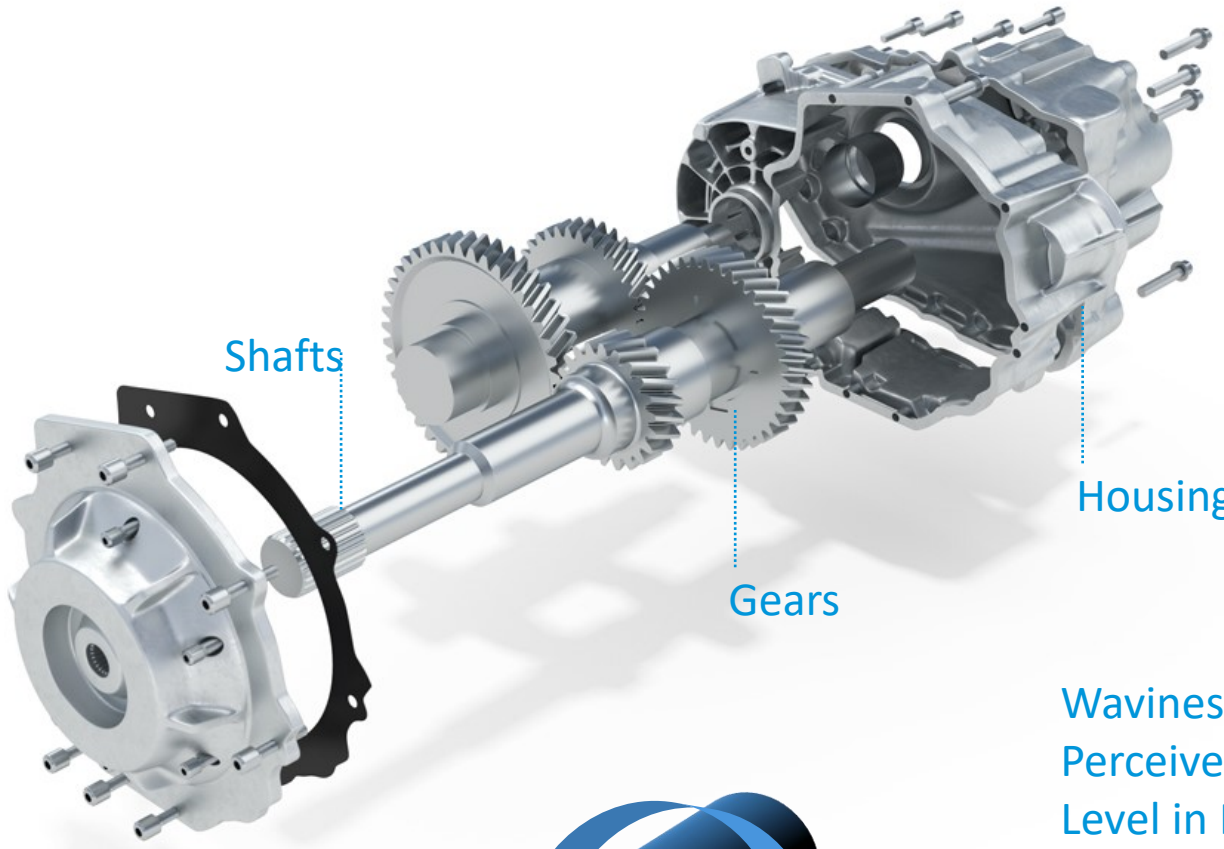
**05** Summary

# Trends in Manufacturing Metrology
# Improving Performance

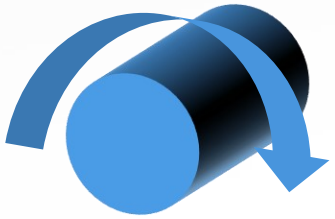



*Source: Imkamp, D./ Berthold, J./ Heizmann, M./ Kniel, K./ Manske, E./ Peterek, M./ Schmitt, R./ Seidler, J./ Sommer, K.-D.: Challenges and trends in manufacturing measurement technology – The 'Industrie 4.0' concept, in: Journal of Sensors and Sensor Systems (JSSS), open-access peer reviewed journal published by the Copernicus GmbH (Copernicus Publications) on behalf of the AMA Association for Sensor Technology, doi:10.5194/jsss-5-325-2016, 2016. (https://jsss.copernicus.org/articles/5/325/2016/ )*

# Performance Challenge: Reducing Form Measuring Errors
# Transmission noise in NEV




| Multiwave-Standard | | Calibration (Form Tester) | CMM | Difference |
|---|---|---|---|---|
| | FFT, wave #5 | 0,500 µm | 0,502 µm | **0,002 µm** |
| | FFT, wave #15 | 0,507 µm | 0,508 µm | **0,001 µm** |
| | FFT, wave #50 | 0,517 µm | 0,521 µm | **0,004 µm** |
| | FFT, wave #150 | 0,527 µm | 0,536 µm | **0,009 µm** |
| | FFT, wave #500 | 0,467 µm | 0,513 µm | **0,046 µm** |



Waviness affects Perceived Noise Level in NEVs significantly





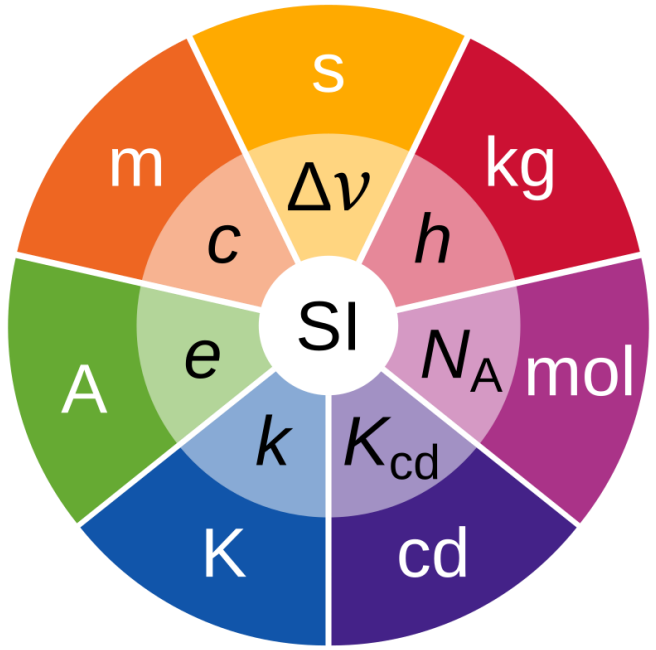
*Source: Jusko, O., Neugebauer, M., Reimann, H., Bernhardt, R.: State of the art in CMM based form measurement by multi-axis scanning, XIth International Scientific Conference, Coordinate Measuring Technique, 2nd – 4th April 2014, University of Bielsko-Biala, Poland*

# Democratize Metrology
# Re-Defintion of the SI

The redefinitions will serve to “**democratize the system**,” he* says. “Now for the first time in the history of this endeavor, anyone can theoretically create their own primary reference of mass. It takes a lot of know-how, like knowing quantum electrical standards, but in principle anyone can make it.”

