AMPOWER INSIGHTS

# Additive Manufacturing **Part Cost and Pricing**

A detailed analysis of part printing cost and market pricing

**INSIGHTS GAINED:**

- What is the cost structure of metal and polymer Additiv Manufacturing parts?
- How much does it cost to buy Additive Manufacturing parts from suppliers?
- What to consider when making a make or buy decision?

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AVIATION BRACKET, 1,000 PARTS/YEAR, 94 CM³, 90 X 86 X 78 MM³, ALUMINUM L-PBF AT PART MANUFACTURING SERVICE BUREAU, AVERAGE PRICING



# Insights gained

What is the cost structure of metal and polymer Additive Manufacturing parts?

How much does it cost to buy Additive Manufacturing parts from suppliers?

What to consider when making a make or buy decision?

# Management summary

Additive Manufacturing is rapidly evolving, and its implications are far-reaching across industries. In this AMPOWER Insights, we look into internal costing and the dynamic pricing landscape, investigating today´s manufacturing cost as well as market pricing by part manufacturing suppliers.

Our analysis focuses on manufacturing cost for AM parts and benchmarking in-house costs against service provider pricing. Key technologies in polymers and metals, including Material Extrusion, Selective Laser Sintering, Multi Jet Fusion, and Laser Powder Bed Fusion, are analysed. The spectrum of materials analyzed in this study spans PA12, APS, TPU, aluminum, stainless steel, and titanium alloys, each with its unique cost dynamics.

The cost structure of in-house metal Additive Manufacturing commences at 0.80 EUR/cm³ for aluminum or 298 EUR/kg, and 1.29 EUR/cm³ for stainless steel alloys, equating to 165 EUR/kg. For polymer components produced through powder bed technologies, in-house costs today are as low as 0.12 EUR/cm³ or 120 EUR/kg.

The market pricing can vary strongly due to different pricing strategies from the part manufacturing suppliers. For the most popular polymer materials PA12 and TPU, the price averages to around 1.00 EUR/cm³ with a spread from as low as 0.20 to 1.20 EUR/cm³.

Looking ahead, the market is witnessing groundbreaking developments that promise to redefine cost paradigms. New technologies such as Area Printing striving to reduce costs and enhance efficiency. Our whitepaper navigates these complexities, highlighting the urgency of not only optimizing costs but also embracing long-term AM strategies that encompass supply chain resilience, value chain strategies, and intellectual property considerations.

Download this paper at www.ampower.eu/insights


DRONE BODY FRAME, 1,000 PARTS/YEAR, 185 CM³, 271 X 140 X 170 MM³, PA12 MJF AT PART MANUFACTURING SERVICE BUREAU, AVERAGE PRICING

# About AMPOWER

AMPOWER is the leading strategy consultancy and thought leader in the field of industrial Additive Manufacturing. The company advises investors, start-ups as well as suppliers and users of 3D printing technology in strategic decisions, due diligence investigations and provides unique access to market intelligence.

On operational level, AMPOWER supports the introduction of Additive Manufacturing through targeted training programs, support in qualification of internal and external machine capacity and technology benchmark studies. The company was founded in 2017 and is based in Hamburg, Germany, operating worldwide.



# Content

# Printing cost drivers

# Navigating Additive Manufacturing Economics

The cost per part have gained increasing significance in Additive Manufacturing (AM) during the past decade. Initially employed primarily for prototyping, AM has since matured into a viable manufacturing technology for end-use components. Consequently, AM applications must now contend with conventional designs on the basis of cost per part.

This whitepaper analyzes the manufacturing costs and market pricing of Additive Manufacturing parts, drawing comparisons between in-house expenses and service provider offerings. It focuses on the most established AM technologies for polymers and metals, namely Material Extrusion, Selective Laser Sintering, Multi Jet Fusion as well as Laser Powder Bed Fusion for metals. The study covers polymer materials PA12, APS, TPU, as well as aluminum (AlSi10Mg), stainless steel (316L), and titanium alloys (Ti-6Al-4V). For market pricing a comprehensive examination of over 5,000 quotations from multiple online part manufacturing service providers was undertaken and analyzed.

AM business cases often hinge on straightforward cost savings facilitated by the AM manufacturing process. Products like hearing aids, endoprostheses, or fuel nozzles, being intricate and expensive to conventionally manufacture, benefit significantly from AM's attributes like mass customization, integral design, and geometrical optimization, leading to direct reductions in manufacturing costs. Contrary to direct cost savings, certain applications, particularly in metal, entail higher additive manufacturing costs. In these instances, the business case becomes favorable only when incorporating additional cost-saving factors during operation of the component or enhanced part performance. For instance, the decreased cycle time and subsequent heightened productivity of optimized AM molding inserts assume a monetary value that can be attributed positively to the AM part. To accomplish this, companies must possess a comprehensive grasp of all underlying costs and benefits related to Additive Manufacturing. This requires describing the cost structure of the entire manufacturing process on one side, while also identifying revenue streams generated through the application, along with direct and indirect cost savings.

For polymer applications, the cost advantages of a one-to-one AM replacement are often more apparent. Lower entry barriers, a higher technological maturity, and enhanced knowledge all contribute to favorable business cases for polymer AM parts. Nonetheless, indirect costs linked to Additive Manufacturing should not be overlooked. Designs are typically more intricate and time-intensive to generate. Initial qualification investments must be accounted for, and post-processing costs frequently remain uncertain during the early stages of AM application development.

To ensure a balanced comparison and mitigate potential sources of confusion, this study exclusively centers the cost and pricing comparison on the "as-built" manufacturing expenses.



# Scope of this cost and pricing study

**IN SCOPE:**

Material feedstock

Machine depreciation

Consumables

Basic post processing (depowdering, sawing, support removal)

Labor

Margins

**NOT IN SCOPE:**

**Cost:**

- Advanced post processing (machining, surface treatment)
- Ongoing quality assurance
- Company overheads
- Initial qualification investment
- Application design and optimization

**Potential savings:**

- Increased revenue by faster time to market
- Reduced cost per part
- Indirect cost savings in operation such as increased part performance, shorter machine cycle time etc.
- Reduced assembly cost
- Reduced quality mitigation cost
- Reduced transport and logistics cost

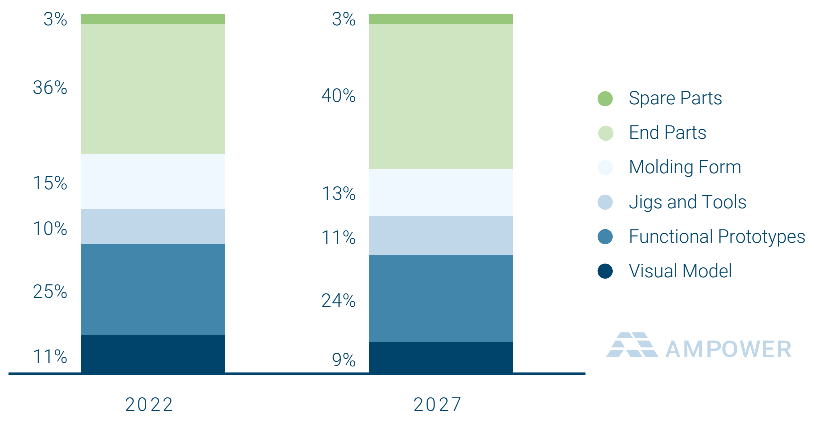
# Profile of Typical Additive Manufacturing Applications

Industrial AM applications span a wide spectrum, encompassing diverse uses such as mass customized medical and consumer products, complex machine components and engine parts, as well as jigs, fixtures, tools, and prototypes. This expansive range of applications introduces complexities when attempting a universal cost calculation approach. To address this challenge, AMPOWER conducted an in-depth analysis of over 100 real-world AM applications, carefully examining the variables that significantly impact manufacturing costs. This thorough examination culminated in the selection of representative demonstrator parts, strategically chosen to encapsulate the array of applications, and serve as the foundation for the subsequent cost and pricing analysis.

