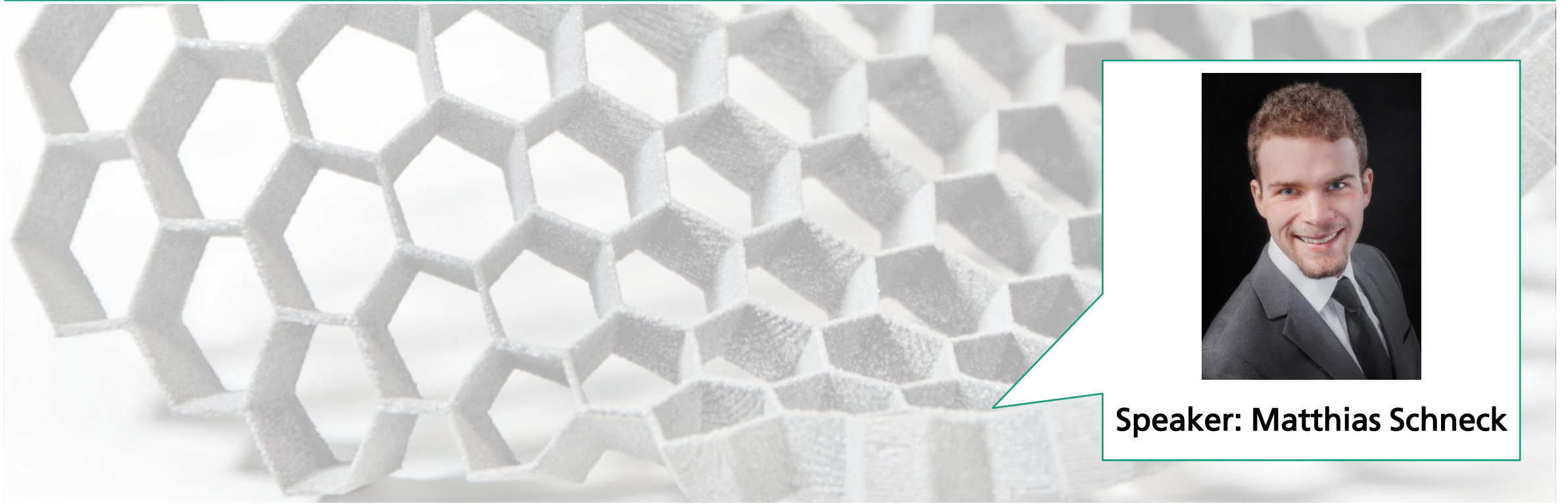# VALIDATED COST PREDICTION FOR ADDITIVE MANUFACTURING – COMBINATION OF A MODEL BASED APPROACH WITH AN EMPIRICAL STUDY

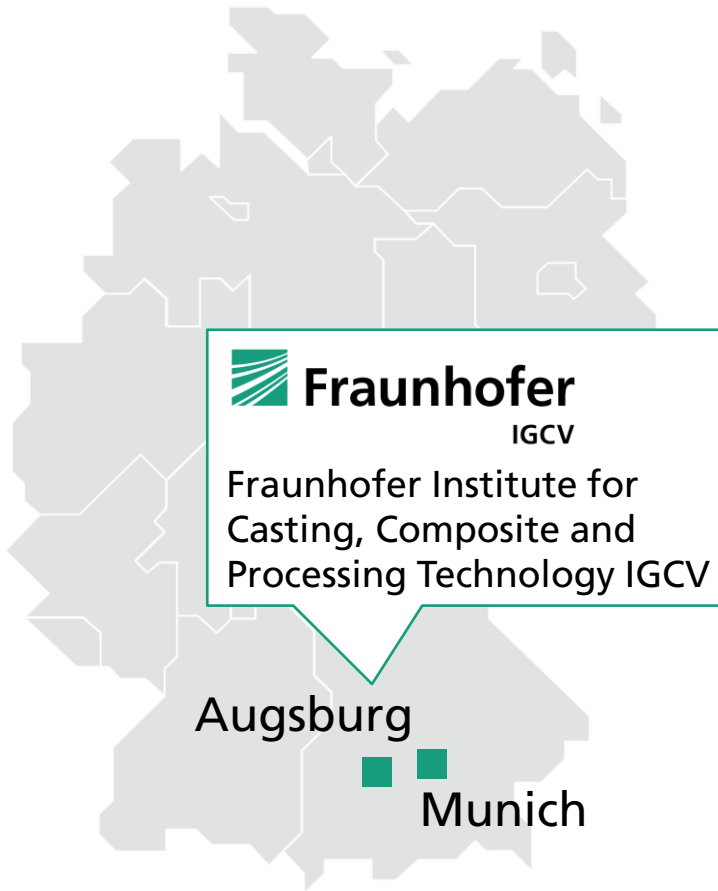Matthias Schneck, Matthias Schmitt, Georg Schlick, Gunther Reinhart

