

Additive Manufacturing as a contribution to (economic successful and) sustainable products

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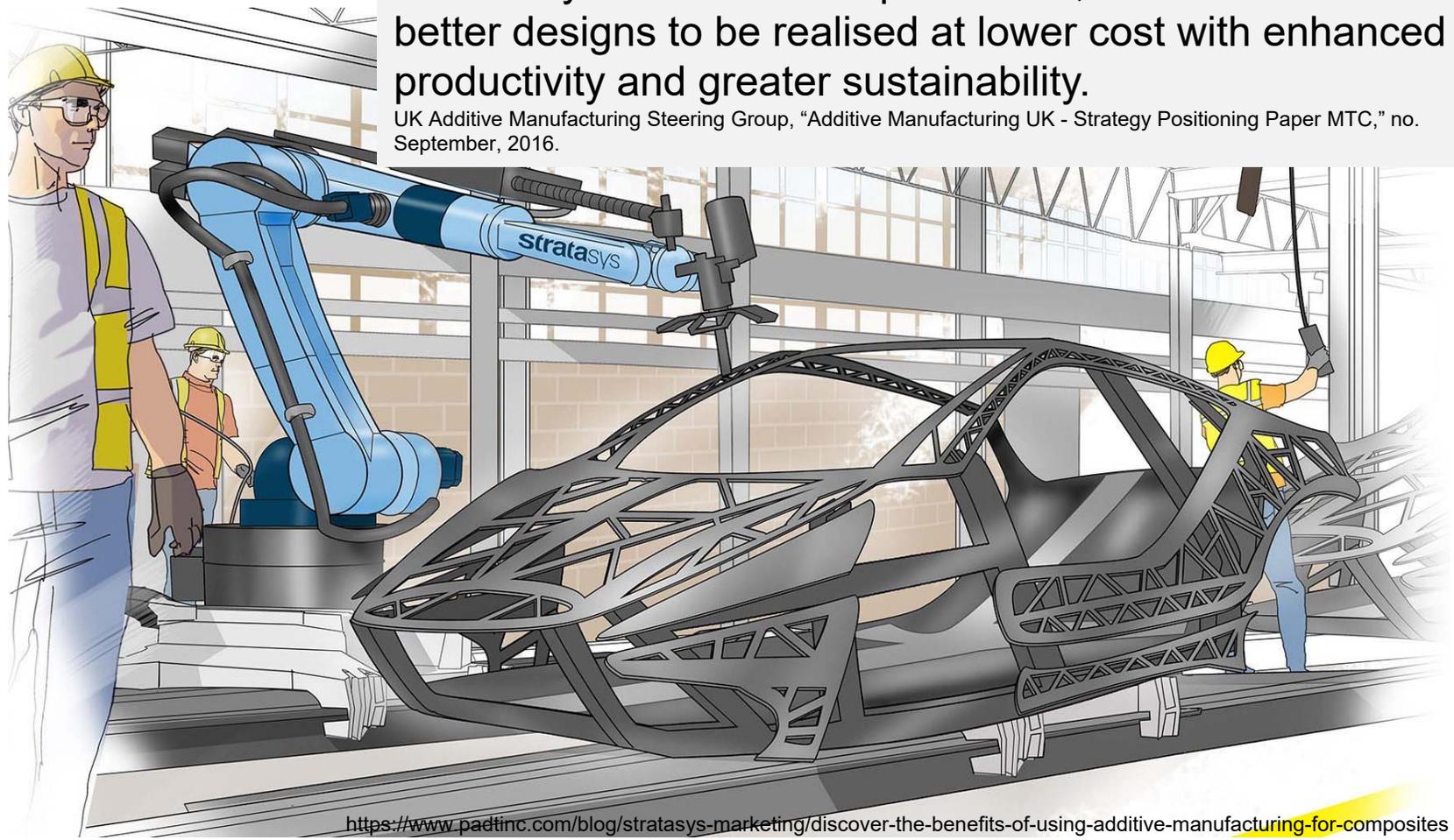
SUSTAINABLE DEVELOPMENT GOALS