The proportion of end parts, in comparison to prototypes and models, has exhibited a consistent increase in the past. The AMPOWER Report 2023 indicates that end parts, molds, and tools account for a majority share, exceeding 60%. While prototypes and models remain significant in polymer AM, their overall contribution is anticipated to decline to 33% by the year 2027. A parallel trend is observed in the metal sector, though the future dominance of end parts is even more pronounced.

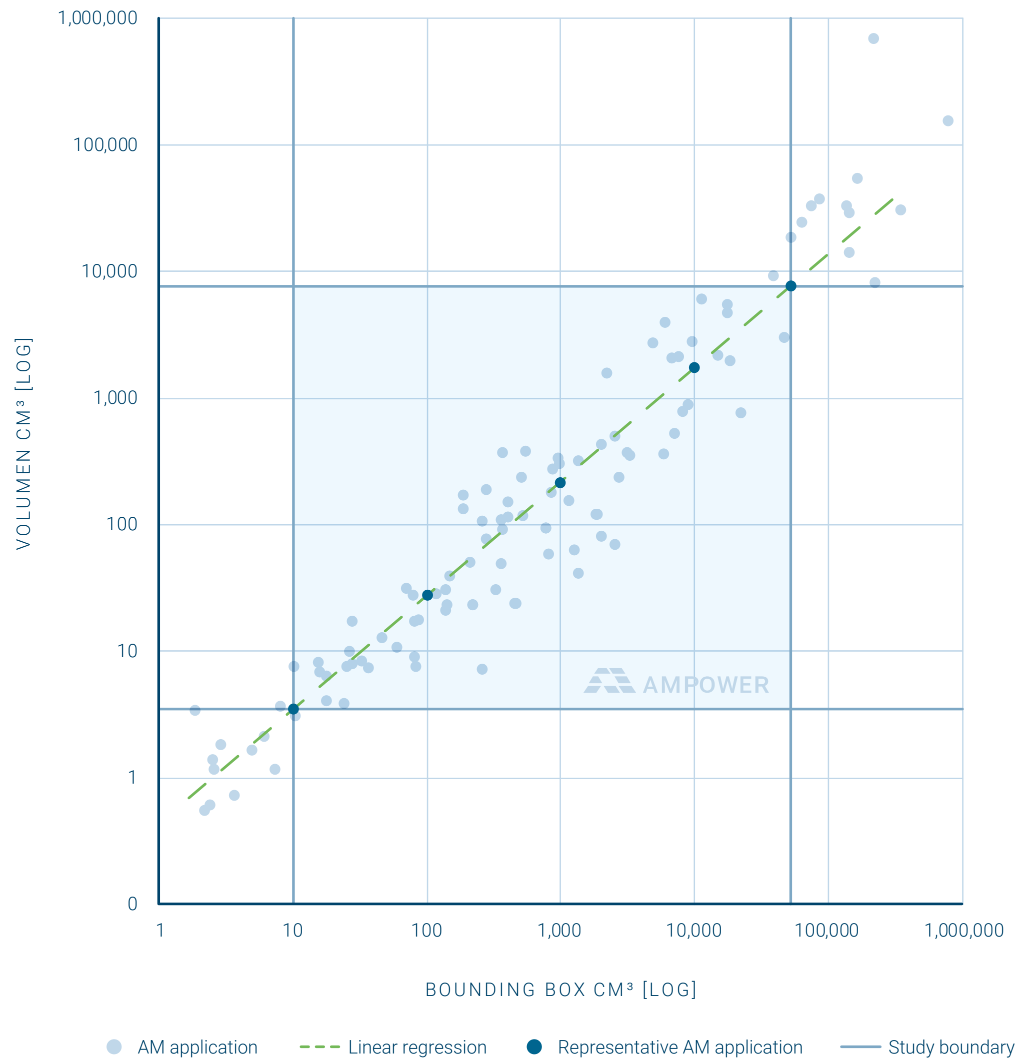
To conduct a comprehensive pricing analysis across online platforms, the inclusion of generic demonstrator parts representative of all aforementioned applications becomes essential. Consequently, an exhaustive study was undertaken, analyzing over 100 established AM applications with a focus on their geometric attributes that drive costs. Earlier analyses have established that AM manufacturing costs are mainly influenced by the size of the part (bounding box) and its corresponding volume.

## Application category of printed polymer parts 2021 to 2022 and forecast 2027






## Part dimension analysis of typical metal AM applications




Over recent years, AMPOWER has provided extensive support to numerous companies on their journey to identify potential Additive Manufacturing applications and subsequently rethink their conventional manufacturing processes. These identified applications span across a multitude of categories, showcasing a diverse array of part sizes ranging from 10 mm to 1,000 mm. With increasing part size, a near linear increase in part volume can be observed.

To enable the acquisition of current market pricing data, a series of standardized sample parts were generated. The sample parts aligning with the linear size-volume regression, effectively embody the characteristics of an average AM part. Notably, a substantial amount of online AM market platforms impose a cap on the maximum part size of typically 400 mm. Therefore, the maximum volume for the bounding box was confined to 50,000 cm³ for the scope of this study.

# Effect of nesting on 3D printing cost

The main cost driver of ‘as-printed’ parts are from the process itself, specifically the machine cost, which is derived from the hourly rate and build time. Consequently, meticulous production planning becomes imperative to minimize secondary process and downtimes. Depending on the chosen AM technology, machine or build chamber utilization has an additional impact on the cost per part by dividing secondary processes equally amongst the parts manufactured.

Material Extrusion and Direct Energy Deposition (DED) technologies use a manufacturing head to produce individual parts by depositing and solidifying material. Print time and secondary process durations, such as head repositioning, remain constant per printed part. Scaling the batch size does not significantly reduce overall manufacturing time, leading to near-constant machine cost per part as lot size increases.

