Exploring Metal Additive Manufacturing

Navigating the Landscape of Metal 3D Printing Technologies

SEURAT

AMPOWER

About this guide

Additive Manufacturing has emerged as a transformative enabler in high-value metal part production over the past 15 years. Sectors such as Energy, Medical, and Aerospace have witnessed groundbreaking innovations, thanks to the technology's capacity for freedom of design and tool-free manufacturing.

Now, new technologies are entering the market to extend this potential to higher-volume metal manufacturing. Seurat Area Printing® technology stands out as a promising candidate among them, offering the potential to broaden the reach of Additive Manufacturing into applications and industries that previously struggled to find a business case for AM due to high costs and low productivity.

This paper aims to provide potential users with a state-of-the-art overview of the current landscape of metal Additive Manufacturing and outlines how Seurat aims to position itself as the next generation AM solution.

Matthias Schmidt-Lehr
Managing Partner of AMPOWER

Choosing the right metal production method is a tall order. There's new technology to research, new risks to weigh, and new environmental pressures to consider. You have an overwhelming number of choices—and likely even more questions. Is additive manufacturing better than traditional techniques? Which technology is right for your application? Will you need to redesign your parts? Should you invest in your own equipment and recruit a highly specialized staff or outsource?

We created this guide to help you find the answers. It was prepared in partnership with AMPOWER, the leading strategy consultancy and thought leader in the field of industrial Additive Manufacturing. It includes valuable context and non-biased insights that explain why additive manufacturing is important to the industry, outlines the traditional manufacturing solutions, and explores a range of additive alternatives.

We hope it jumpstarts your search for the best approach for your company, your part, and your budget.

James DeMuth
Co-Founder and CEO of Seurat Technologies

Executive Summary

Traditional metal manufacturing methods, such as casting, forging, and machining, have long been fundamental to industrialization but face challenges including high resource consumption, limited design flexibility, and environmental impact. Additive Manufacturing (AM) technologies, emerging over the past two decades, offer new possibilities for complex and high-value component production, particularly in industries like medical, energy, and aerospace. Despite its potential, AM's high-cost structure limits its adoption to niche markets. However, advancements aim to reduce costs, potentially expanding AM's reach into broader metal manufacturing sectors.

While traditional methods excel in high-volume production, they face challenges such as supply chain vulnerabilities, high energy consumption, and environmental impact. Increasingly, there is a trend toward reshoring manufacturing, particularly in high-tech and critical infrastructure sectors, driven by supply chain risks and sustainability concerns. AM presents itself as an environmentally friendly alternative, offering design flexibility and potential energy savings, but its high total cost of ownership remains a barrier to widespread adoption.

Various AM technologies exist, including Laser Powder Bed Fusion (L-PBF), Electron Powder Bed Fusion (E-PBF), Direct Energy Depositioning (DED), and Metal Binder Jetting Technology (BJT), each with its advantages and applications. L-PBF and E-PBF are established but costly, while DED and Binder Jetting offer potential cost savings but are still evolving. Build rate, level of detail and cost per part are major challenges for AM, consequently development efforts are focused on increasing efficiency and scalability.

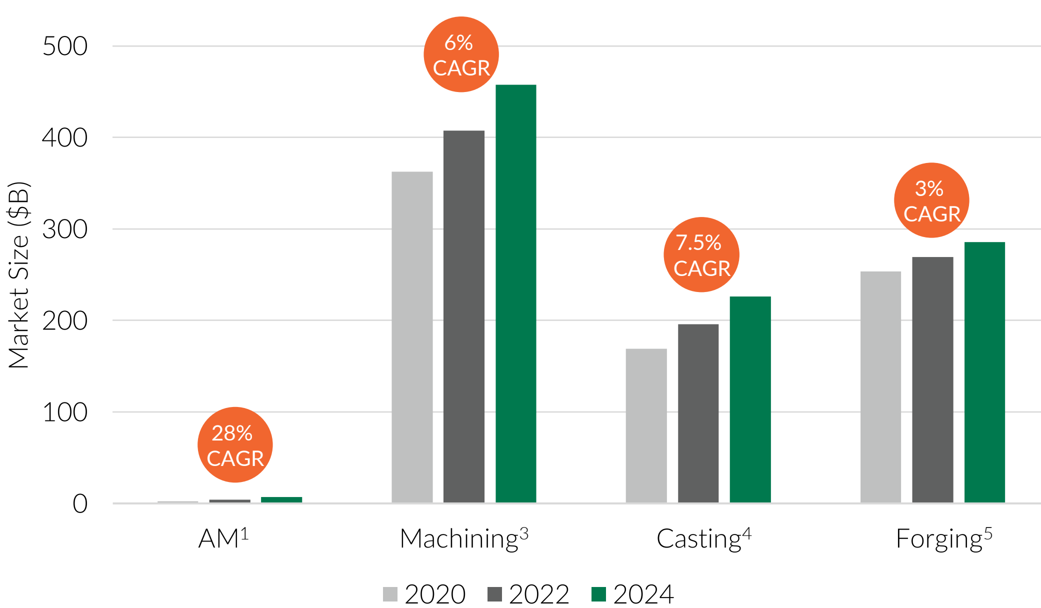
Seurat's Area Printing® technology represents a promising advancement in AM productivity, utilizing a high-power pulsed laser to simultaneously melt a larger area of metal powder, reducing costs and increasing scalability while maintaining a high level of detail.