*Jon R. Pratt, Chief of the Quantum Measurement Division of the Physical Measurement Laboratory (PML) at the National Institute of Standards and Technology (NIST)

Source: https://spectrum.ieee.org/a-vote-of-mass-importance-historic-si-unit-overhaul-redefines-kilogram-ampere-and-more




Source: https://en.wikipedia.org/wiki/International_System_of_Units

**Access to accurate and complex metrology regarding**

- **use and**
- **costs**

**may become easier.**

# Democratize Coordinate Metrology
# Triangulation Manual Scanner for Ease-of-Use Digitizing











https://www.handsonmetrology.com/blog/3d-scanning-water-pumps-for-mro/

# Agenda


**01** Metrology/Inspection Equipment Efficiency

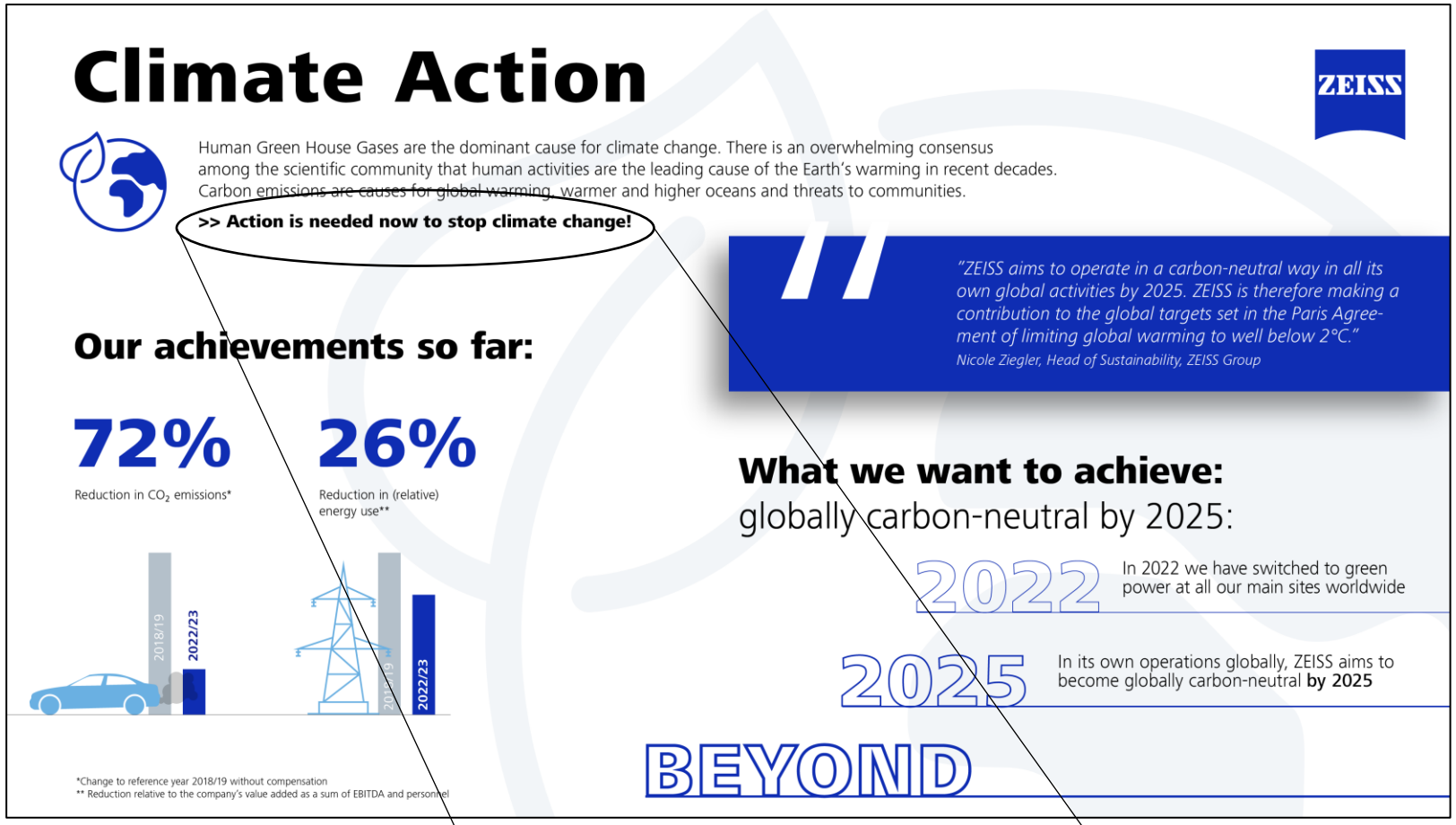
**02** Carbon Emission Effiiency

**03** Product Efficiency

**04** Production Efficiency

**05** Summary

# Need for Action
## ZEISS's Climate Actions

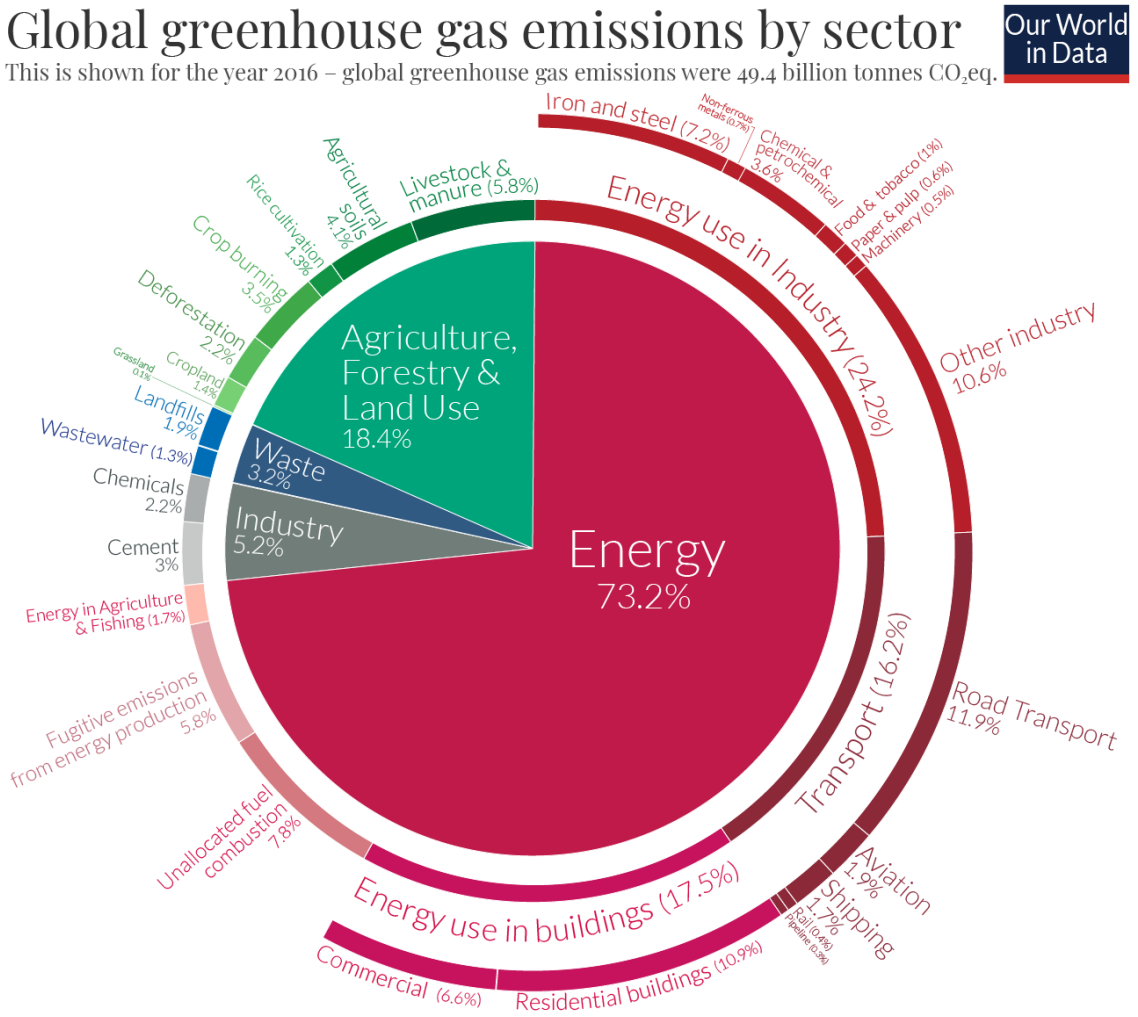