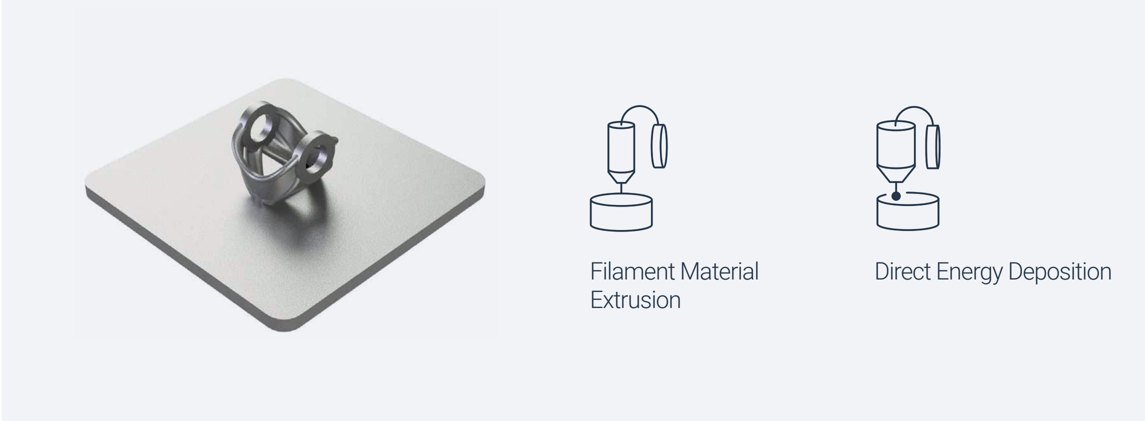
In contrast, many AM technologies operate on a platform or build chamber basis. Common platform-based approaches are Laser Powder Bed Fusion (L-PBF) and Area-Wise Vat Polymerization (also known as DLP). These technologies entail distinct material deposition and solidification stages, with material being deposited across the entire build platform, regardless of the number of parts in the batch. For platform-based AM technologies, densely arranging parts in a 2D configuration becomes essential to distribute costs associated with secondary processes, like powder application and unpacking, alongside downtime during machine turnaround, across multiple parts.

Other build chamber based AM technologies, like metal-based Binder Jetting and Electron Beam Powder Bed Fusion, or polymer-based Laser Powder Bed Fusion (also known as Selective Laser Sintering, SLS) and Thermal Powder Bed Fusion (also known as Multi Jet Fusion, MJF), largely benefit from dense 3D nesting. In industrial applications, a typical 3D nesting density ranges from 5-15% of the build box.

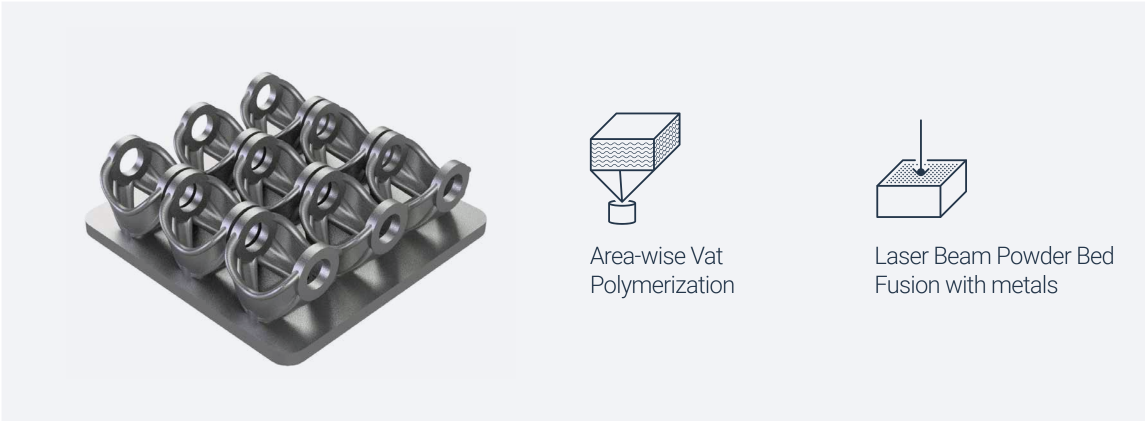
For many AM technologies, dense nesting and consequently increased machine utilization are pivotal to reducing cost per part. In a serial production setting, planning build jobs with high nesting density and machine run times is relatively manageable to minimize downtimes. However, for part manufacturing service providers, particularly those focused on prototypes and low-volume batches, precise planning is considerably more challenging. Instant quoting often relies on average machine utilization rates, experience, and additional risk mitigation factors. The inherent volatility of these factors contributes to the observed spread in market pricing within this study.



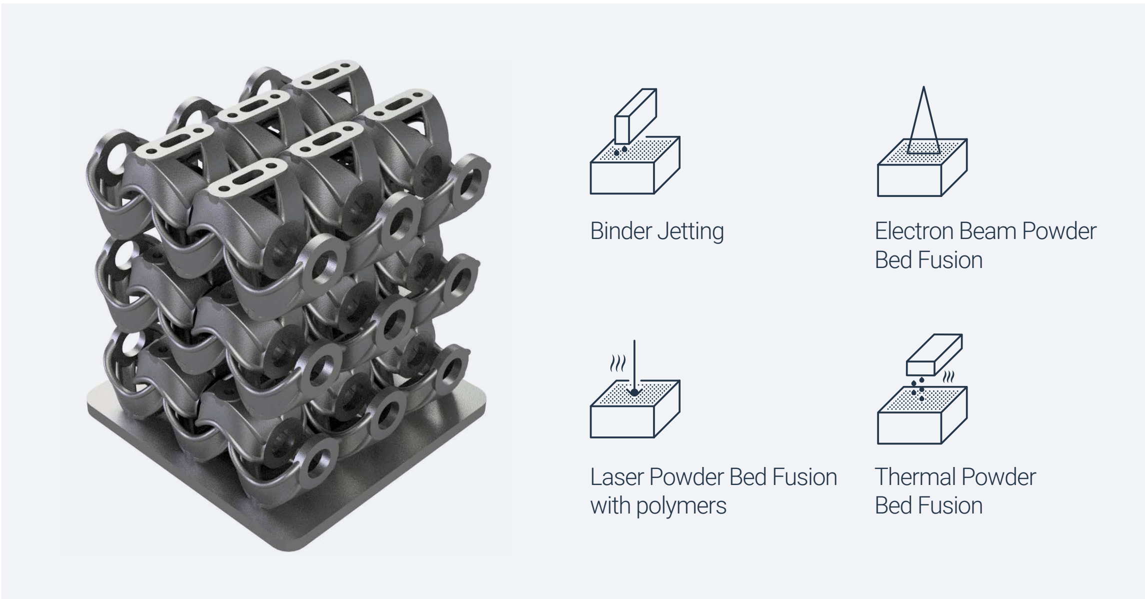
## Single part




## 2D nesting




## 3D nesting



# In-house manufacturing

SIEMENS ENERGY ADDITIVE MANUFACTURING PRODUCTION FACILITY AT FINSPÅNG, SWEDEN.
COURTESY OF SIEMENS ENERGY

# Lowering Additive Manufacturing Costs

Reducing the cost for Additive Manufacturing unlocks further applications. Established equipment manufacturers continuously try to turn every screw in order to drive down cost per part to grow the overall AM market. Many machine and process innovations entering the market target have the goal to reduce costs even further.