<p>1 NO POVERTY</p> 	<p>2 ZERO HUNGER</p> 	<p>3 GOOD HEALTH AND WELL-BEING</p> 	<p>4 QUALITY EDUCATION</p> 	<p>5 GENDER EQUALITY</p> 	<p>6 CLEAN WATER AND SANITATION</p> 
<p>7 AFFORDABLE AND CLEAN ENERGY</p> 	<p>8 DECENT WORK AND ECONOMIC GROWTH</p> 	<p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p> 	<p>10 REDUCED INEQUALITIES</p> 	<p>11 SUSTAINABLE CITIES AND COMMUNITIES</p> 	<p>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</p> 
<p>13 CLIMATE ACTION</p> 	<p>14 LIFE BELOW WATER</p> 	<p>15 LIFE ON LAND</p> 	<p>16 PEACE, JUSTICE AND STRONG INSTITUTIONS</p> 	<p>17 PARTNERSHIPS FOR THE GOALS</p> 	 <p>SUSTAINABLE DEVELOPMENT GOALS</p>

AM Legends, daydreams, visions

AM is set to revolutionise businesses globally by providing a radically new method of production, that enables new and better designs to be realised at lower cost with enhanced productivity and greater sustainability.

UK Additive Manufacturing Steering Group, "Additive Manufacturing UK - Strategy Positioning Paper MTC," no. September, 2016.



<https://www.padtinc.com/blog/stratasys-marketing/discover-the-benefits-of-using-additive-manufacturing-for-composites>

Reality today

- ... **Only limited quantitative data are available** on how AM manufactured products compare to conventionally manufactured ones in terms of energy and material consumption, transportation costs, pollution and waste, health and safety issues, as well as other environmental impacts over their full lifetime.
- Reported research indicates that the specific energy of current AM systems is **1 to 2 orders of magnitude** higher compared to that of conventional manufacturing processes ...

K. Kellens, M. Baemers, T. G. Gutowski, W. Flanagan, R. Lifset, and J. R. Dufloy, "Environmental Dimensions of Additive Manufacturing: Mapping Application Domains and Their Environmental Implications," *J. Ind. Ecol.*, vol. 21, pp. S49–S68, 2017.

Where is your AM process? Why and what is necessary to reach the plateau?

Shortcut?



<https://www.3dnatives.com/en/gartner-hype-cycle-3dprintingpredictions-150120194/>