# Need for Action

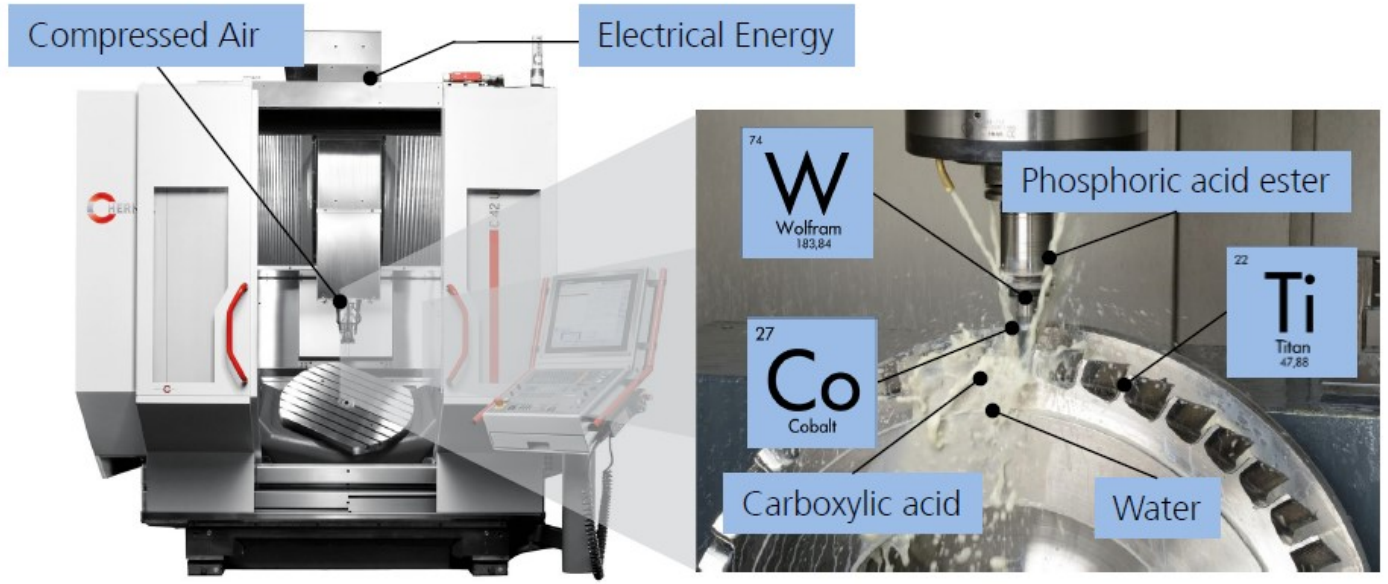
**requires quantifiable information about resources and their consumption**

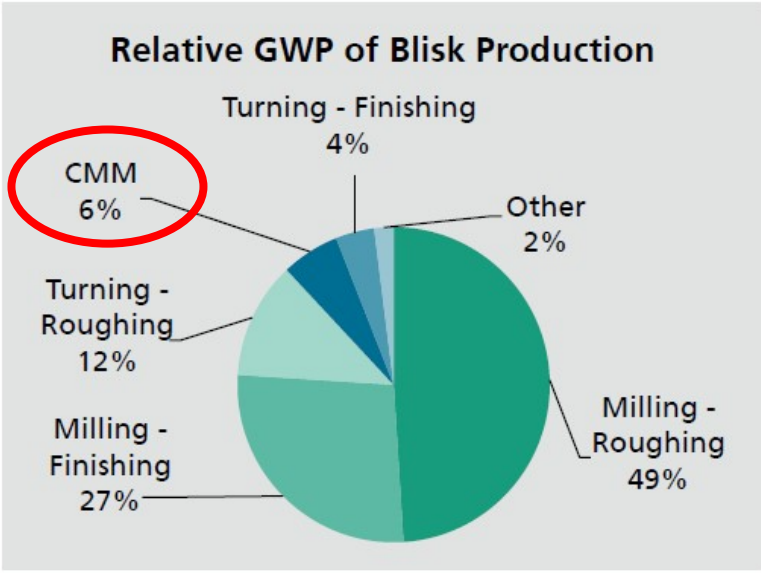
# Global Warming and Energy Use in Industry

## Sector by sector: where do global greenhouse gas emissions come from?



# The contribution of metrology to GWP (Global Warming Potential): Example Blisk (Blade on Disk) Production for Aero Engines




CMM=Coordinate Measuring Machine

Calculation using Software OpenLCA based on LCIA Method "CML"

*Source: Fricke, K.: Life-Cycle-Assessment for Turbomachinery Manufacturing R&D 2021 –ICTM (International Center for Turbomachinery Manufacturing) Annual R&D Meeting, Aachen, Germany June 15th, 2021 (not published)*

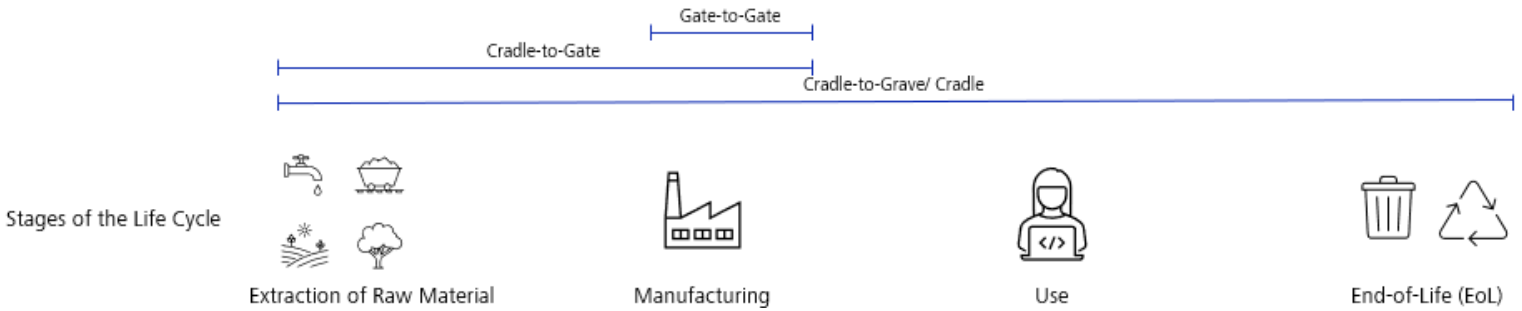
# Life Cycle Assessment (LCA) for CMM

**Key drivers**

- Addressing increasing **customer requests**
- Understanding the **need for potential product improvements**