Overall, while AM offers potential benefits for complex component manufacturing and sustainability, addressing cost barriers and advancing technology maturity are crucial for broader adoption across metal manufacturing sectors.

Introduction

Why we need Additive Manufacturing to advance

Traditional metal manufacturing technologies enabled the industrial world as we know it today. Nearly every metal component we use today, is manufactured by either casting, forging, forming or machining. Often, an additional joining technology, such as welding, is involved to achieve the final part. A common feature in all of these technologies is that they are designed and optimized for high volume manufacturing which nowadays often takes place far away from the point of assembly and use. Moreover, most traditional manufacturing technologies are tool bound which leads to limitations in design and flexibility. Additive Manufacturing (AM) technologies have emerged over the past 2 decades revolutionizing manufacturing of highly complex and high value components from industries like medical, energy and aerospace. While the technology offered significant cost savings for the implant manufacturing industry, in the energy and turbine industry efficiency increases through advanced designs made all the difference. In the past 5 years, the trend towards reduced carbon emissions accelerated the growth of metal AM technologies due to the potential of highly efficient engines, valves or heat exchanger designs. This trend will continue to fuel growth of the AM market leading to USD 10.6 billion in 2027[1]. However, todays high-cost structure of metal Additive Manufacturing limits the addressable market to high-value applications. By improving the economics of AM and reducing cost per part, the addressable market can be expanded, potentially to the overall global metal manufacturing market which is currently valued at USD 2.85T according to analysts [2].



[1] Source: AMPOWER Report 2023
[2] Source: https://www.thebusinessresearchcompany.com
[3] Source: https://www.prnewswire.com
[4] Source: https://www.globenewswire.com, https://www.gminsights.com
[5] Source: https://www.grandviewresearch.com, https://www.alliedmarketresearch.com

What is driving AM growth

1

Increased adoption in high-end applications

In the past decade, high qualification hurdles have been overcome in order to qualify Additive Manufacturing in high-end industries (like Aerospace and Medical) for the first products. The technology now expands into other product families and across company peers.

2

Carbon emission reduction efforts

The industry today is striving towards reducing energy consumption and increasing efficiency in their machines and products. The global pressure on reduced carbon emissions is fueling those efforts and with the design freedom of Additive Manufacturing, engineers have an additional asset to make highly efficient components feasible.

3

Increasing supply chain resilience

In the past years the trend for globalization came to a halt and even turned into a reshoring trend, making manufacturing more local. Additive Manufacturing with its potential to reduce waste and reshore manufacturing is playing a major role in those efforts.

...or slowing it down

Cost

1

Cost per part is the major threshold Additive Manufacturing has to overcome in order to penetrate metal manufacturing markets beyond high value applications. Further significant advances can only be achieved with new technology approaches.

Know-how and conviction

2

Traditional manufacturing technologies are deeply rooted in today's engineering environments. While some industries are open to new technologies, others are more resistant to change, mostly due to lack of understanding, trust and experience.