While labor costs have traditionally been a significant driver in conventional manufacturing, leading to a rise in automated production, Additive Manufacturing presents a contrasting picture. Here, the majority of the cost per part is attributed to the labor-free AM printing process. In Laser Powder Bed Fusion (L-PBF) technologies, equipment suppliers have adopted distinct approaches to tackle these costs.

On one hand, companies like ONE CLICK METAL and XACT METAL are entering the market with low priced machines. Priced at 100,000 EUR, the low initial investment reduces the entry barrier and subsequently the hourly machine rate. On the other side, many companies such as SLM SOLUTIONS have chosen a different path. Integrating up to 12 lasers into systems with very large build platforms enhance productivity and overall machine efficiency. However, this increases the initial investment to several million Euros.

On the other hand, for polymer PBF AM, the machine cost plays a less dominant role in the cost split. With materials like PA12, the cost per part is significantly influenced by material expenses, and to a lesser extent by labor. Automation solutions like job preparation and depowdering would bring large potential for additional cost reduction in this area. However, challenges, especially concerning automated unpacking, still impede the broader adoption of these systems.

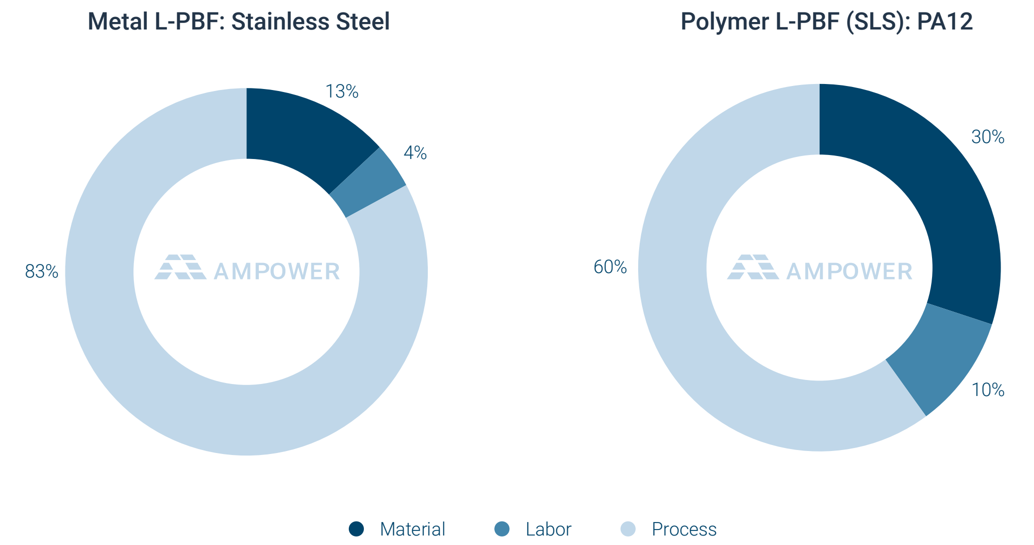
Similar to the metal AM sector, original equipment manufacturers in polymer L-PBF are pursuing diverse strategies to drive down the end user's cost per part. EOS, for example, is actively developing diode laser-based technology to boost productivity and enhance cost efficiency. Additionally, recent market entrants like SINTRATEC offer budget-friendly machines to lower the initial investment necessary. Furthermore, technology concepts, such as Thermal Powder Bed Fusion (e.g., MJF by HP), closely matching material and part properties of SLS, possess the potential to further decrease costs due to the absence of high-priced machine components such as the laser sources.

The **AMPOWER Investment Performance Index** for L-PBF compares system competitiveness by considering the major factors on cost per part: investment, platform size and number of lasers.

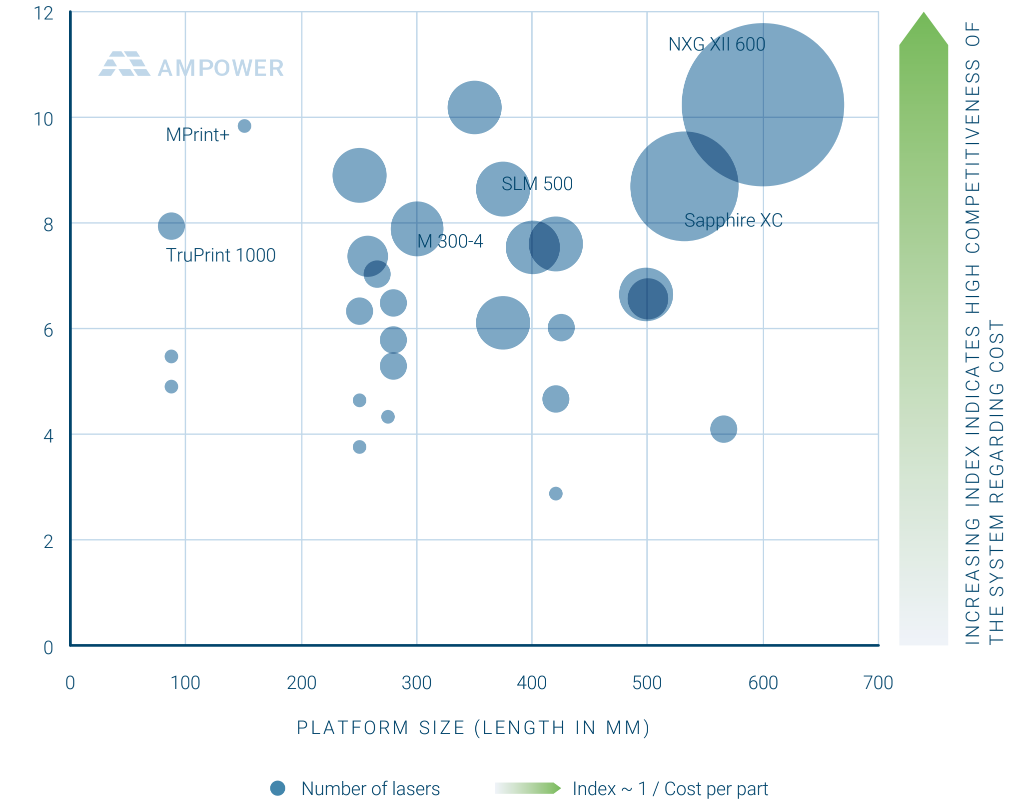
$$\text{Investment Performance Index} = \frac{\text{Platform}^{\alpha} \quad \text{Laser}^{\beta}}{\text{Investment}^{\gamma}}$$



## Average cost split in PBF technologies




## AMPOWER Investment Performance Index for selected metal L-PBF machines



# The AMPOWER Cost Calculator

The AMPOWER Cost Calculator is a comprehensive tool designed to assess the total manufacturing cost of ownership for Additive Manufacturing parts. It is based on real life production data, through the utilization of numerous build job protocols and extensive research, this tool allows to compare various technologies and gain transparency regarding the actual cost of Additive Manufacturing parts. The Additive Manufacturing cost calculator, developed by AMPOWER, is based on a model that has been refined over several years.

The cost of metal Additive Manufacturing parts is strongly influenced by the volume and part size. However, the complexity of the part can alter process strategies and therefore the cost as well. The complexity influence is considered in the calculator thru a value set by the user. Parts with multiple cavities or lattice structures are considered and can be differentiated from less complex parts. Consequently, all process steps that are affected by complexity, such as depowdering will be adapted in the calculation according to the chosen setting.

