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Siemens Corporate Technology | March 2016

Industrialisation of Additive Manufacturing

Additive World Conference; March 23rd, Eindhoven; Netherlands

Martin Schäfer

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- General remarks Siemens and AM
- AM process chain and opportunities
- Applications and Industrialisation

Additive Manufacturing @ CT RTC MAT COA-DE

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Customer-oriented organization
Setup as of October 1, 2014

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Global presence and go-to-market of our businesses

Americas | Europe and Africa | C.I.S.[1] and Middle East | Asia and Australia

Power and Gas	Wind Power and Renewables	Energy Management	Building Technologies	Mobility	Digital Factory	Process Industries and Drives	Healthcare (separately managed with global supply chain)	Financial Services
Power Generation Services								

Corporate Services | **Managing Board** | Corporate Core

1 Commonwealth of Independent States.

Our global presence – Partner to customers all over the world

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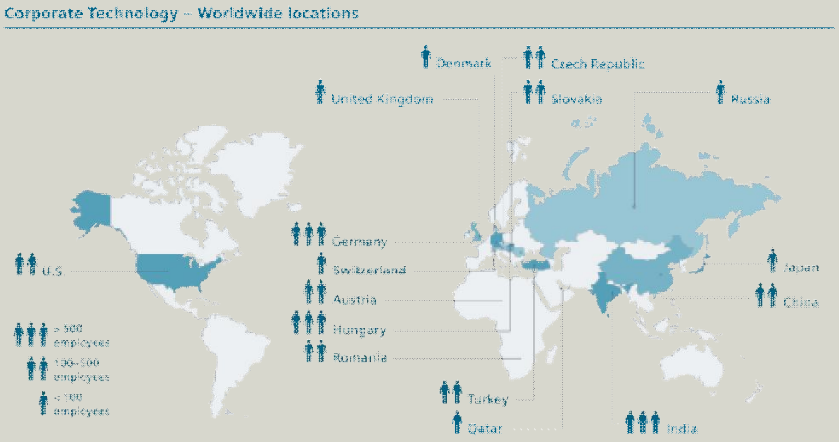

A worldwide presence

lies at the heart of the Siemens brand – and that goes for us as well.

That presence enables us to quickly offer targeted solutions that are tailored to regional requirements.

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Additive Manufacturing at Siemens

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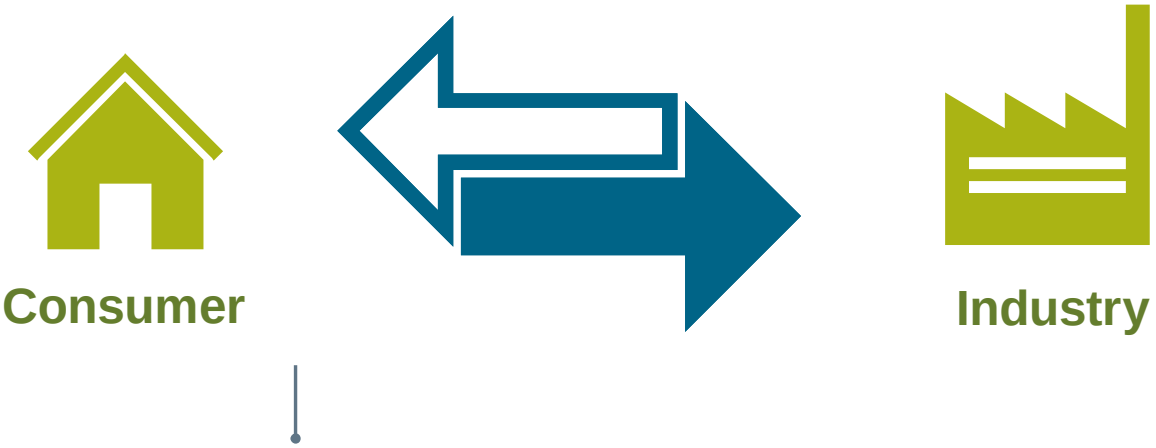
Different requirements