DDMC Conference, 23.06.2020

Speaker: Matthias Schneck

Fraunhofer
IGCV

Introduction Fraunhofer IGCV
Spotlight on research activities in Additive Manufacturing

Fraunhofer Institute for Casting, Composite and Processing Technology IGCV
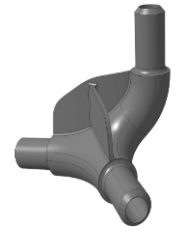
Augsburg

Munich

### Process development and multi-material processing

Exemplary Case study by Fraunhofer IGCV, SLM Solutions, ABB: "Multi-material Part (CCZ, 1.2709) for High Volume Injection Moulding Components" shown at Formnext 2017, Frankfurt

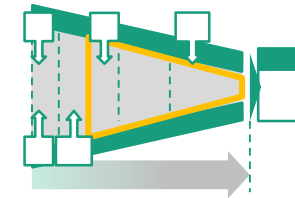### Indirect Additive Manufacturing of metal parts

Binder jetted sand mould (left), target metal part (right)

Design and Engineering for Additive
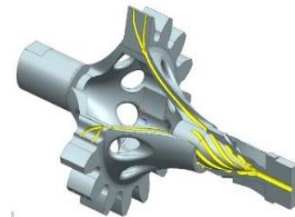
Award-winning design „Functionally Integrated Shaft and Gear", Additive World Congress 2018 in Eindhoven

Implementation and training

Implementation model (left) and logo of partner for quality-focussed training (right)

Motivation
Implementation of Additive Manufacturing in Industry

"How can our products and processes benefit from Additive Manufacturing technologies?"

Company-specific knowledge

Building of knowledge

AM technology knowledge

3D Printer
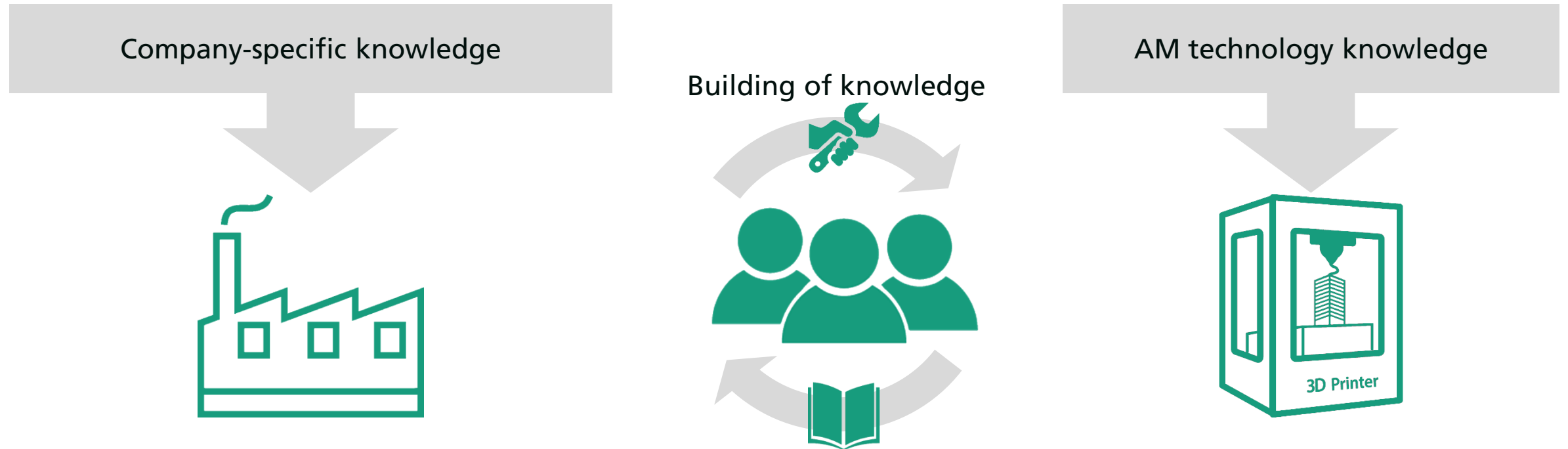
→ **Knowledge of cost structure is one of the main hindrances for the utilization of AM as production technology.[1]**