In addition to part features, the quantity of parts to be produced is also considered separately. While Additive Manufacturing is advantageous for low quantities, the cost of an individual part depends significantly on how well the full build chamber is utilized.

The AMPOWER Cost Calculator provides additional option fields to analyze individual process chains. Depending on the desired scope, production steps from the pre- and post-processing stage can be included or excluded in the cost assessment.

Moreover, the calculator includes the estimation of external manufacturing costs in addition to inhouse manufacturing costs, based on the extensive research of this study.

Overall, the calculator takes various factors into account to provide a comprehensive cost estimation for Additive Manufacturing parts, considering part complexity, quantity, and additional customizable options.

AMPOWER Cost Calculator available at ampower.eu/tools



## Part

| | |
|---|---|
| | Sample part 1 |
| Material | Stainless Steel |
| Part Volume | 20 cm³ |
| Part X | 40 mm |
| Part Y | 60 mm |
| Part Z (build direction) | 80 mm |
| Part complexity | high |
| Quantity | 10.000 parts |

**Sample parts and part history**
Defined sample parts allow for fast and easy cost comparison. Additional individual standard parts can be added by the user and retrieved at any time.

**Specific part geometry**
User specific data input allows for high degree of individualization. Additionally, detailing part properties for each manufacturing technology increases calculation accuracy and gives a "fair" comparison between technologies.

## Options

**What to inlcude in result:**

| | |
|---|---|
| Data preparation | not included |
| Material cost | included |
| Heat treatment | auto |
| Support removal | not included |

**Analysis options**
Specific process steps can be included or excluded in the calculation and the process chain adapted to the users needs.

**Up to 10 process and machine combinations**
Multiple machine-process combinations to compare different technologies and processes. For example, Binder Jetting versus L-PBF or 30µm vs. 60µm layer thickness.

**Cost per part breakdown**
Detailed cost breakdown of inhouse manufacturing and a cost range for external manufacturing.


**Annual throughput**
Annual manufacturing volume of the selected machines based on individual machine and process thruput.

**Lead time estimation**
Some process chains take several days until the first part is produced. Compare the lead time for a single part and identify the most time consuming process steps.

# Cost of in-house AM production

Production cost of metal AM start at 0.80 EUR/cm³ or 298 EUR/kg for aluminum, and at 1.29 EUR/cm³ (165 EUR/ kg) for stainless steel alloys. Using powder bed technologies, polymer parts can be manufactured at cost as low as 0.12 EUR/cm³ (120 EUR/kg).

In-house cost structures for Additive Manufacturing can vary significantly based on company-specific depreciation rates, overheads, and labor costs. The AMPOWER Cost Calculator offers the capability to compute internal production costs across tailored to each user. This can be achieved either through the use of pre-defined industrial standard values or user-specific data for all the aforementioned parameters provided by the particular user.

The cost values presented for metal and polymer PBF AM technologies are based on typical industry settings derived from multiple benchmarks for internal cost estimation, process speeds, and material expenses. The range in the data accounts for variations in using diverse machine configurations, encompassing single laser setups with low investments to extensive multi-laser arrangements for metal AM. In the realm of polymers, the variance arises from comparing Laser Powder Bed Fusion (e.g., SLS) with Thermal Powder Bed Fusion (e.g., MJF), both employing PA12 feedstock.

## Calculation assumptions

A generic part geometry suitable for all technologies and materials was used for the calculation with 25 cm³ volume and a bounding box of 50 mm x 50 mm x 40 mm.

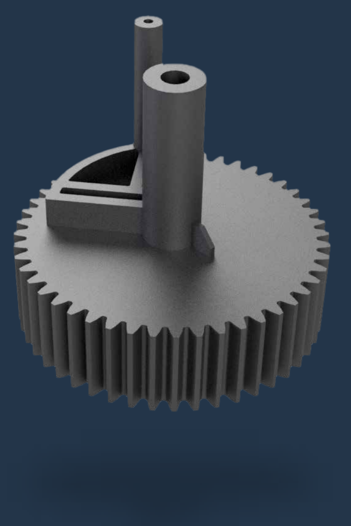
Machine investment in the metal calculation ranges from small L-PBF machines such as a ONE CLICK METAL MPRINT+ to very large machines such as the SLM SOLUTIONS NXG XII 600.

The PA12 calculation accounts for different HP MJF and EOS SLS machine equipment.

For all machines and materials, 60 µm parameter sets where used for metal and 80 – 120 µm parameter for polymer. Process time is based on real world benchmark prints.

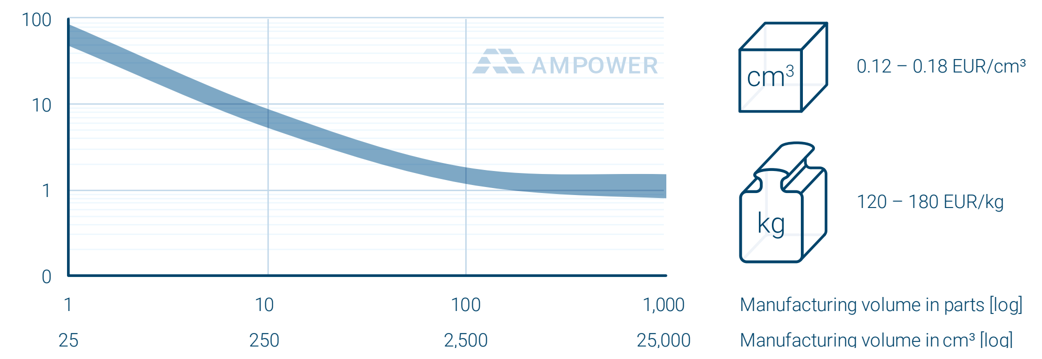
Furthermore, the calculation is based on a 24/7 manufacturing environment with 80% machine availability and a 5-year depreciation period for the AM equipment. Overheads of 30% are included as well as average European salaries for technicians and engineers.

Post processing cost are not included. Only separation from build plate and powder removal are considered.