Different requirements



Source: makerbot.com

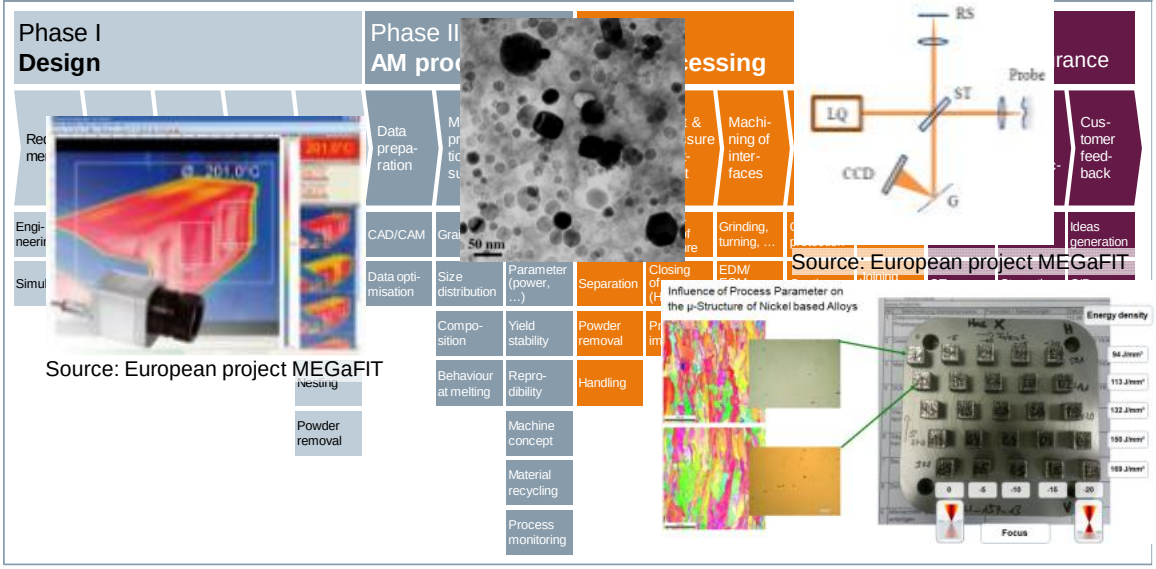
Source: EOS

“3D printing” versus Additive Manufacturing

Established market requirements are driving the industrialization of Additive Manufacturing

Additive Manufacturing – Process Chain

Process chain Additive Manufacturing (AM)



Source: European project MEGaFIT

Source: European project MEGaFIT

Potential for unique features are based on the mastery of knowledge intensive process chain and the interaction between manufacturing process, material condition and component properties

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Applications

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Additive Manufacturing for Gas Turbine Applications: Opportunities and Challenges

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Power and Gas Division

Power and Gas (PG) — Division

Large Gas Turbines, Generators (PG GT)	Distributed Generation (PG DG)	Steam Turbines (PG SU)	Compressors (PG CP)	Energy Solutions (PG ES)	Instrumentation and Electrical (PG IE)
Business Units					
▸ Gas turbines from 100 to 400 MW ▸ Electrical generators from 25 up to 2,235 MVA ▸ Fuel gasifiers ▸ System Integration	▸ Industrial gas Turbines from 5 to 50 MW ▸ Aero derivative gas turbines from 4 to 64 MW	▸ Steam turbines from 45 kW to 1,900 MW ▸ Steam turbines for industrial applications & power generation	▸ Turbo compressors for - Oil & Gas - Industrial applications ▸ Compressor packages incl. drives ▸ Compressor automation	▸ 50 HZ and 60 HZ Gas turbine power plant solutions ▸ CHP* ▸ IGCC** ▸ Repowering ▸ Integrated solar combined cycle ▸ HRSG	▸ Control solutions ▸ Electrical solutions ▸ Energy management solutions ▸ Solutions for distributed and hybrid power generation
					