Fraunhofer
IGCV

State of Research
Cost modelling approaches and cost structure of powder bed processes

Product cost estimation methods[1]

Qualitative techniques

Quantitative techniques

Intuitive techniques

Analogical techniques

Detailed analysis techniques

Parametric techniques

…

Activity-based cost estimation

Cost per part in EUR

7

6

5

4

3

0   500   1000 1500 2000 2500 3000 3500 4000

Number of parts[2]

Filling a layer (2D)

Filling a bed (3D)
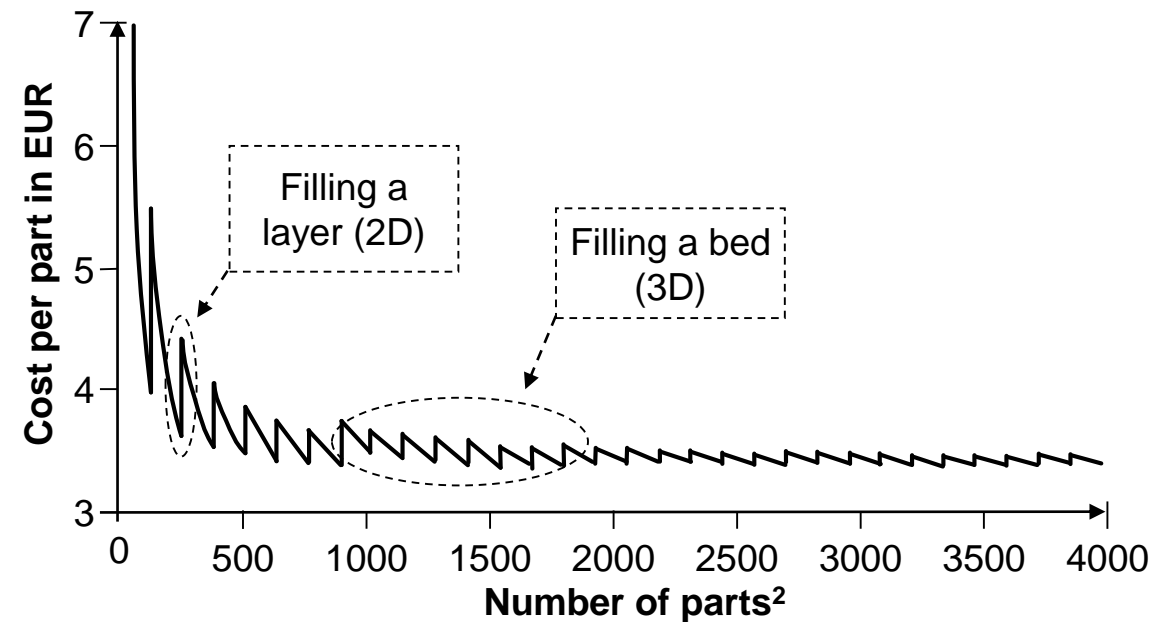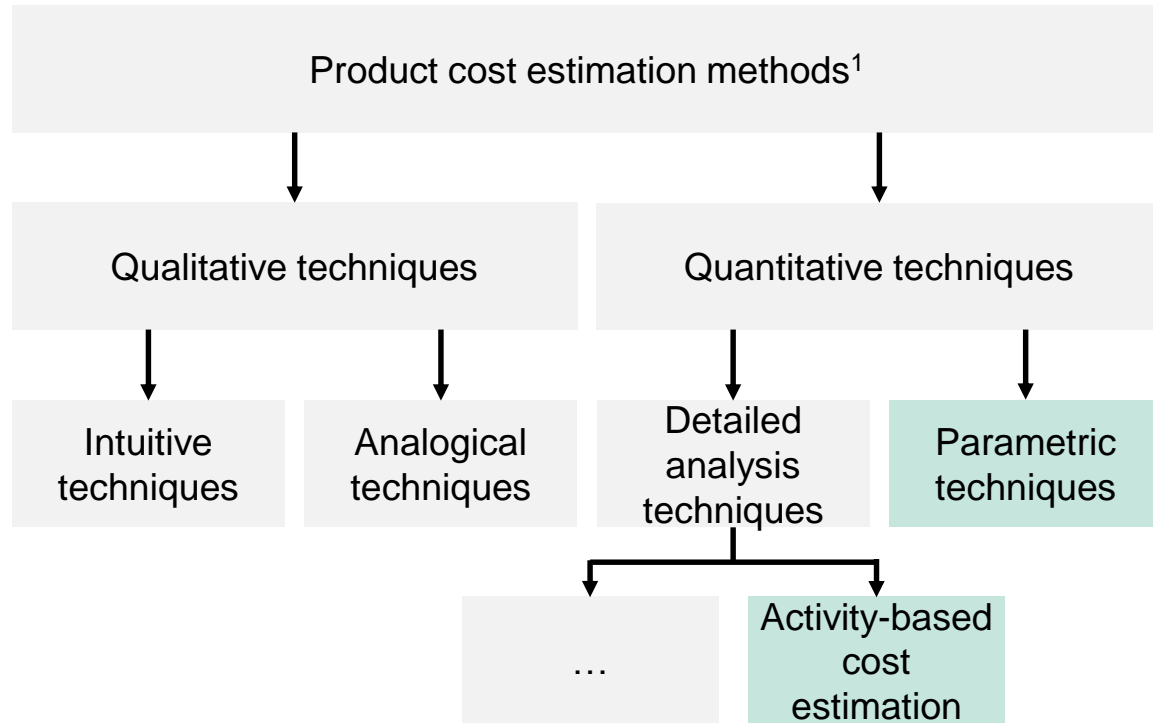
→ **Cost modelling approaches calculate the cost on an analytical basis using process parameters.**