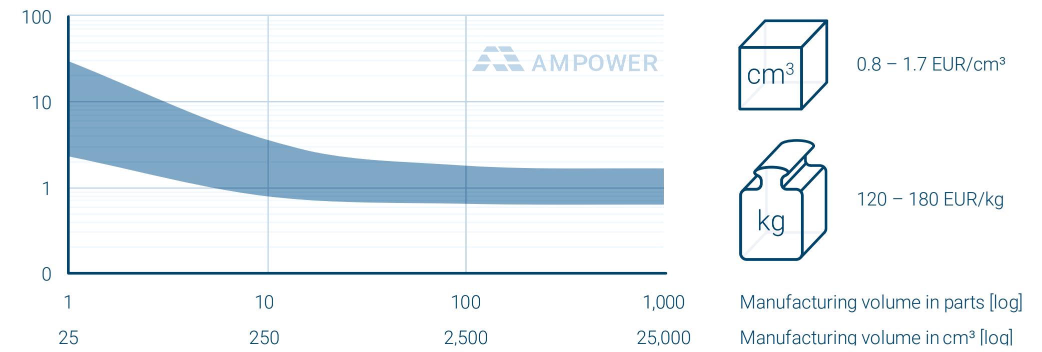


## Polyamide PA12 cost per volume in EUR/cm³ [log]

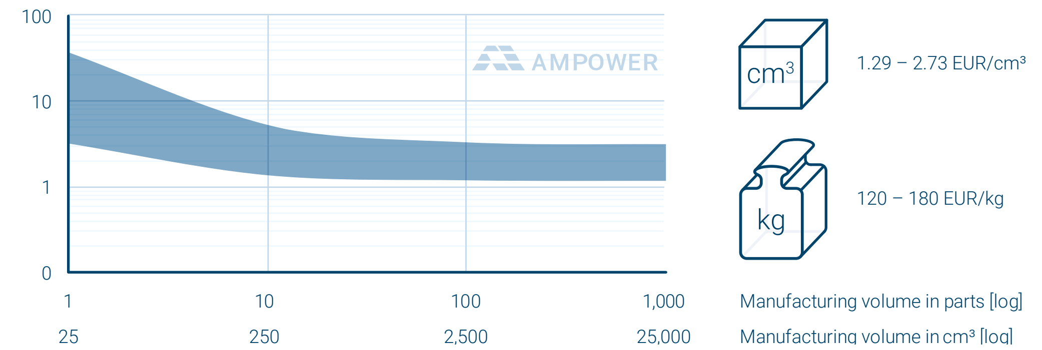



## Metal Laser Powder Bed Fusion Cost per volume in EUR/cm³ [log]

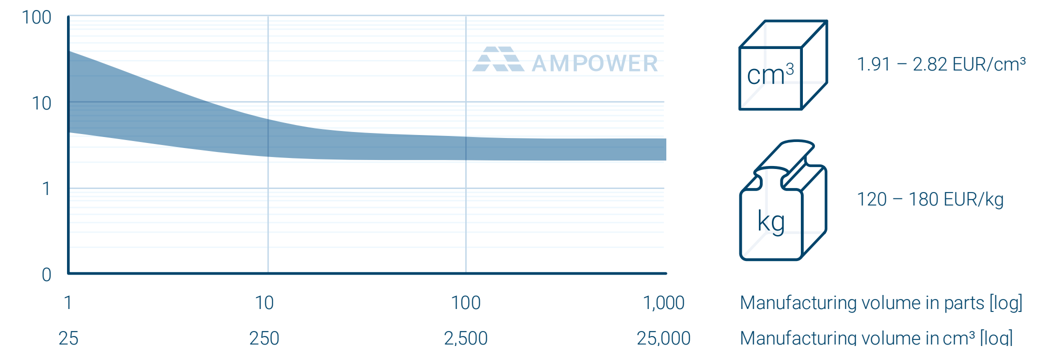
**Aluminum Alloy AlSi10Mg**




**Stainless Steel 316L**




**Titanium alloy Ti-6Al-4V**



# External manufacturing


MATERIALISE ADDITIVE MANUFACTURING PART MANUFACTURING FACILITIES IN LEUVEN, BELGIUM.
COURTESY OF MATERIALISE

# The global part manufacturing service market

Part manufacturing service bureaus have a pivotal role in the industrialization of Additive Manufacturing. They facilitate users in accessing a range of technology and material combinations, substantially diminishing the necessity for upfront investments and accompanying risks. Over the past decade, a growing number of online AM market platforms have surfaced, further lowering the entry barriers for procuring AM parts.

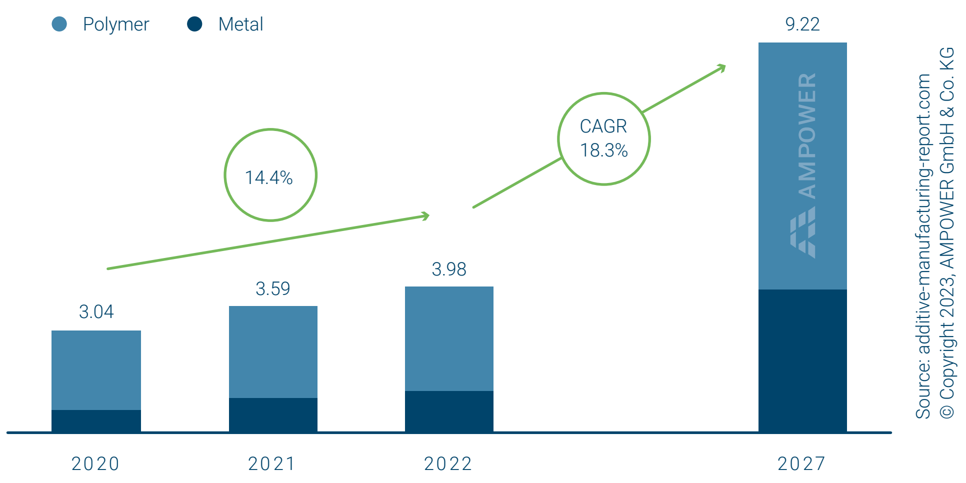
Through emerging online AM market platforms, Additive Manufacturing is experiencing heightened accessibility. Presently over 40 AM market platforms that focus on Additive Manufacturing exist across the globe. While certain platforms make available their internal production capacity to customers, others function as marketplaces that connect users with third-party manufacturing capacities.

While marketplaces like XOMETRY do not reveal the part manufacturing service bureau behind the part production, other platforms like PROTIQ have a completely transparent process, where customers directly chose the service provider.

Although numerous platforms primarily concentrate on small series and prototyping applications, others, such as MAKERVERSE, prioritize serial production. However, this specialization introduces challenges relating to standardization and the implementation of qualified processes to effectively serve industrial customers in their serial production endeavors.

All market platforms operate via instant quote systems, where CAD files are uploaded and corresponding attributes like material and AM process are selected. Nevertheless, not all technology-material combinations are available with an instant quote option. Particularly in the case of metals, quoting options tend to be more limited, often necessitating manual quoting due to heightened process constraints and complexity.

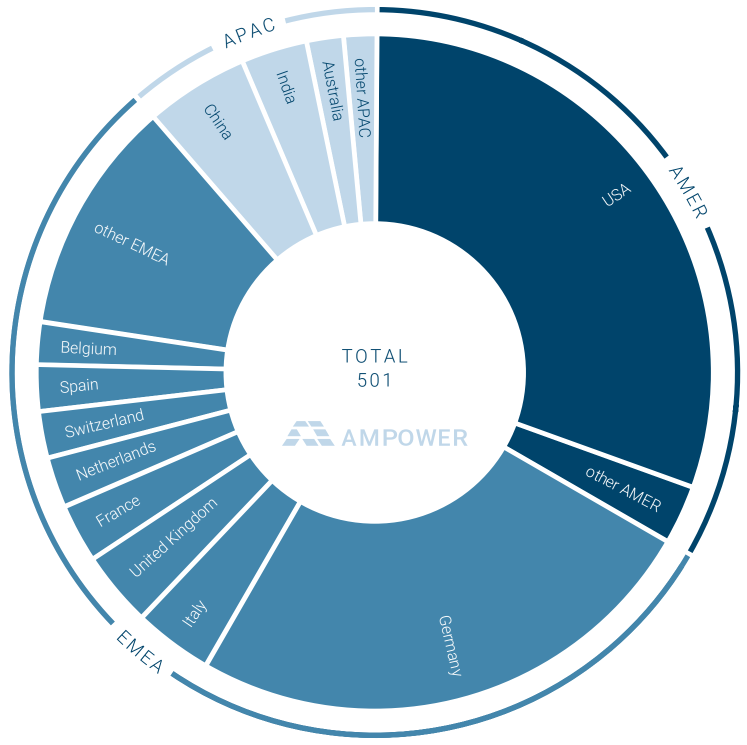
## Additive Manufacturing part manufacturing supplier market [EUR billion]