Traditional Metal Manufacturing Technologies

The backbone of industrialization

For centuries, traditional metal manufacturing technologies have been the backbone of industrialization. Casting, one of the oldest techniques, involves pouring molten metal into molds to create intricate shapes. It excels at producing relatively complex parts compared to AM but can be resource-intensive and may generate considerable waste. Also, the manufacturing supply chain has become vulnerable due to outscoring to other continents and the production is inflexible with high up front tooling costs and lead times of several months. Forging, with its roots in ancient blacksmithing, involves shaping metal through compressive forces. It results in strong and durable components but can be labor, energy and resource-intensive and less suitable for intricate designs. Machining employs cutting tools to remove material from a solid metal workpiece. It provides precision and fine detail but can be time and energy consuming and often generates large amounts of waste material.

All traditional technologies are generally extremely cost efficient for their specific applications. However, it is often neglected, that traditional technologies are only cost efficient, when it comes to large manufacturing volumes of the same component. Initial investments especially into tooling equipment make small manufacturing volumes less economically feasible.

In the past decades, traditional metal manufacturing went through a global consolidation phase which led to a reduced number of suppliers. The remaining suppliers are often producing in low-cost countries. This development drove down cost but at the downside of increased supply chain risk, as the Pandemic in 2020 clearly showed. Coupled with an increase in political destabilization between the larger global players, this is driving the trend of reshoring manufacturing in the US as well as many European countries. Especially for high-tech industries and critical infrastructure technologies, OEM's now increase their efforts to onshore metal manufacturing.

Sustainability is the other major challenge traditional manufacturing is facing. Metal production accounts for 40% of total industrial greenhouse gas emissions, consumes 10% of the world's energy, involves the extraction of 3.2 billion tons of minerals, and generates several billion tons of by-products annually[1]. Hence, there is a pressing need for metal production technologies to undergo a transition towards greater sustainability.

From the raw material down to the finished assembly, many industries are looking more closely at the CO2 footprint along their value chain, identifying potential to reduce emissions or compensate them otherwise. Metal manufacturing is often associated to high energy consumption. Melting, forging or cutting material consumes vast amounts of energy which bear a significant potential for optimization.

[1]Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9999434/

Machining

+ Machining is versatile and ideal for creating precision parts and intricate designs. Its main purpose is to create functional surfaces for technical applications.

- Machining can be time-consuming, leading to higher machining costs. Material waste is a concern as significant material removal is involved, which has a negative impact on costing as well as CO_2 emissions.

Casting

+ Casting is often cost-effective for producing complex shapes and large quantities. Higher accuracies allow for post processing to often be limited to machining the functional surfaces.

- Initial tooling costs for creating molds, and their ongoing maintenance can be high, making casting less economical for small production runs. The material waste generated during casting can also add to costs and have a negative influence on the CO_2 emissions.

Forging

+ Forging generally results in strong and durable parts with excellent mechanical properties. It is efficient for simple shapes and high-strength applications.

- The machine and energy-intensive nature of forging, especially for intricate or customized components, can lead to higher production costs and CO_2 emissions. Tool wear and maintenance can also contribute to expenses.

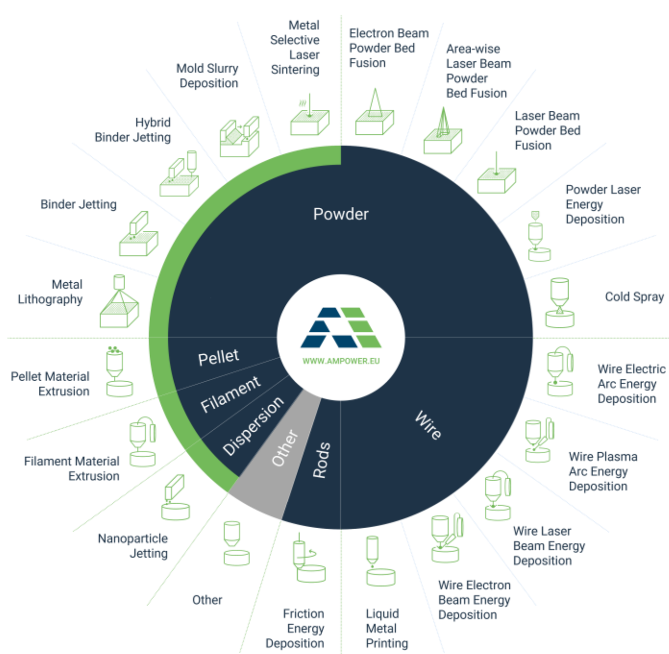
Metal Additive Manufacturing Technologies

Additive Manufacturing is not just one technology

In theory Additive Manufacturing is presenting itself as the ideal manufacturing technology. Not only does it offer great flexibility and freedom of design, but it also enables companies to increase the performance of their products to levels that were not possible before.