Business Fields

* Combined heat and power ** Integrated gasification combined cycle

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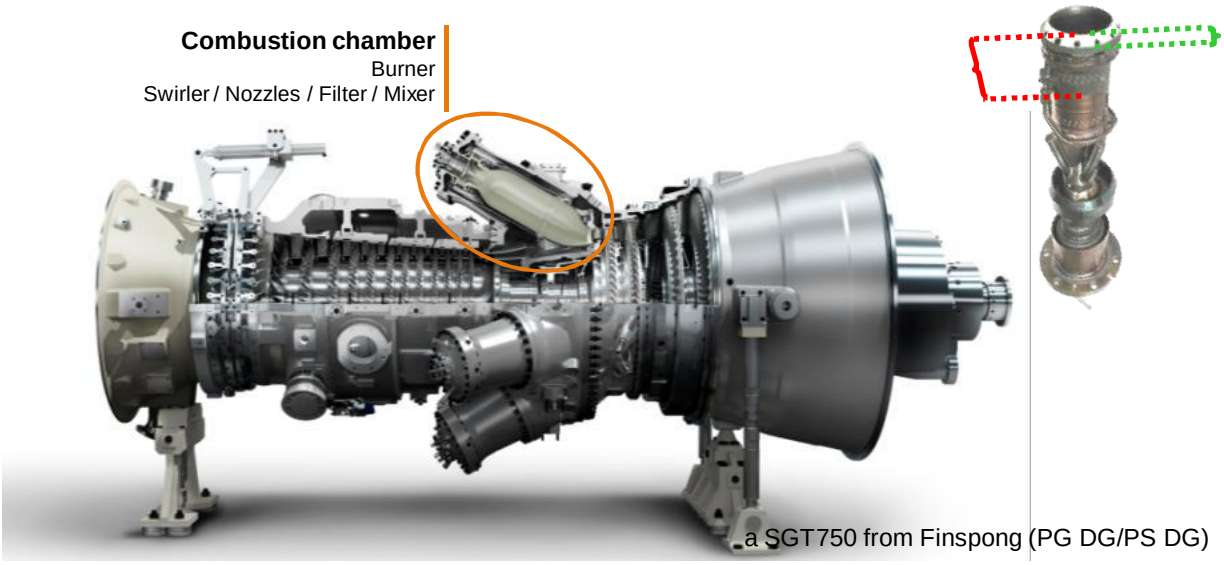
AM at is PG DG and PS DG; Industrial Gas Turbine
Selective **L**aser **M**elting **(SLM)**

Combustion chamber
Burner
Swirler / Nozzles / Filter / Mixer



a SGT750 from Finspong (PG DG/PS DG)

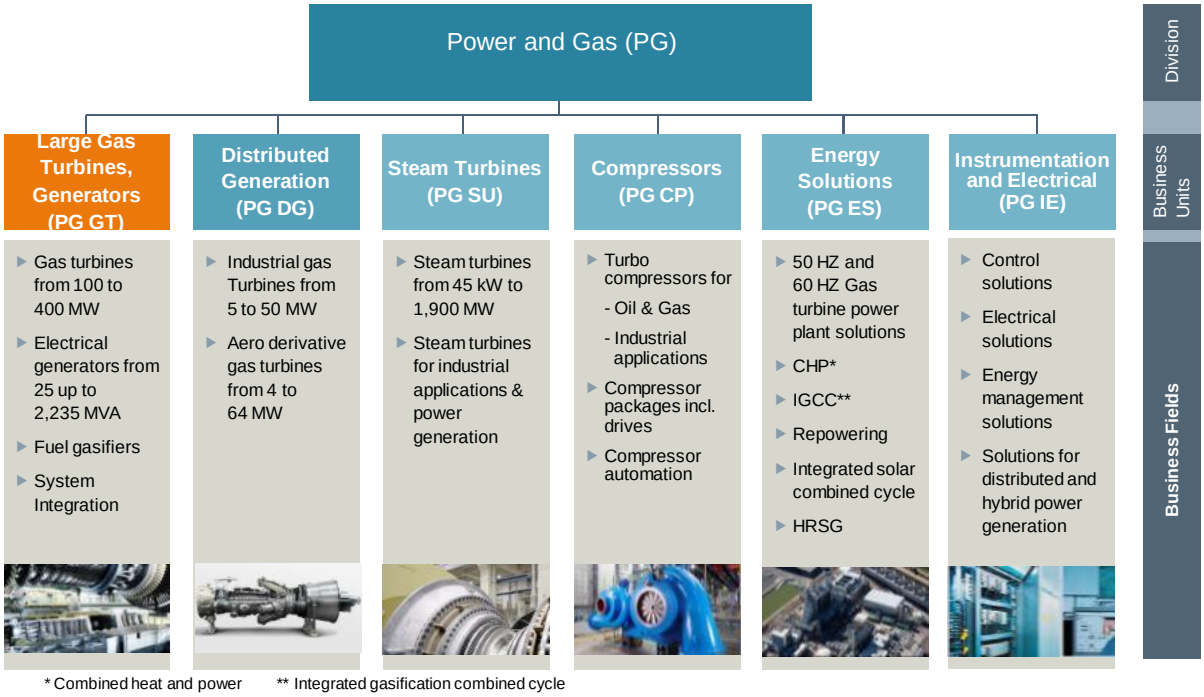
High Tech-Components with complex design and high potential to increase the benefits of the customer (e.g. efficiency; life time)