1.) Baumers & Tuck 2019

2.) Ruffo et al. 2006

Fraunhofer
IGCV

Research Approach
Validated cost indicator for Additive Manufacturing (LPBF[1])

1st Source	2nd Source	3rd Source
Literature review: Cost modeling for AM		
Analytical cost model (ACM)	Literature review: Supplier cost of AM	Benchmark study of supplier cost
Sensitivity analysis		

Cost indicator for Laser-based powder bed fusion (LPBF)
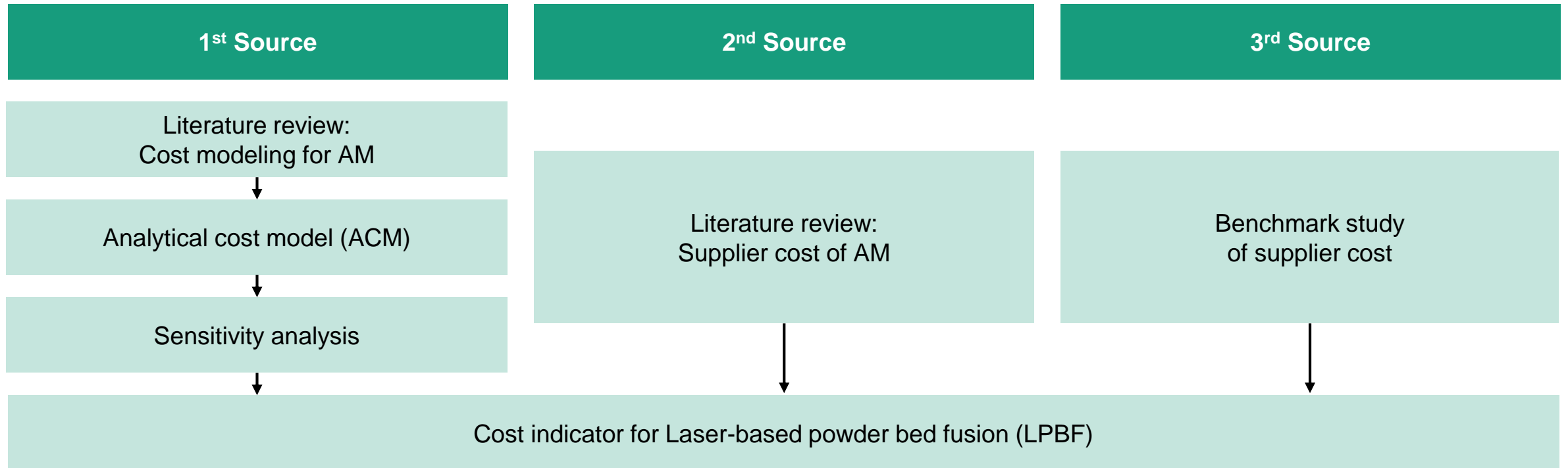
→ **Three independent sources are compared to obtain the validated cost indicator for 1.4404 (316L).**