As of today, there are a select number of profitable and established Additive Manufacturing low volume serial production applications which can be found in the energy, medical and aerospace sectors. Besides those high-end industries, the technology has a limited rate of adoption. The main reason is neither due to lack of knowledge nor poor performance of the technology, but rather in the high total cost of ownership. Hence, Additive Manufacturing today is the perfect technology for high end and highly complex applications that already involve expensive manufacturing processes. However, new companies with new technologies are striving to bring down the cost to make AM a viable alternative to traditional manufacturing on a broader part spectrum.

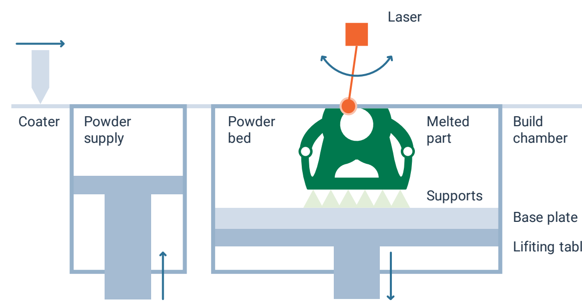
When metal Additive Manufacturing is mentioned, it is often associated with Laser Powder Bed Fusion (L-PBF), the most common technology on the market. However, there are around 20 different technologies known today, which label as "Additive Manufacturing" and are capable to generate 3D geometries from metal. Many of them have significant differences and often aim for a completely different application groups.



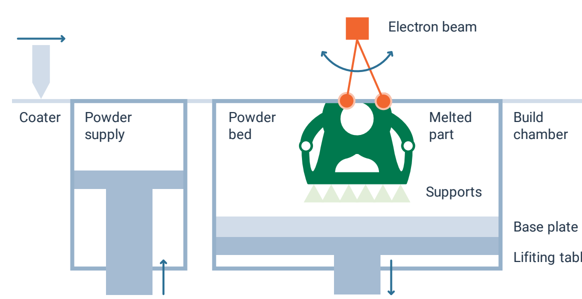
Source: ampower.eu

Powder bed technologies are state of the art in industrial metal AM

Laser Powder Bed Fusion is the most common and widely established metal Additive Manufacturing technology. Applications range from medical implants, aerospace components to turbine parts. Due to its high cost, the technology is suited for highly complex components in engines, turbines or medical applications. The fine resolution makes it a perfect fit for fine structures, complex geometries and sophisticated designs. In order to increase productivity, machine OEMs are following multi-laser approaches with simultaneous melting. However, with each additional laser source, the investment cost and complexity of the machine increases which hinders this technology to significantly reduce cost per part.

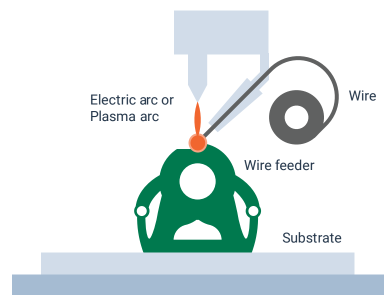


Electron Powder Bed Fusion has many similarities with L-PBF but uses an electron beam instead of a laser as its energy source. It has seen wide commercialization by Arcam AB, a Swedish company acquired by GE. The technology is less accessible due to the complex beam shaping mechanisms in electron beam deflection but has some advantages such as a pre-heated build surface. The resulting possibility of stacking parts on top of each other leads to higher machine utilization. The higher melting speed of E-PBF comes at a cost of less fine surface quality and higher technology complexity. The cost advantage versus Laser technologies has been utilized predominantly in medical implants and turbine blade applications so far, where surface machining is a common subsequent process step.