SLM: RaBuTiR (3)

Main benefits:

- Faster repair
- Technology updates included

Power and Gas Division



* Combined heat and power ** Integrated gasification combined cycle

SLM Rapid Manufacturing and Rapid Repair

Additive manufacturing has arrived in customer engines

Rapid Manufacturing

Driver

- Long lead times
- Long time line for implementation of new designs

SLM-Swirler

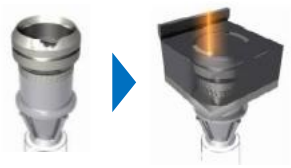
Result

- Lead time reduction by six months
- short term implementation of re-designs

Rapid Repair

Driver

- Long repair times
- Costs for repair



SLM burner repair

Result

- Significant lead time reduction

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Industrialization Line Integration

Hannover Fair 2015
Digitalization Forum

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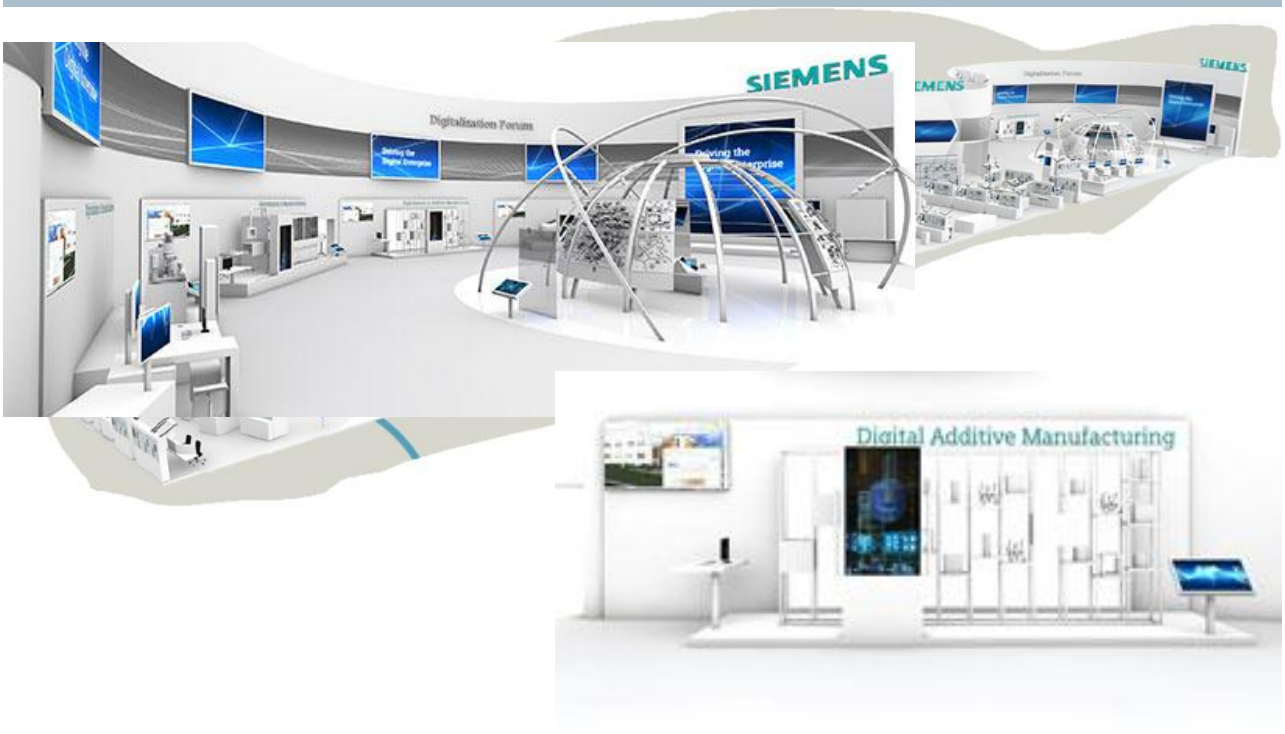

Additive Manufacturing process overview

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CAD / CAM design

2D conversion

Additive Manufacturing

Product

Additive Manufacturing summarizes various production processes.