Fraunhofer IGCV

Validated cost indicator for Additive Manufacturing (LPBF)
1st Source: Cost model and sensitivity analysis

Analytical cost model (ACM)

[Model and assumptions are presented in the paper][1]

→ Cost of 0.55 T€/kg for 1.4404

Sensitivity analysis of ACM

Exponential cost parameter

1. Theoretical build rate
2. Machine productive time
3. Depreciation time
4. Build volume utilization
5. Layer thickness
6. Build height utilization

Linear cost parameter

7. Invest
8. Maintenance
9. Labor cost & Manual processing monitoring

→ Cost for 1.4404 calculated with the ACM are 0.55 T€/kg.

→ Most important cost influences are build rate, machine productive time, depreciation time and machine invest.

1.) Structure of cost model derived from Klahn et al. 2018

Fraunhofer
IGCV

Validated cost indicator for Additive Manufacturing (LPBF)
2nd Source: Literature review on external supply cost (buy option)
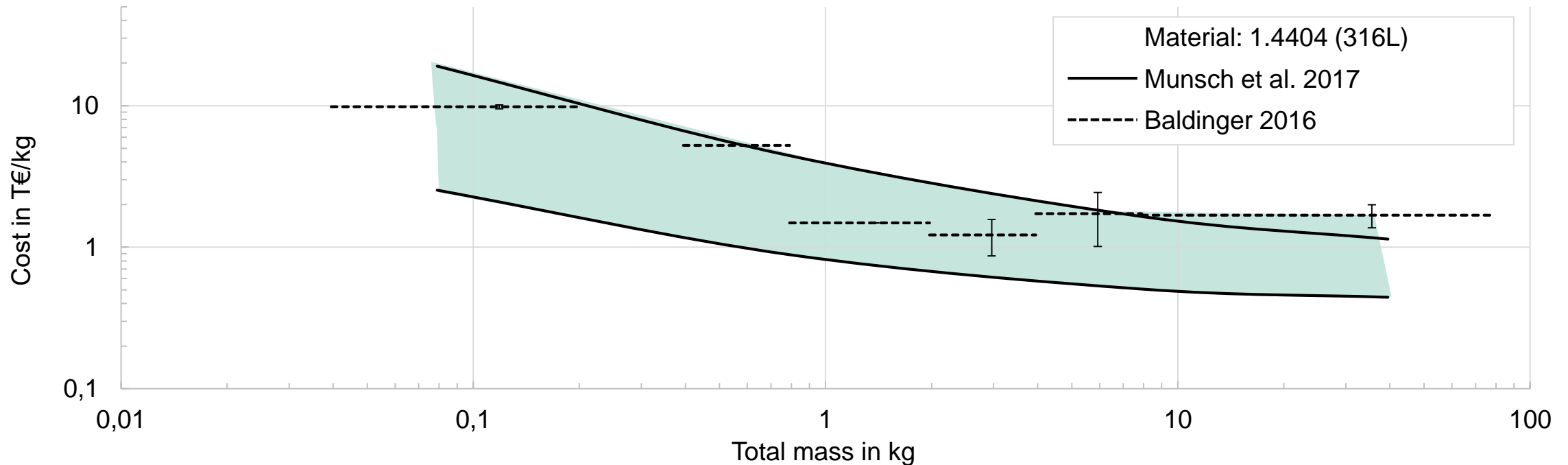
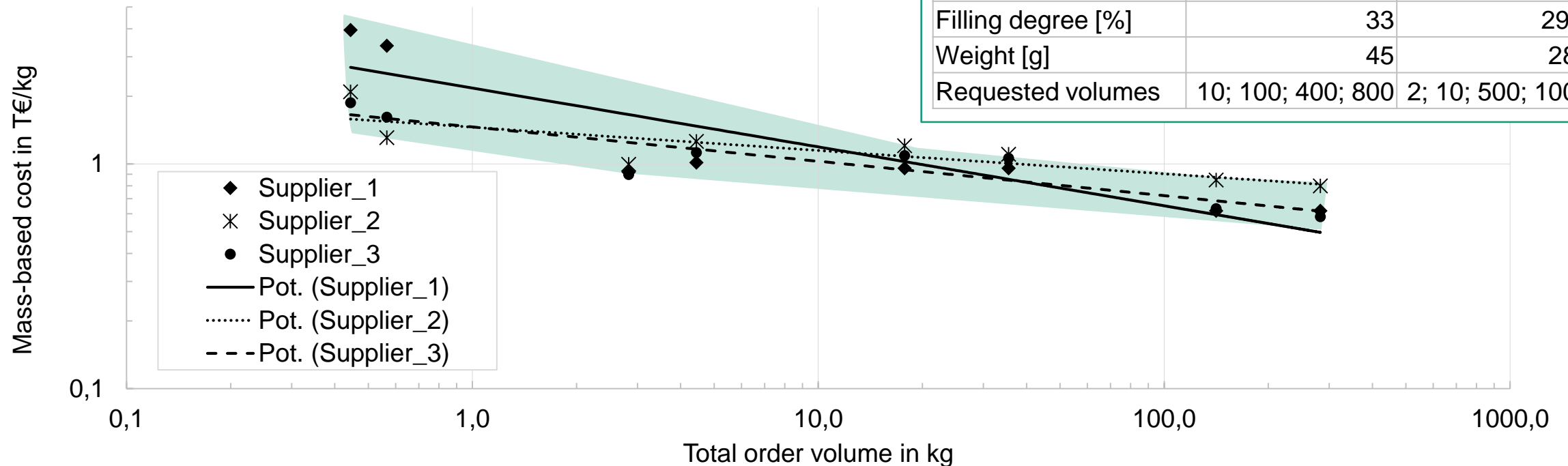→ **Mass-based cost decrease with raising order volume.**