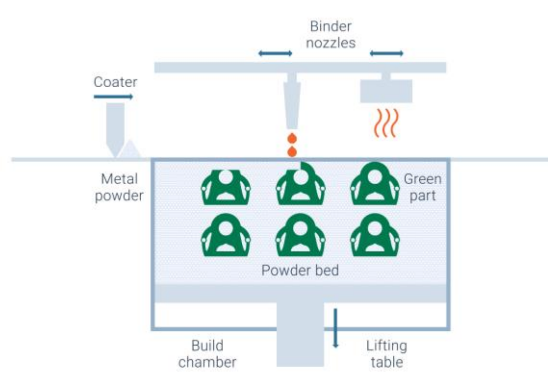


DED and sinter technologies enhancing application range

Direct Energy Depositioning technologies follow a quite simple principle. It usually utilizes a traditional welding technique such as Plasma or Electric Arc welding, and applies it to a 3D geometry, which is built on a baseplate. The welding head is mounted on a gantry or robot system. This simple yet effective principle usually leads to parts with less geometrical detail but high build rates. Cost per part is often much lower than with powderbed technologies. Due to the lack of resolution, those technologies are currently used to generate near-net-shape blanks that are machined to final geometry. This is the case for components where the manufacturing volume or the lead time make a forged or casted raw part unfeasible. The largest application fields are currently structural Titanium aviation brackets as well as spare parts in the oil and gas industry. This technology group also has a high potential in the repair sector of large metal components.



Sinter technologies and especially **Metal Binder Jetting** is almost as old as L-PBF but has just recently seen an increased industrialization dynamic. In this process the powder is joined by a binder and not directly melted. This creates green parts which are sintered in a traditional sintering process known from Metal Injection Molding or Press-Sinter technologies to reach its final properties. This technology can generate highly detailed components with a fine resolution and the print process itself is much more cost efficient. However, the complete process chain is complex and the maturity level has not yet reached that of L-PBF. Part consistency and the know-how around part shrinkage are challenges that still need to be overcome and are hindering broad industrialization.



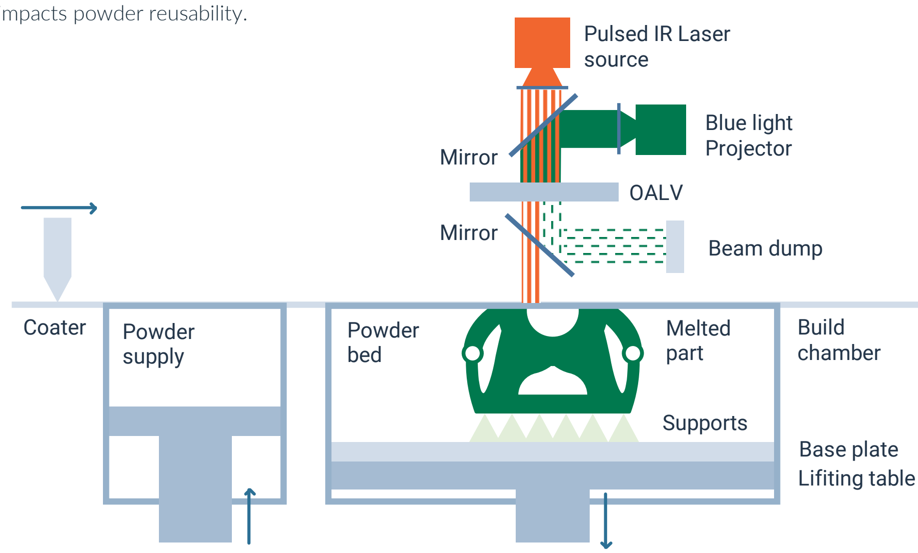
Next generation Area Printing® is the new technology leap