**Norm used & Methodology**

- Approach: “Cradle-to-grave”







- The study is based on ISO 14040/44 “Environmental management - Life cycle assessment“
- Professional software with information data bases applied for calculation
- Certification by TÜV Süd

**Overall results of example CMM**

- Total emissions vary between 16 and 19 $tCO_2eq$ depending on the machine size & average use case scenario
- The biggest hot spot is the usage phase (between 65% and 80%)

# Agenda


**01** Metrology/Inspection Equipment Efficiency

**02** Carbon Emission Effiiency

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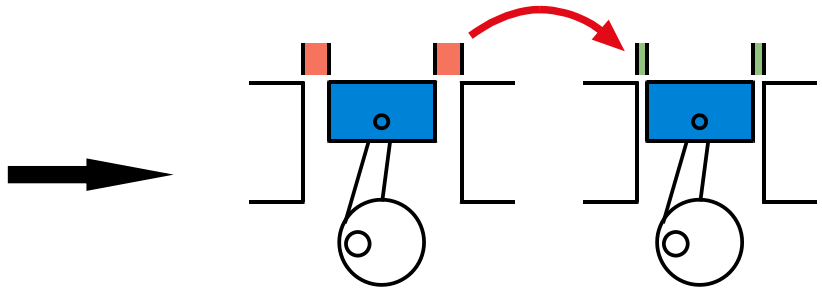
# How does coordinate metrology contributes for the “3-liter car”?

Symposium; Jena, Germany 1999

Dr.-Ing. Rainer Ohnheiser (former CEO of ZEISS Industrial Metrology)

**Examples**

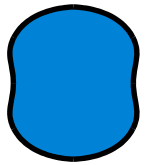
**The gap between the cylinder hole and the piston is getting smaller and smaller. That leads to smaller tolerances.**



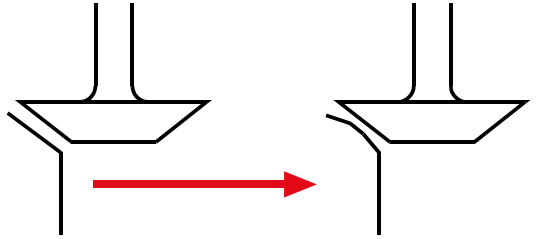


Von Rudolf Stricker - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4104272 https://de.wikipedia.org/wiki/VW_Lupo#/media/Datei:VW_Lupo_front_20080524.jpg

**Piston form becomes more complex “unrounded shape”.**



**Valve seats have more precise, more complicated contours.**

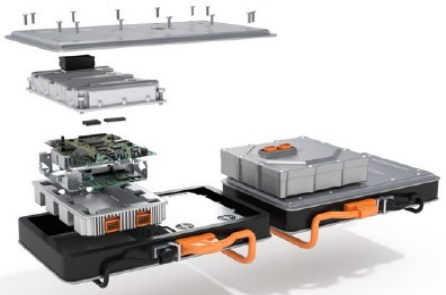


**Nozzles and fuels channels are getting smaller and smaller.**

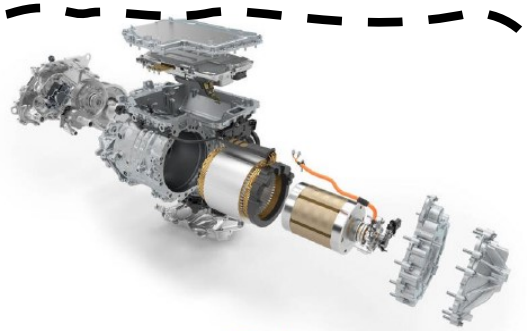
# Measurement tasks for NEV (New Energy Vehicles)



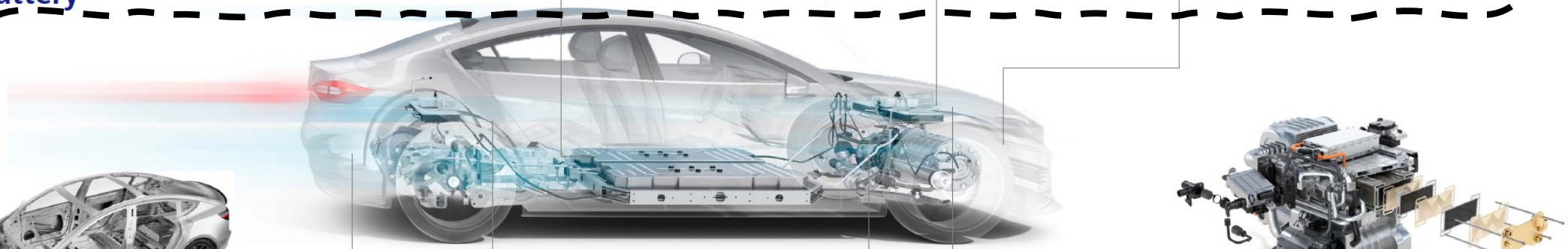
Battery



Power Electronics



eDrive



OEM



Car Body



Fuel Cell



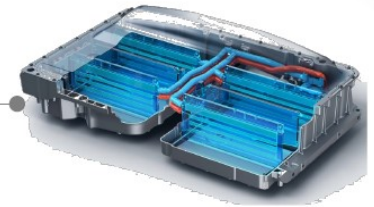
Chassis / Underbody



Battery Tray



NEV Interior



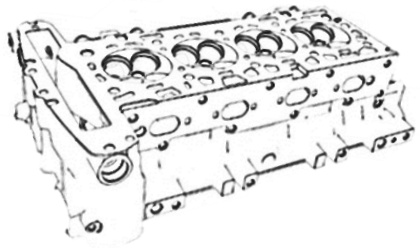
NEV Cooling System & HVAC

# Electric drive replaces combustion engine
# Changing Requirements for Metrology

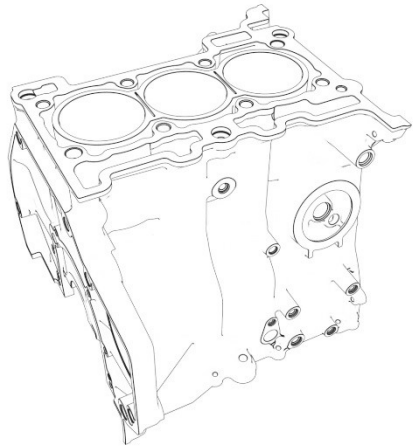
**Crankshaft**



**Head**



**Block**



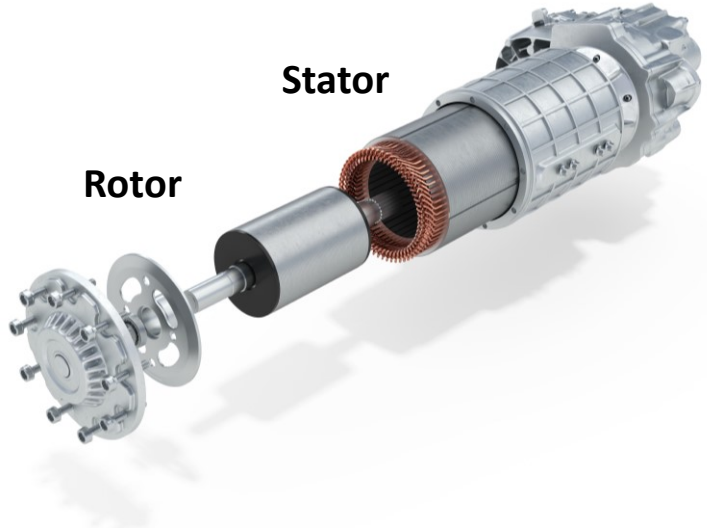
**Combustion Engine**

- >1000 parts
- many different versions and variants
- established manufacturing technology
- decades of experience in production and metrology