→ **External supply cost of AM parts (buy scenario) is negligible addressed in literature.[1]**

1.) Baldinger 2016

Validated cost indicator for Additive Manufacturing (LPBF)
3rd Source: Benchmark study of supplier cost

Definition of reference parts:

	Part A	Part B
Bounding box [mm³]	21.5 x 21.5 x 36.5	47 x 47 x 55
Filling degree [%]	33	29.5
Weight [g]	45	285
Requested volumes	10; 100; 400; 800	2; 10; 500; 1000

Legend:
- ◆ Supplier_1
- ✳ Supplier_2
- ● Supplier_3
- — Pot. (Supplier_1)
- ⋯ Pot. (Supplier_2)
- – – Pot. (Supplier_3)

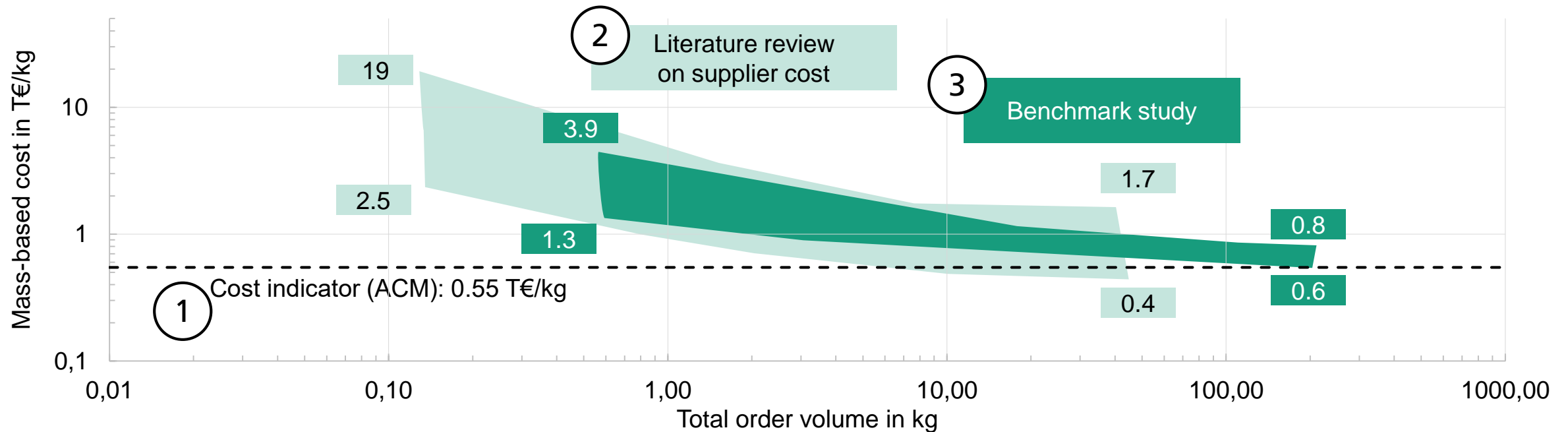X-axis: Total order volume in kg
Y-axis: Mass-based cost in T€/kg

→ External supply cost range between 3.94 T€/kg and 0.58 T€/kg. → Cost spread by a factor of 6.8.