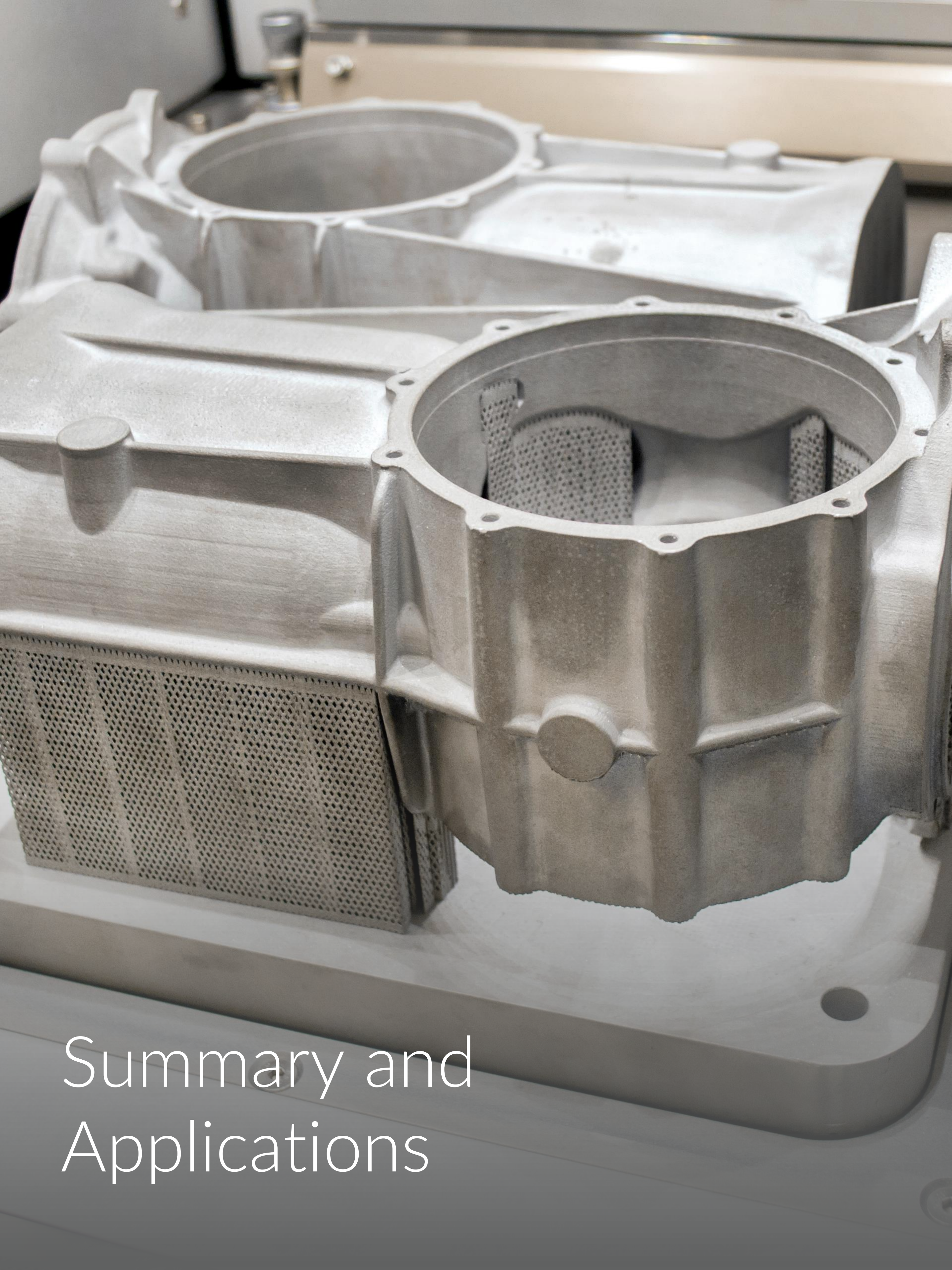
As indicated before, the major obstacle for metal Additive Manufacturing is productivity and cost per part. Typically, the additive processing cost contributes over 70% of the cost of each part. Decreasing the AM parts processing cost requires either increasing the productivity or reducing the machine investment.

For many L-PBF printers, productivity increases are mainly achieved by increasing the number of lasers which has physical and economic limits. Each additional laser source requires a scanner unit which adds additional space as well as significant cost. Scanners are highly complex systems which require exact calibration and dedicated heat management to work accurately. Each additional laser source adds up in complexity and risk of failure due to miss-calibration or failure of a single element. Additionally smoke and spatter can limit the number of lasers operating at the same time on the powderbed and also impacts powder reusability.

Instead of single or multiple laser sources, Seurat's Area Printing technology utilizes a high-power pulsed laser which reduces the interaction time with the metal powder and is dimensioned to expose a larger field, the "area", simultaneously. Area Printing goes through multiple steps to shape and pattern the laser melting the metal powder. Including overlaying the laser beam with a patterned blue light projector and passing through an Optically Addressable Light Valve (OALV) which polarizes the laser beam according to the blue light pattern.

With this approach, the productivity of the machine can be increased by several factors. Instead of just melting one single laser spot, a whole area is being melted simultaneously with minimal spatter and soot. This leads to overall reduced cost per part and higher scalability of the technology.