Production process	Material
Powder bed fusion	• Metal • Polymer • Ceramic
Vat photopolymerization	• Photopolymer
Directed energy deposition	• Metal
Material extrusion	• Polymer
Material jetting	• Photopolymer • Wax • Metal
Binder jetting	• Polymer • Ceramic

1 based on ASTM F2792-08

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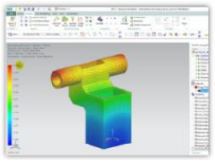
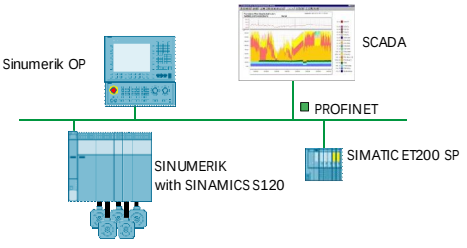
Our Portfolio for AM covers the entire Value Chain

Added value	Siemens competence
PLM software	PL portfolio
Materials	CT expertise, plants: Application know-how
"Print heads"	Scanlab
Automation & Drives	AS, MC, PL portfolio
OEMs	
Production	Plants, energy, railways
Products & services	Plants, energy, railways





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Additive Manufacturing is influencing high end and daily life applications

Energy, aerospace, automotive

Medical and health care

Daily life

Siemens vision of industrialized Additive Manufacturing

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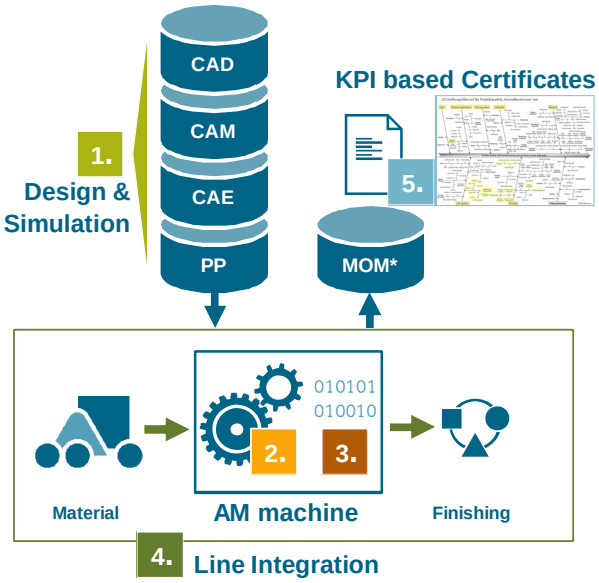

1. Increased part accuracy
One seamless software platform synchronizing the entire PLM tool chain down to the machine runtime (e.g. optimized formats w/o “STL-triangles”)

2. Increased process quality
Real time acquisition, analysis and control of the relevant process data on the machine level (= closed loop control)

3. Increased machine efficiency & flexibility
Open CNC enables comprehensive machine data analytics for continuous improvement (e.g. condition monitoring)

4. Enhanced process stream
Fully automated horizontal work flow integrating pre- and post- processes in one production line (strong analogies with production machines)

5. Increased production efficiency
KPI based certificates for documented part quality of produced parts w/o inefficient workarounds (e.g. w/o computer tomography)

The Siemens portfolio along the entire value chain enables the industrialization of AM