**Stator**

**Housing**

**Rotor**



**Electric Drive**

- < 500 parts
- small number of variants
- new advanced manufacturing techniques
- very few experience

# Battery and Electronic Inspection with Computer Tomography
# ZEISS VersaXRM with FlatPanel and RaaD (2-stage magnification)

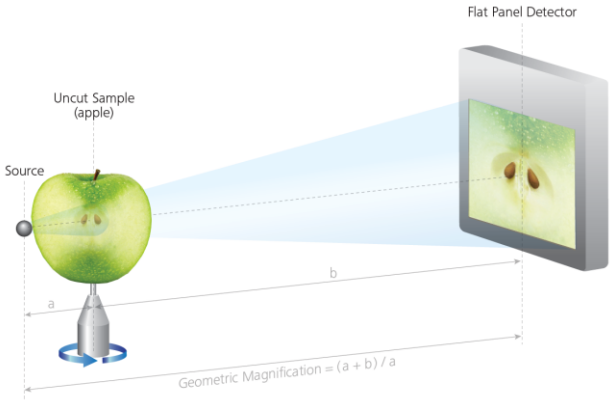
## FPX – Flat Panel Extension

FPX combines microCT with RaaD™, offering the best of both technologies in one system

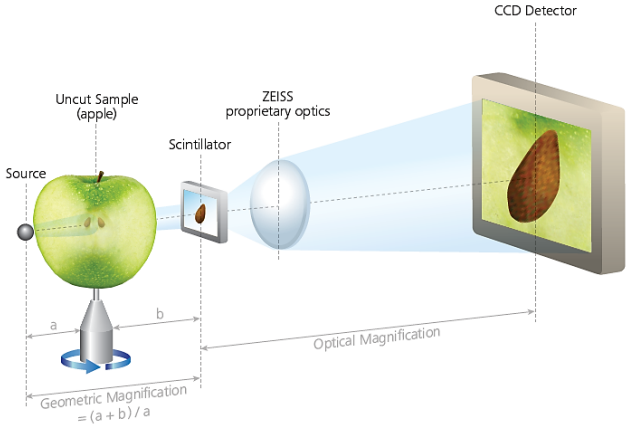


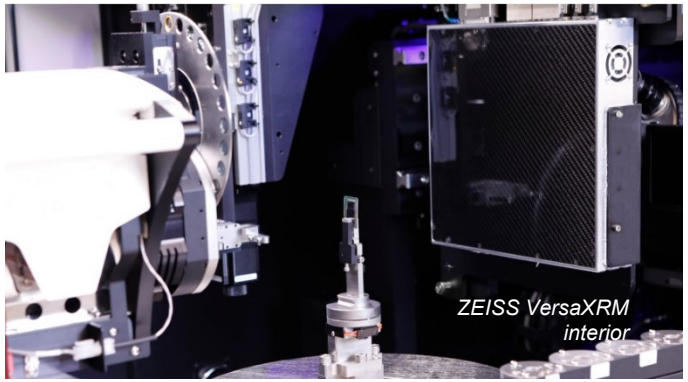

**ZEISS Versa XRM**
**FPX and RaaD™ systems**

**FPX**




**ZEISS Versa RaaD™**
**2-Stage X-ray Microscopy**




**FPX: "Scout"**
Image large samples with speed

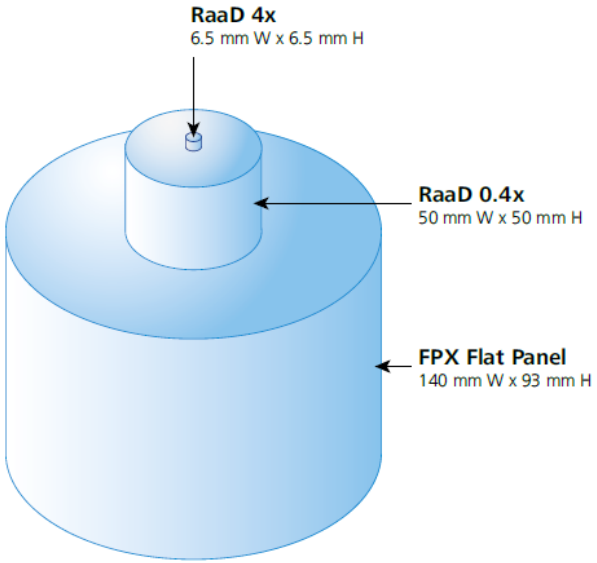
+

**RaaD™: "Zoom"**
Image with highest resolution

=

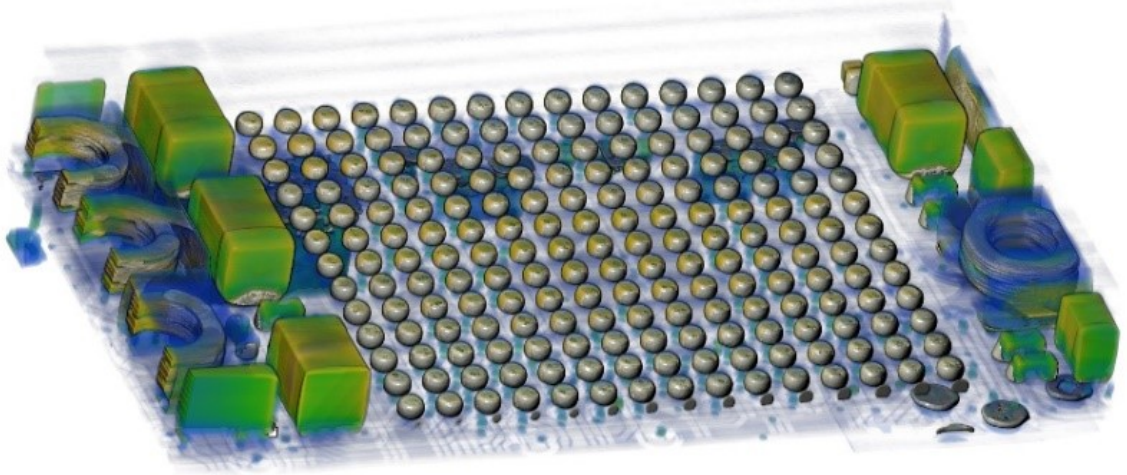
**ZEISS Versa XRM with FPX**
All-in-one imaging solution