Summary and Applications

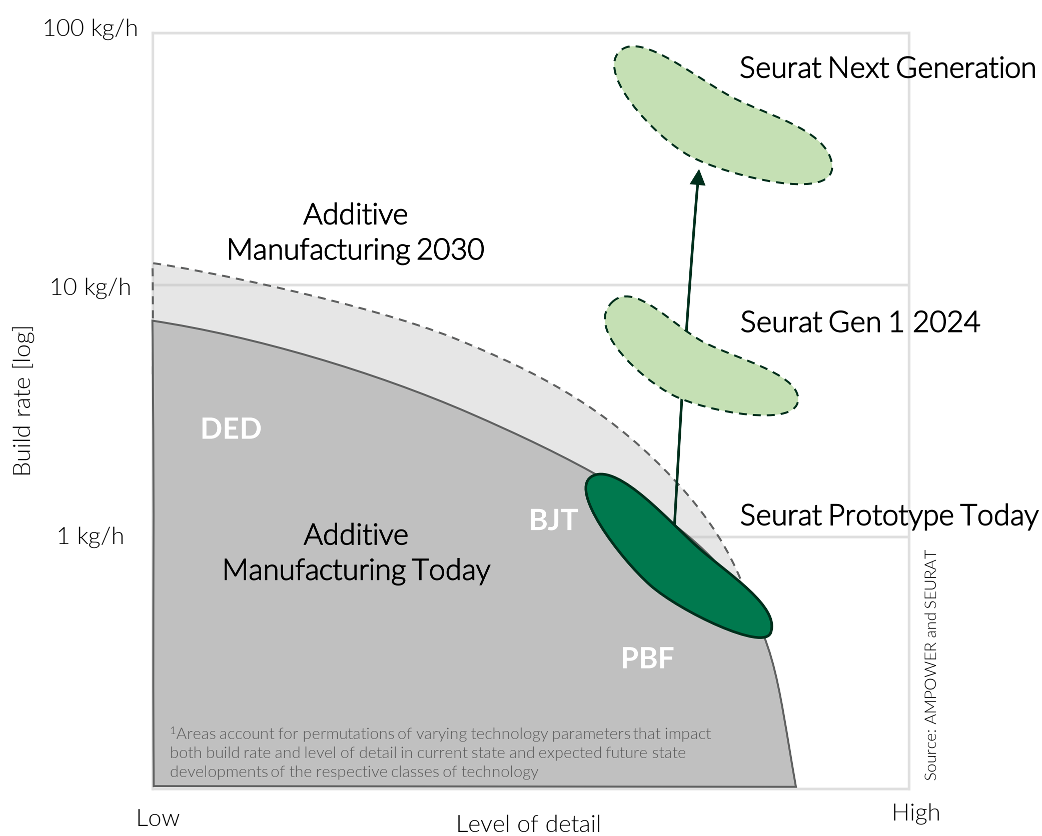
Navigating pros and cons of today‘s AM technologies

The 4 major metal Additive Manufacturing technologies each have their advantages and disadvantages as well as a different level of maturity in their relevant sectors. L-PBF and E-PBF are by far the most established and mature technologies which is reflected by the range of applications that have made it into production.

For DED, two major applications are currently being investigated and qualified. Besides repair applications especially in tooling and oil & gas environments, raw parts for subsequent machining are a major business case in aerospace.

Binder Jetting (BJT) on the other hand is still at an early stage of industrialization with many different application segments under development. The most advanced ones are jewelry applications or watch cases as well as medical instruments.