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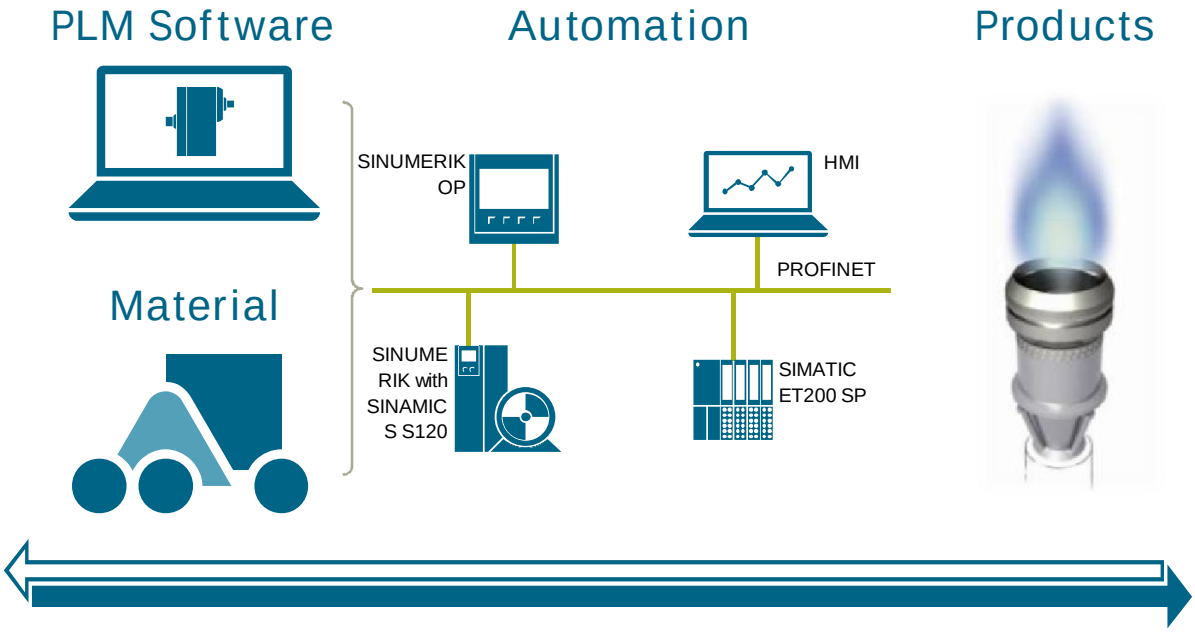

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Production

Siemens Bets Big on Metal 3D Printing with €21.4 Million Facility

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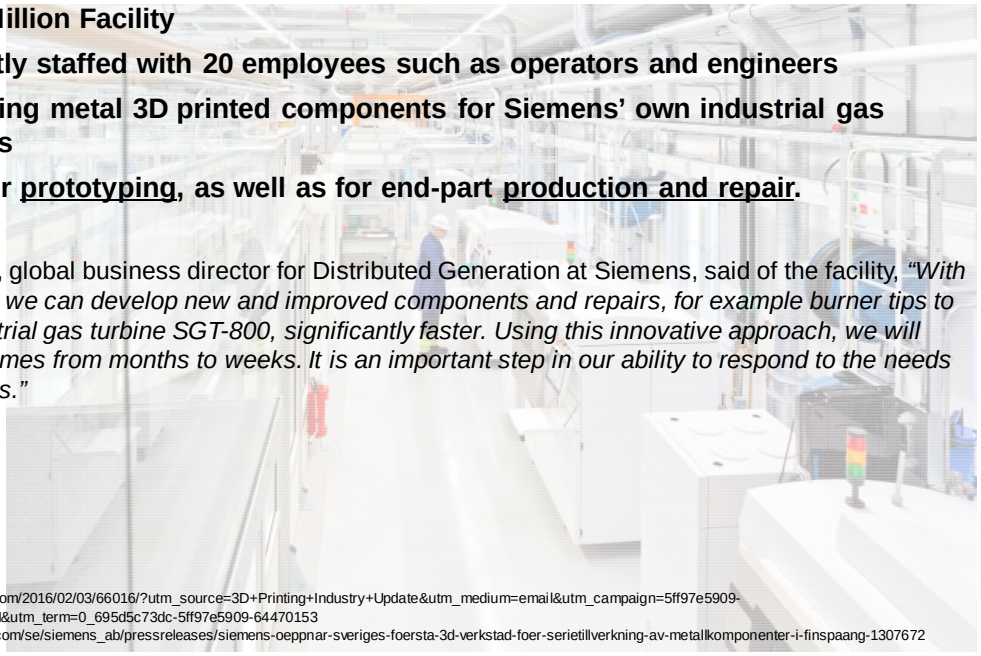

- **€21.4 Million Facility**
- **Currently staffed with 20 employees such as operators and engineers**
- **Producing metal 3D printed components for Siemens' own industrial gas turbines**
- **Both for prototyping, as well as for end-part production and repair.**

Thorbjorn Fors, global business director for Distributed Generation at Siemens, said of the facility, *"With this investment, we can develop new and improved components and repairs, for example burner tips to serve our industrial gas turbine SGT-800, significantly faster. Using this innovative approach, we will shorten repair times from months to weeks. It is an important step in our ability to respond to the needs of our customers."*

http://3dprintingindustry.com/2016/02/03/66016/?utm_source=3D+Printing+Industry+Update&utm_medium=email&utm_campaign=5ff97e5909-RSS_EMAIL_CAMPAIGN&utm_term=0_695d5c73dc-5ff97e5909-64470153
http://www.mynewsdesk.com/se/siemens_ab/pressreleases/siemens-oeppnar-sveriges-foersta-3d-verkstad-foer-serietillverkning-av-metallkomponenter-i-finspaang-1307672