# Application Samples from Electronics and Battery




**Single FOV volume**

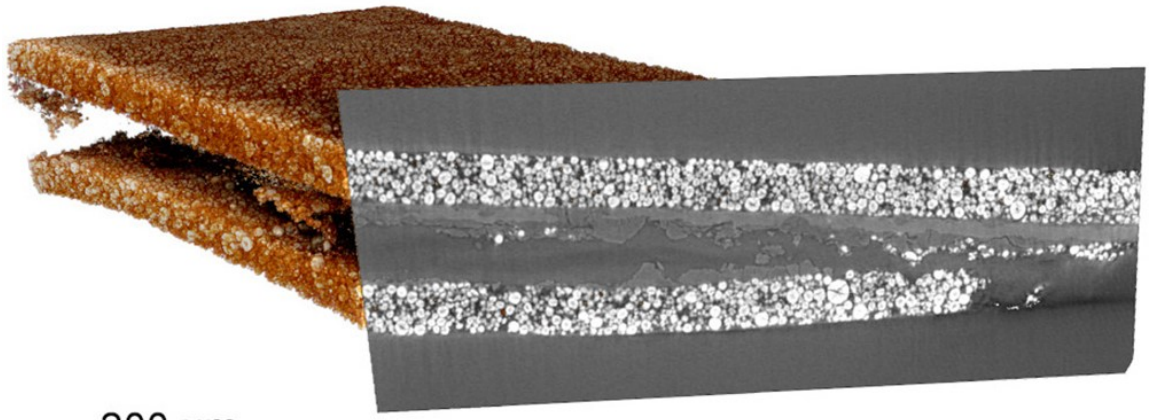


1 mm



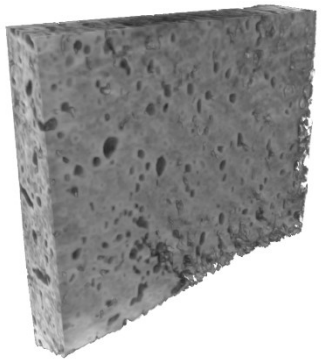
**Li Battery**
45 x 30 mm
@ 15 µm/vox

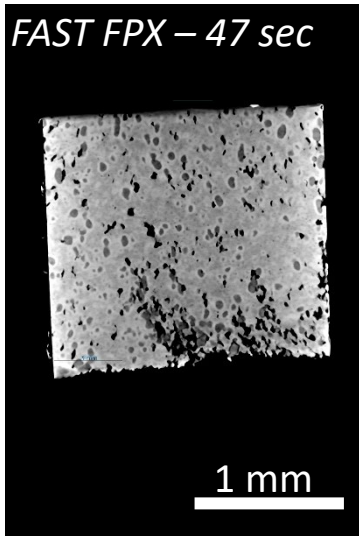


# Application Range of ZEISS VersaXRM

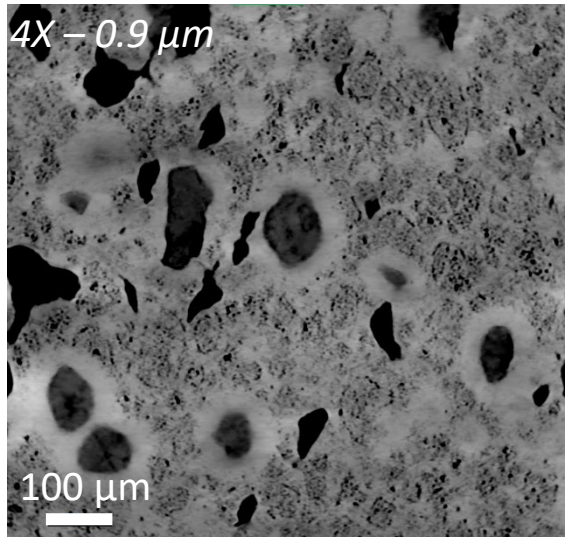
## Full-field of view

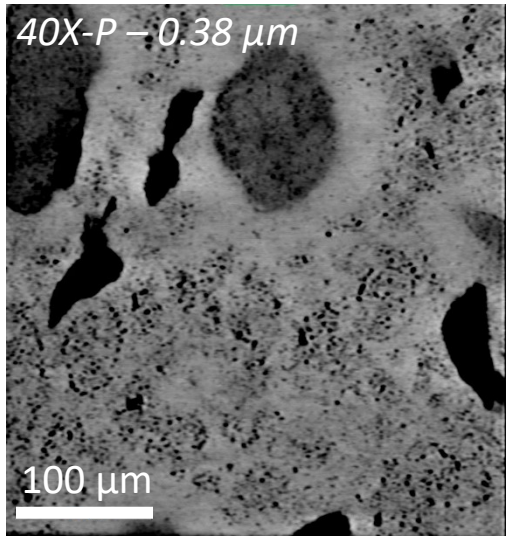







## Higher Resolutions




**ZEN navx**: *Setup Guidance, SmartShield, Quick Tomo*

**FAST Mode:** *Rapid scans with FPX*

**40X-P**: *Res. Perf.*

**ZEN navx**: *Volume Scout, Parameter Guidance, Objective Selection*

**DeepRecon Pro**: *Best Image Quality*

# Agenda


**01** Metrology/Inspection Equipment Efficiency

**02** Carbon Emission Effiiency

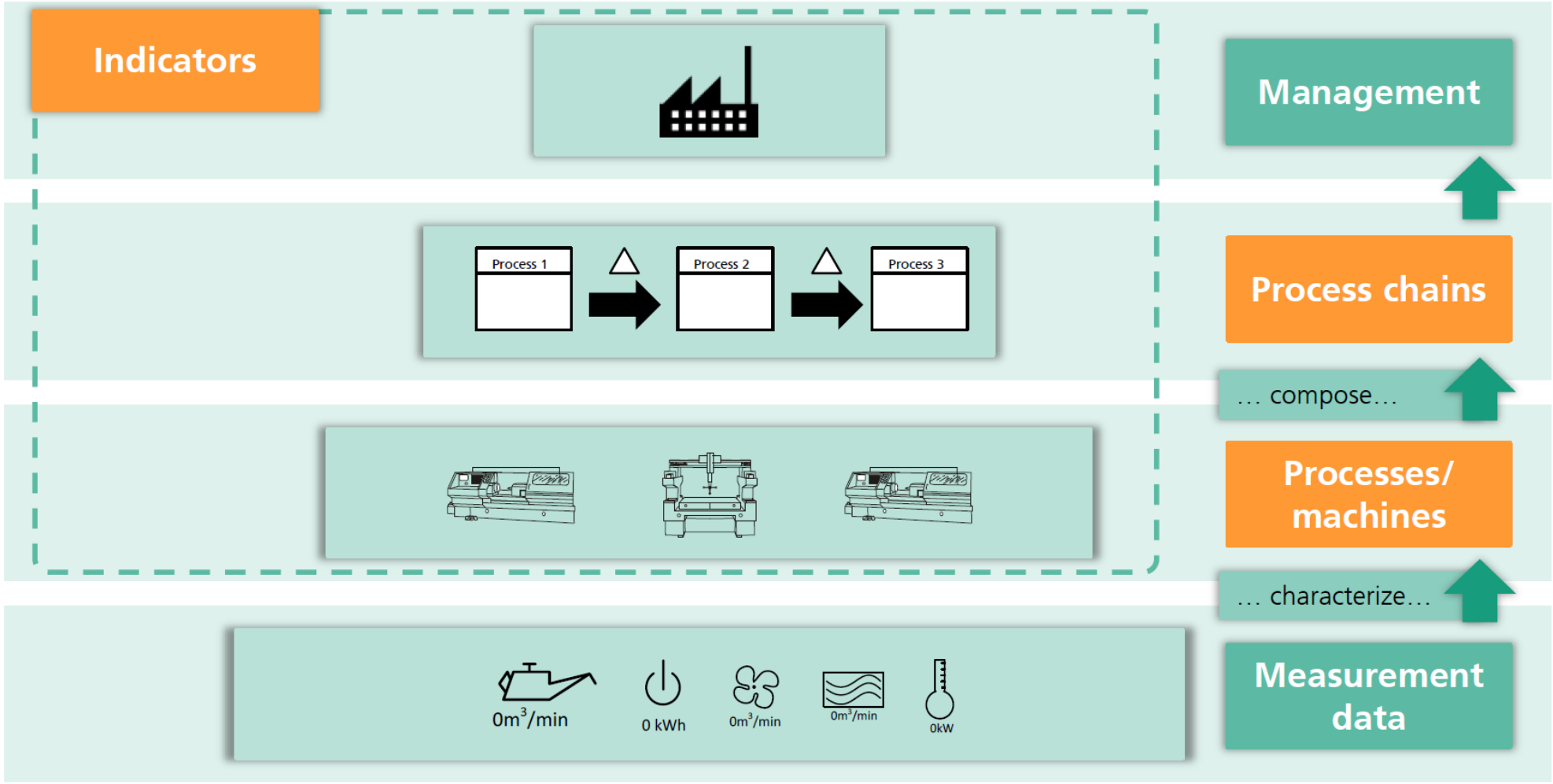
**03** Product Efficiency

**04** Production Efficiency

**05** Summary

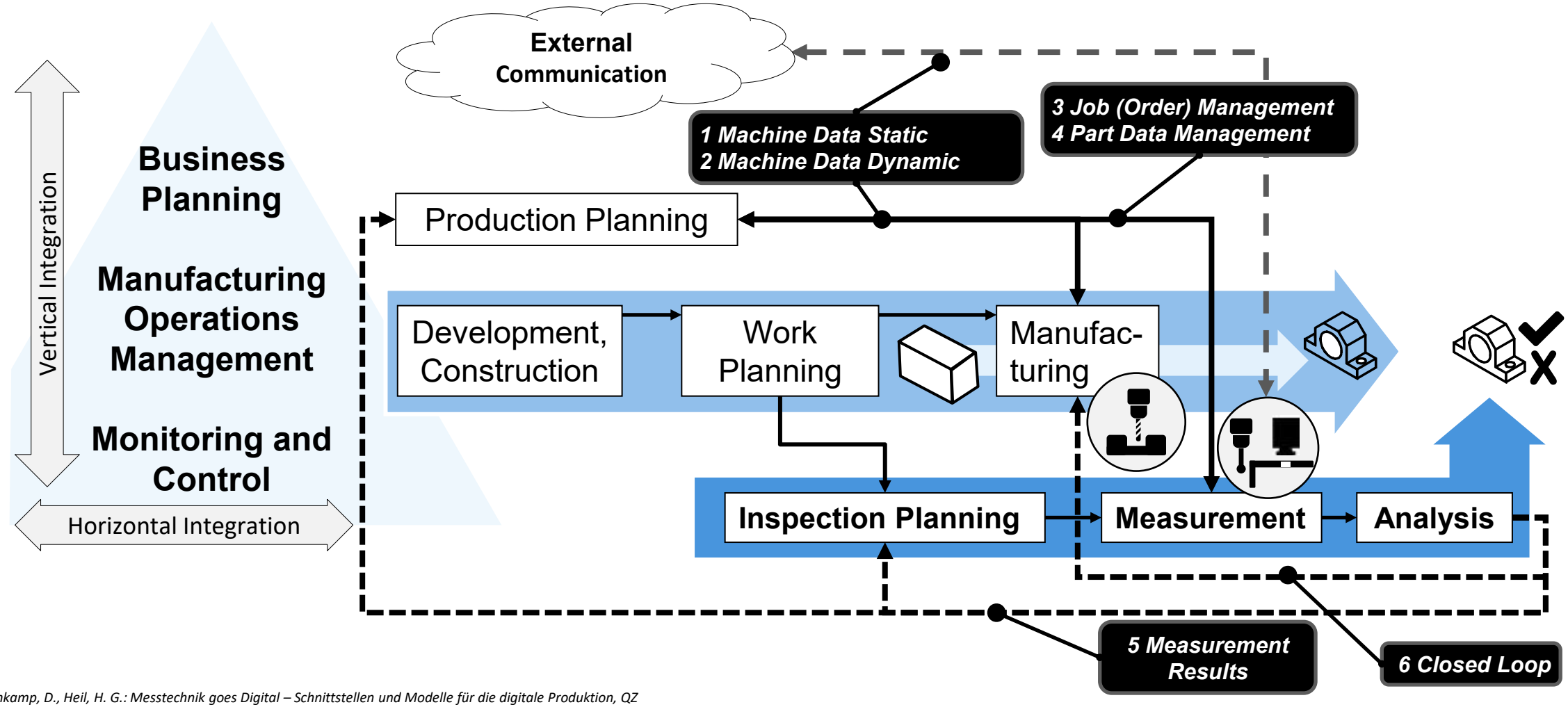
# Production Efficiency based on Measurement Data
# Value-Stream Mapping*

*Value-stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product from the beginning of the specific process until it reaches the customer. A value stream map is a visual tool that displays all steps in a specific process and easily quantifies the time and volume taken at each stage. Value stream maps show the flow of both materials and information as they go through the process.




*Source: Vollmer, T., Böckmann, M., Schmitt, R.: (2014). Resource Value Stream Map. Systematic identification and optimization of consumers. https://publica-rest.fraunhofer.de/server/api/core/bitstreams/aded4ac6-bcf3-48ec-a77b-eea6af157307/content, Vollmer, T., Kerkhoff, J., Große Böckmann, M., Permin, E.: Resource Efficiency Value Stream, Simply reducing resource streams, Hrsg.: Robert Schmitt; Fraunhofer IPT, Aachen; WZL der RWTH Aachen, 2018*