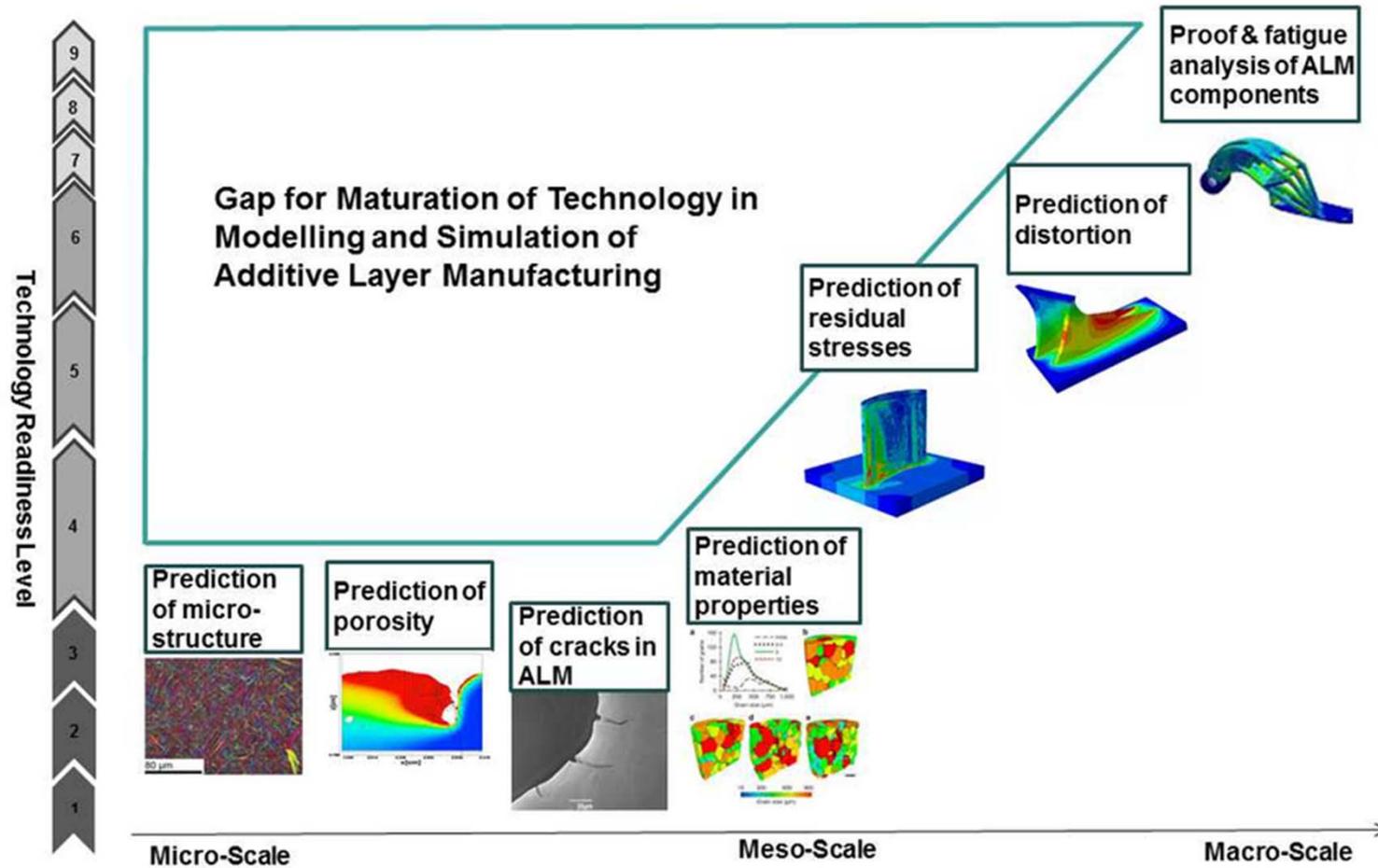
© 2018 Gartner, Inc.

(Current) challenges in AM

- Part and process design
- Process control
 - Integrity
 - properties
 - thermal management
 - control residual stresses and distortion
- costs

Chances in AM

- Complex parts with respect to
 - Geometry
 - Material (e.g. gradients, ...)
- Reduced material input
 - improved fly 2 buy
 - reduced CO2 footprint
- Produce parts where and when you need it
 - Reduced stock
 - Reduced transportation



Example



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AMAZONE

Disc Harrow bionic rocker arm

Welded construction:

- 16 Meters of welds

Optimized casted part:

- Integral part
- 35% costs reduction
- 10% weight reduction
- 250% fatigue performance

Casted part with 3D printed form:

- 11% weight reduction
- kept performance
- 75% tooling lead time reduction

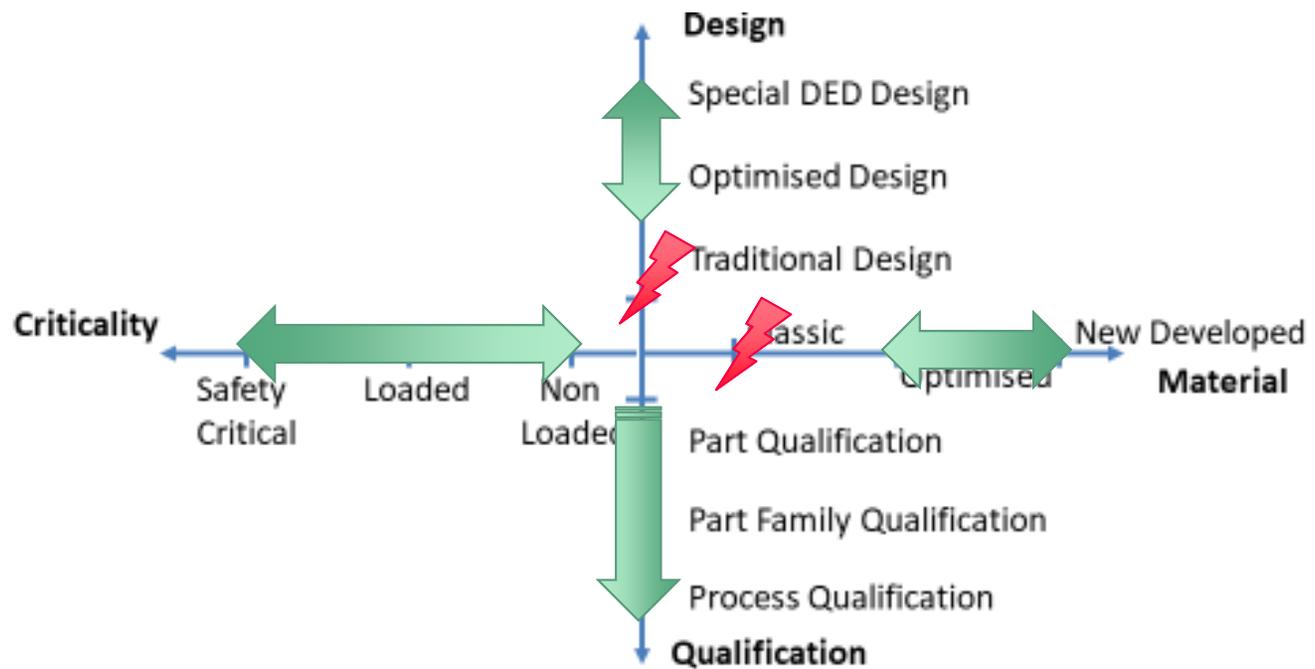


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- Reported research indicates that the specific energy of current AM systems is 1 to 2 orders of magnitude higher compared to that of conventional manufacturing processes ...
- From an environmental perspective, AM manufactured parts can be beneficial for very **small batches**, or in cases where AM-based redesigns offer **substantial functional advantages** during the product use phase (e.g., lightweight part designs and part remanufacturing)

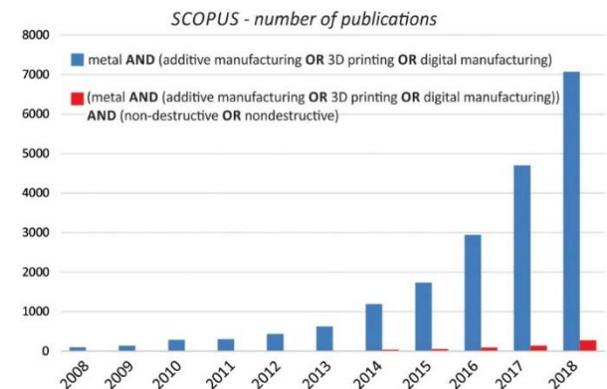
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Ingredients for successful WAAM Parts



Current

- applications, ideas
 - Optimized design (lightweight, ...)
 - Print 2 forge (fly to buy)
 - Direct alloying
 - Tailored properties
- ... & challenges
 - Software & desing interfaces
 - Process properties relationship
 - Quality
 - NDT
 - Costs



Catalin Mandache (2019) Overview of non-destructive evaluation techniques for metal-based additive manufacturing, *Materials Science and Technology*, 35:9, 1007-1015, DOI: [10.1080/02670836.2019.1596370](https://doi.org/10.1080/02670836.2019.1596370)

Necessary next steps

- Consider integrity and final properties
- Understand process details
- Minimize/optimize Postprocessing (surface quality, ...)
- Develop design rules
- Optimize & automate path strategy development
- Provide software tools with standardized interfaces
- coordinated modelling, simulation & experimental validation

T. W. Simpson, "Additive manufacturing with metals tutorial," vol. 0, 2018.



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