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Summary and Outlook

Additive Manufacturing is a key technology to fulfill market requirements

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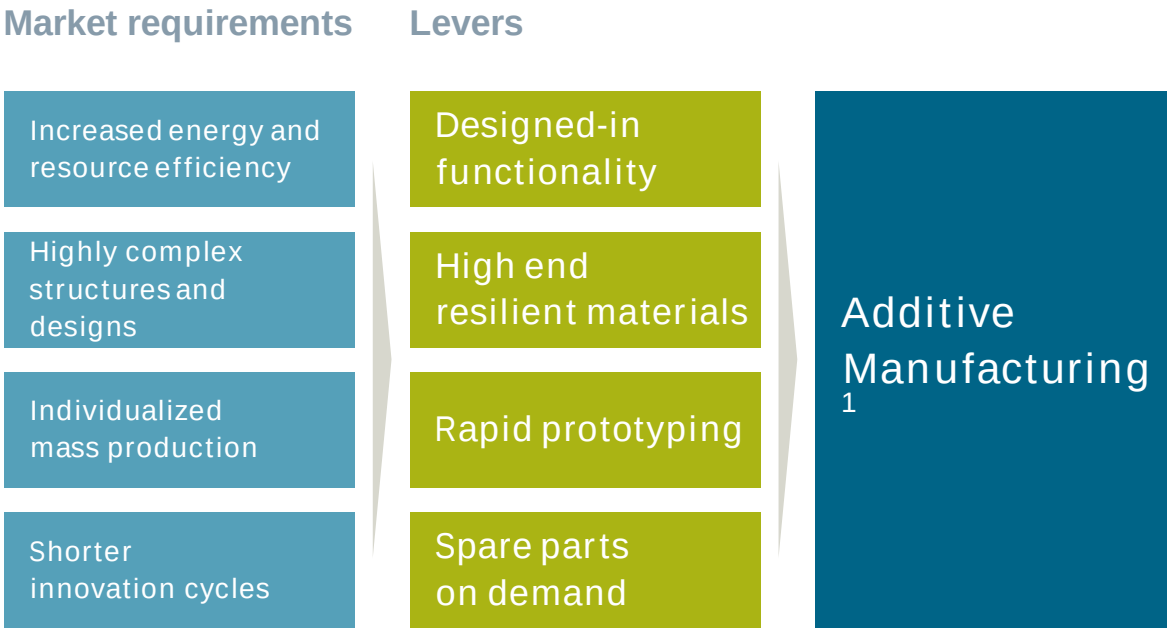

1) ISO/TC 261 – Additive manufacturing

Summary

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Additive Manufacturing …

… facilitates optimization potentials.

… is on the path of industrialization.

… requires a holistic digitalized approach.

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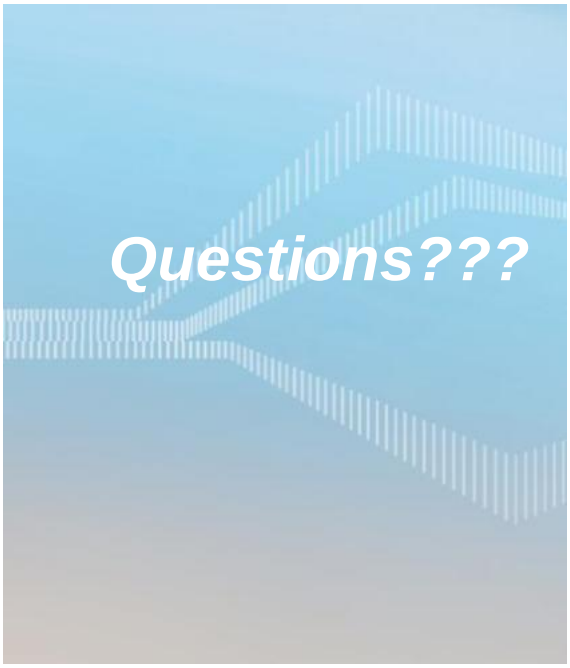
Many thanks for your attention!



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