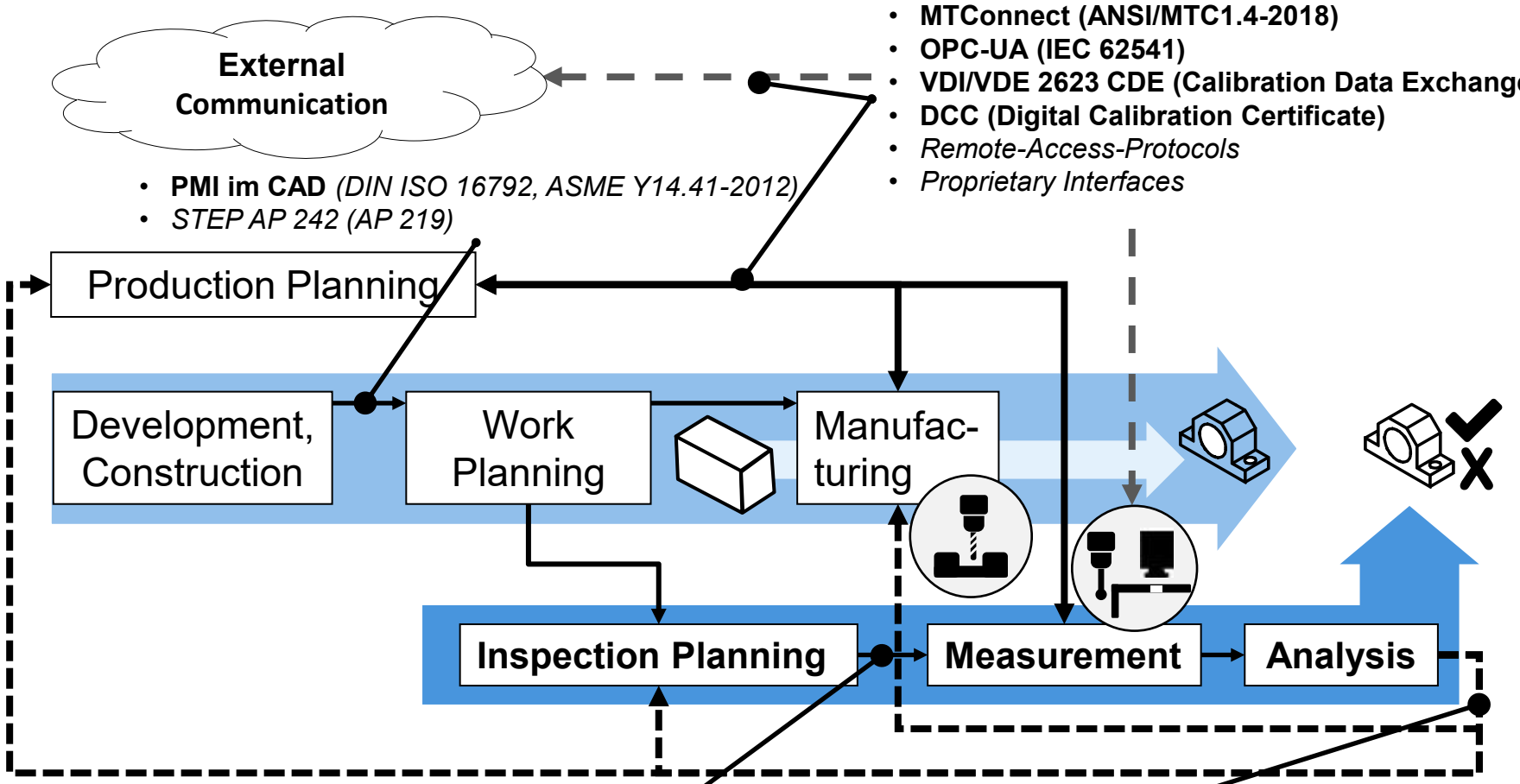
# Standardized Use Cases for digital data transfer of measurement equipment along the value stream of industrial production




*Source: Imkamp, D., Heil, H. G.: Messtechnik goes Digital – Schnittstellen und Modelle für die digitale Produktion, QZ Qualität und Zuverlässigkeit, Carl Hanser Verlag, München Jg. 66 (2021), Nr. 5, S. 40-43.*

# Integration of quality inspections into industrial production
# Interfaces for Geometrical Measurement Systems

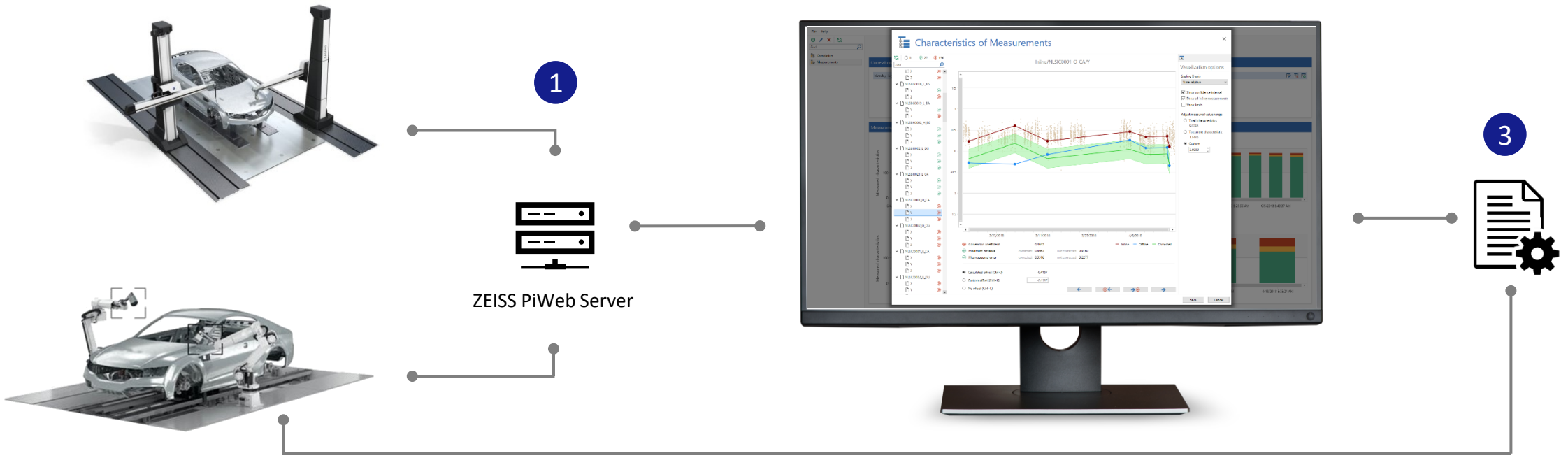
*Source: VDI/VDE-Gesellschaft für Mess- und Automatisierungstechnik (Edt.): VDI status report, 2023* Metrology in digital production | VDI




Abbreviations:
AQDEF= Advanced Quality Data Exchange Format (https://www.q-das.com/en/service/data-format-aqdef )
CAD=Computer Aided Design
DCC=Digital Calibration Certificate (https://www.ptb.de/dcc/ )
DMIS=Dimensional Measuring Interface Standard (ISO 22093)
I++DME=Inspection++ Dimensional Measuring Equipment (https://sourceforge.net/projects/iplusplusdme/ )
PMI=Product Manufacturing Information (https://en.wikipedia.org/wiki/Product_and_manufacturing_information )

# Example: Correlation of Inline and Offline Metrology Equipment
# ZEISS PiWeb Correlation

## Functionality




Measuring data are collected inline/offline and sent to ZEISS PiWeb Server.

Offset values are centrally computed in ZEISS PiWeb inline correlation.

Offset values are exported back to inline devices by means of INDI/Perceptron formats.

# Agenda


**01** Metrology/Inspection Equipment Efficiency

**02** Carbon Emission Effiiency

**03** Product Efficiency

**04** Production Efficiency

**05** Summary

# Eco-Efficiency as Driver for Metrology Market Transformation

- **Metrology/Inspection Efficiency**
  - **Increased measurement performances and ease of use**
- **Carbon Emission Efficiency**
  - **LCA shows impact of measurement on global warming potential in production**
- **Product Efficiency**
  - **New technologies deliver quality information about electrical systems for emission-free mobility**
- **Production Efficiency**
  - **Standardization enables digital integration of information from metrology into value chain of production**




Seeing beyond