Build rate vs. level of detail

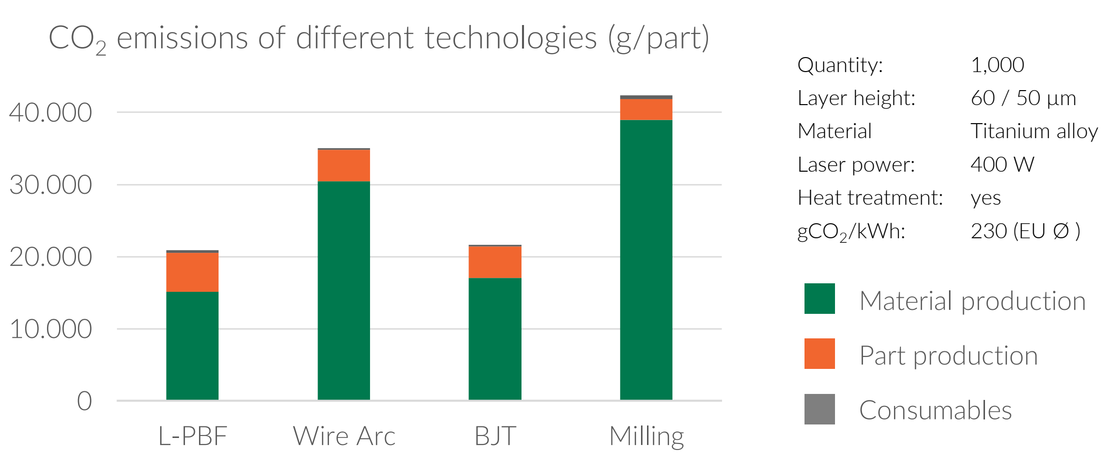


Where AM contributes to lower CO2 emissions

There is no general answer to which manufacturing technology has the lowest carbon footprint. The overall footprint is heavily influenced by the alloy group as well as the part geometry and the location of manufacturing. Complex geometries with high buy-to-fly ratio are favorable for net-shape technologies such as AM and casting, while simple parts might be most sustainable if milled. Depending on the alloy, AM technologies of PBF can reduce the carbon footprint significantly when compared to milling. Due to the ability to manufacture weight optimized designs, the material input and therefore the embodied energy is significantly smaller and compensates for higher energy consumption in the part manufacturing process. Especially for typical raw material production sites such as Russia and China with their unfavorable CO_2 footprint of their electric grid, the embodied energy in the raw material will increase and the overall sustainability can tip towards AM technologies.

Original design for milling and Wire Arc process

Optimized L-PBF, BJT and casting design with 50 % weight saving



Source: ampower.eu

L-PBF

+ The technology is ideal for complex geometries with fine features and high material and part performance requirements.

- Low productivity and high-cost are limiting the technology to high-value applications, small series and prototype manufacturing.

E-PBF

+ Potentially offering lower cost than L-PBF due to speed and stackable build jobs. Also, the process can produce crack-free structures and can process brittle intermetallic materials.

- High technology complexity and limited availability are limiting industrialization beyond high-value medical and aviation components.

Binder Jetting

+ Moderate cost and productivity can enable limited series manufacturing of small and complex components that are expensive to machine or cast. High resolution and fine details allow for intricate designs.

- Sintering deformation is limiting freedom of design. Lower mechanical strength is challenging for high-performance applications.

DED

+ High throughput make this technology ideal for repair, large spare parts or near-net-shape blanks from high-value alloys.

- Low level of detail and high design constraints require machining of the complete component thus limiting adoption to low volume series.

Area Printing®

+ High throughput similar to DED with resolution comparable to L-PBF. Ideal for high volume manufacturing due to the low cost and scalability.

- Low maturity, limited available case studies of finished parts. Single source and only available through contract manufacturing.


At Seurat, we realized there wasn’t an ideal solution for serial production
So we made one

Future-ready manufacturing. Ready now.

Seurat is an additive metal contract manufacturer. But we like to think of ourselves as an innovation company.

We've reimagined metal manufacturing because we believe today's processes are broken. It forces companies to make unacceptable tradeoffs between speed, cost, and quality. Our unique Area Printing® technology and print depot are a next-generation solution to the age-old dilemma. Available exclusively from Seurat, our process delivers high-volume low-cost production, and high-fidelity craftsmanship.

Our goal is nothing short of transforming how metal parts are made.

Seurat is the only contract manufacturer with our state-of-the-art depot. To be clear, we are not selling printers. And frankly, you don't want us to. That saves you the time of investing in expensive equipment, hiring specialized talent, and becoming a subject matter expert in a discipline you don't need to learn.

High performance. High fidelity. Made highly responsible.

Our current depot is located in MA and future depots will be located globally based off of logistics and customer demand. Because your parts can be manufactured in our local print depots, your supply chain shortens, and your dependence on offshore resources decreases. And because our depots are powered by 100% green energy, we're able to minimize environmental impact. As a result, you'll get the right quantity of the right parts at the right time at the right price—all while doing right by the environment

Seurat. The smarter manufacturing solution for parts, people, and planet.

If you're frustrated with your current metal-making options, we're looking for a select handful of forward-thinking companies who share our passion for innovation. Our team of experts will help you determine if Area Printing is a good fit for your high-volume parts. Contact us at info@Seurat.com

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