→ Cost of external supply decrease for high order volumes.

Fraunhofer IGCV

Validated cost indicator for Additive Manufacturing (LPBF)
Result: Comparison of the information sources

Mass-based cost in T€/kg

Total order volume in kg

2 Literature review on supplier cost

3 Benchmark study

1 Cost indicator (ACM): 0.55 T€/kg

19
3.9
2.5
1.3
1.7
0.8
0.4
0.6

→ **Significant spread of cost: From 0.55 T€/kg up to 19 T€/kg.**

→ **Analytically obtained costs (based on ACM) meet the market prices for high order volumes.**

→ **Economic evaluation of AM parts should always include a benchmark of supplier quotes.**

Fraunhofer IGCV

Outlook on certified training programs in Additive Manufacturing
Fraunhofer "Metal Additive Manufacturing Professional"

**Certified Fraunhofer
Metal Additive Manufacturing Professional**
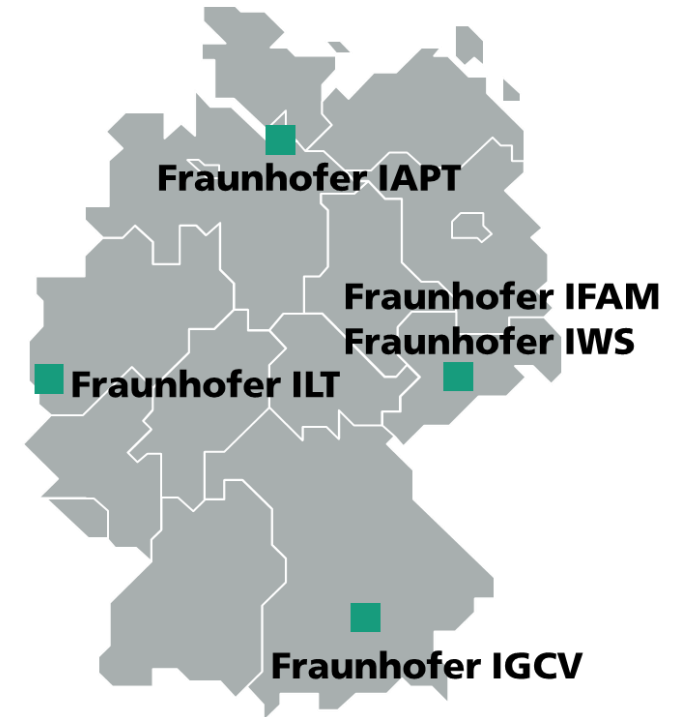
Certificate according to ISO 17024

| Production	Design
→ Organize an AM production environment	→ Develop and design AM parts

... including cost calculation, make-buy-evaluations and supply chain management for AM technologies.

Fraunhofer IAPT

Fraunhofer IFAM
Fraunhofer IWS

Fraunhofer ILT

Fraunhofer IGCV

→ Learn at **5 Fraunhofer Institutes** offering a comprehensive background in Metal-based Additive Manufacturing!

Fraunhofer
IGCV

Thank you very much for watching!
Questions or remarks? → Leave a comment or get in touch!
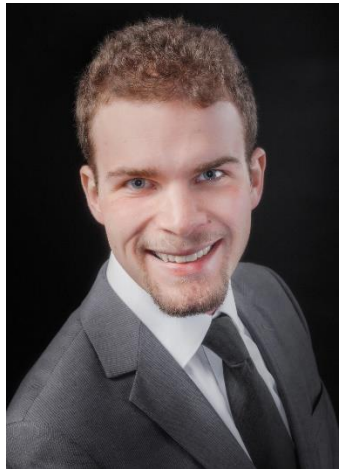
Speaker: Matthias Schneck

M. Sc. Matthias Schneck
Research Associate
Additive Manufacturing

Fraunhofer IGCV

Am Technologiezentrum 10
86159 Augsburg
Phone +49 821 90678-140
matthias.schneck@igcv.fraunhofer.de

www.igcv.fraunhofer.de

www.amlab.de