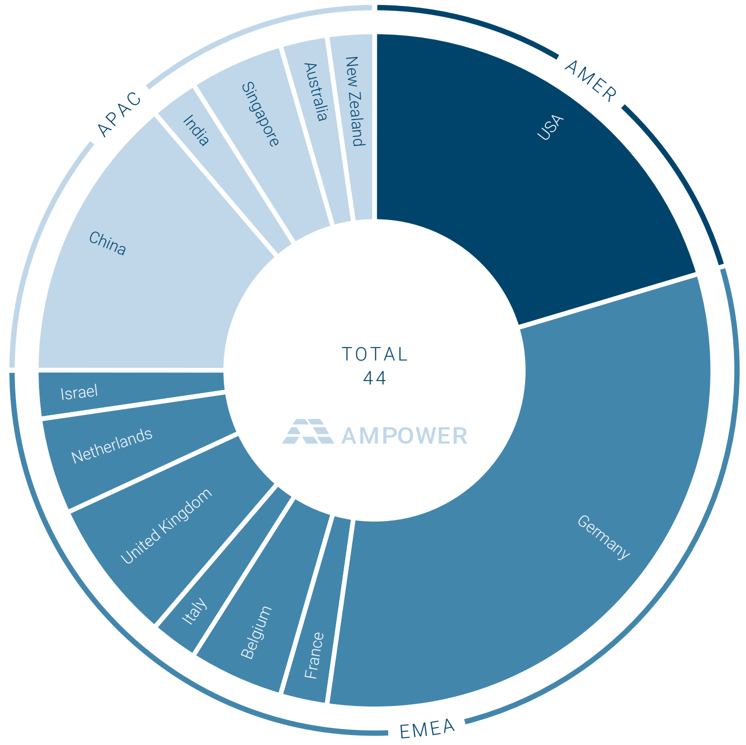



For this study, part manufacturing suppliers and online portals where included, that are globally accessible. Many suppliers that are based in the APAC region and especially in China are not accessible for Western customers due to their regionally limited customer focus.

**Identified globally accessible part manufacturing suppliers by region**




**Identified globally accessible online AM market platforms by region**



# Market pricing in Polymer AM

Based on an assessment of over 5,000 instant quotes from online marketplaces, AMPOWER analyzed the current market pricing, considering technology, material, and production volumes. The data highlights a significant price reduction up to an order volume of around 100 parts. Moreover, price variations among offers are substantial, ranging between 10-15x for TPU and PA12, and up to 80x for Material Extrusion ABS parts.

In standard applications, pricing reaches its minimum point when the order volume surpasses 1,000 cm³ or approximately 100 units. Notably, in most online quotation systems across various marketplaces, higher volumes do not yield additionally reduced prices. For high-end polymer Additive Manufacturing methods like Selective Laser Sintering and MultiJet Fusion, the pricing for commonly utilized materials PA12 and TPU levels out at about 1.00 EUR/cm³, with a range spanning from 0.20 to 1.20 EUR/cm³. This corresponds to roughly 1,010 EUR/kg for PA12, and a spread of quotes between 200 to 1,200 EUR/kg. The lowest price observed was 130 EUR/kg for PA12 components produced via SLS technology.

Material Extrusion ABS components demonstrate market pricing stabilization at 0.46 EUR/cm³, exhibiting a range spanning from 0.05 to 1.00 EUR/cm³. Unlike MJF and SLS methods, Material Extrusion displays a notably wider pricing range. This variation in prices can be attributed to significant disparities in printer costs among suppliers. Some base their calculations on industrial-grade equipment with investments exceeding EUR 100,000, while others rely on semi-professional desktop printers requiring investments below EUR 10,000. While these distinctions may affect part quality, they are often concealed from the customer's view. In numerous applications, lower-cost machines are anticipated to yield satisfactory Material Extrusion ABS quality. Furthermore, technology-specific printing parameters, such as infill and other variables, differ among suppliers and are frequently undisclosed to marketplace users.

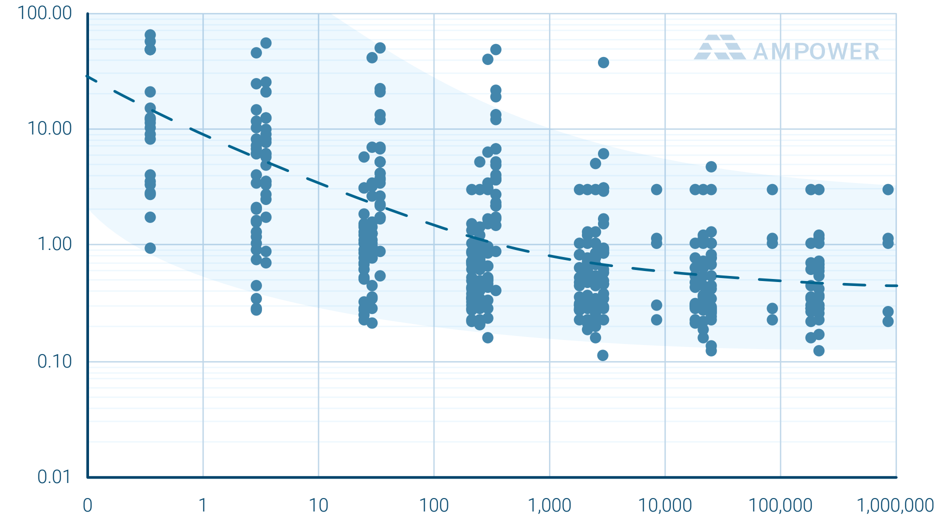
Remarkable regional price discrepancies are apparent in online marketplaces. Suppliers situated in China offer the most competitive price per kilogram for Selective Laser Sintering components. Intriguingly, when procured from Chinese marketplaces, TPU parts generated via MJF machines carry the highest cost.

Across all technologies and materials, the analysis underscores that exceptionally small parts, approximately 10 mm in size, incur considerably higher expenses compared to those exceeding 20 mm. Even with increased manufacturing volumes, the pricing for very small parts remains relatively high, likely due to heightened handling costs per unit.

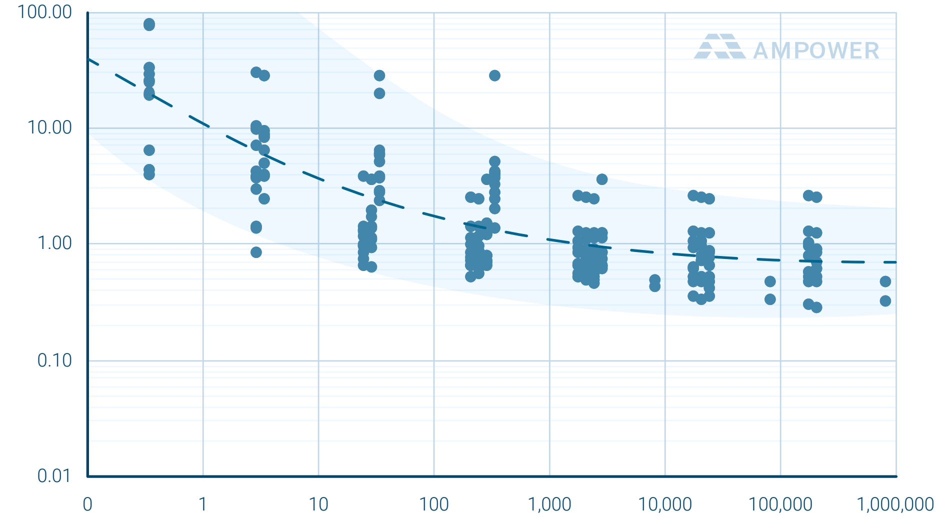


## Polymer Additive Manufacturing pricing per volume in EUR/cm³ [log]

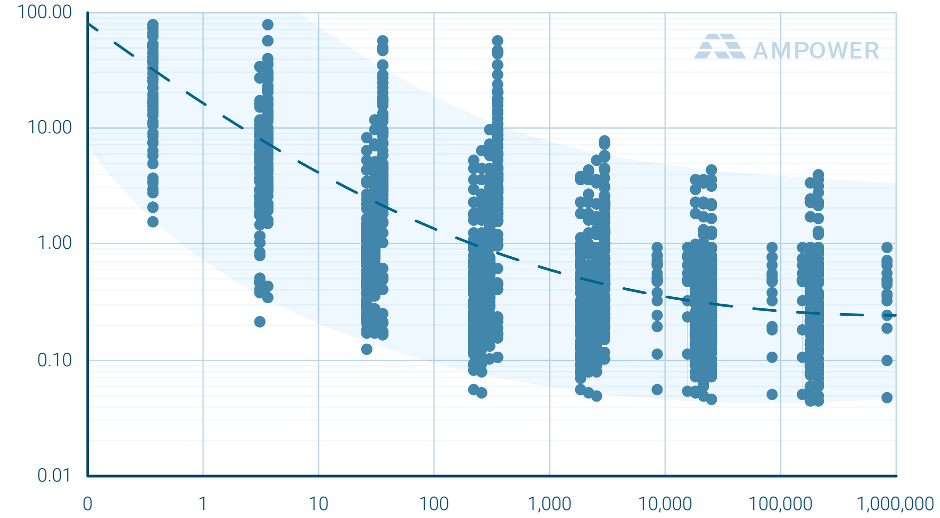
### Laser Powder Bed Fusion (Selective Laser Sintering, SLS), PA12




### Thermal Powder Bed Fusion (Multi Jet Fusion, MJF), TPU




### Material Extrusion, ABS




TOTAL ORDER VOLUME IN CM³

Online pricing — Average — Range

# Market pricing in Metal AM

In metal Additive Manufacturing, the design strongly affects processability due to thermal stresses, warping, and need of supports. Hence, third party designs are more complex to calculate and the risk for service bureaus of build job failure is much higher without extensive design evaluation or re-design. Surprisingly, many online platforms still offer an instant pricing for L-PBF in multiple materials.

316L stainless steel the most commonly available material on part manufacturing online platforms with over 30 identified suppliers. With offers starting as low as 160 EUR/kg the low-end market pricing of 316L is identical to in-house manufacturing cost. However, on average, customers must pay around 500 EUR/kg of 316L. Pricing for Aluminum parts ranges between 1 – 10 EUR/cm³ which equals to 370 – 3,700 EUR/kg. For the metal part supplier market identical effects of small parts and batch sizes can be seen. Additionally, risk mitigation factors on pricing can be observed resulting in a significant spread in the quoted prices.

In 2017, AMPOWER published its first Insights on cost of Additive Manufacturing. Comparing the average pricing of stainless steel, the price dropped by 50% from previously 750 EUR/kg 6 years ago. This indicates an increased competition on the market and a large available capacity of stainless-steel L-PBF machines at part manufacturing service bureaus and might be an explanation for prices close to in-house manufacturing cost. A similar market pricing development is seen when looking at the average pricing of aluminum parts today and 6 years ago. The minimum price for aluminum parts has decreased by factor 3x over this timespan. However, it should be noted, that for aluminum, the regional influence is significant. Especially Chinese part manufacturer are offering aluminum AM parts at very low cost while western supplier still ranges at a similar price level as 6 years ago.

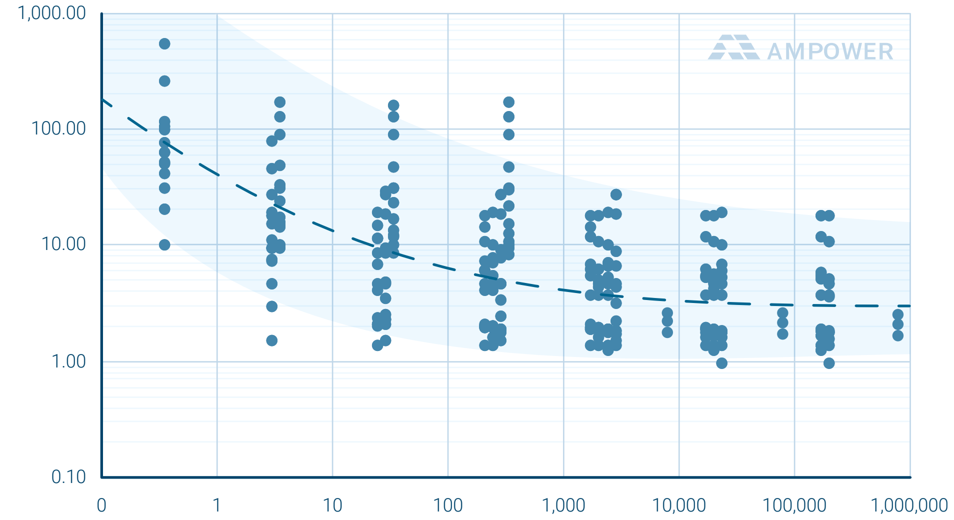
Contrary to developments described above, the average pricing for titanium AM parts almost doubled, despite constantly reduced cost for titanium powder over the last 6 years. Due to the difficult processability and high requirements for titanium parts, customers tend to build a tight relationship to their titanium AM supplier rather than using online platforms. Therefore, only a handful supplier offer titanium with online instant quoting. The high prices are most likely due to mark ups for risk mitigation in the quoting process.

> "Market pricing of stainless steel and aluminum parts have decreased by 50% over the last 6 years, in part facilitated by easier access to part manufacturing suppliers based in China."

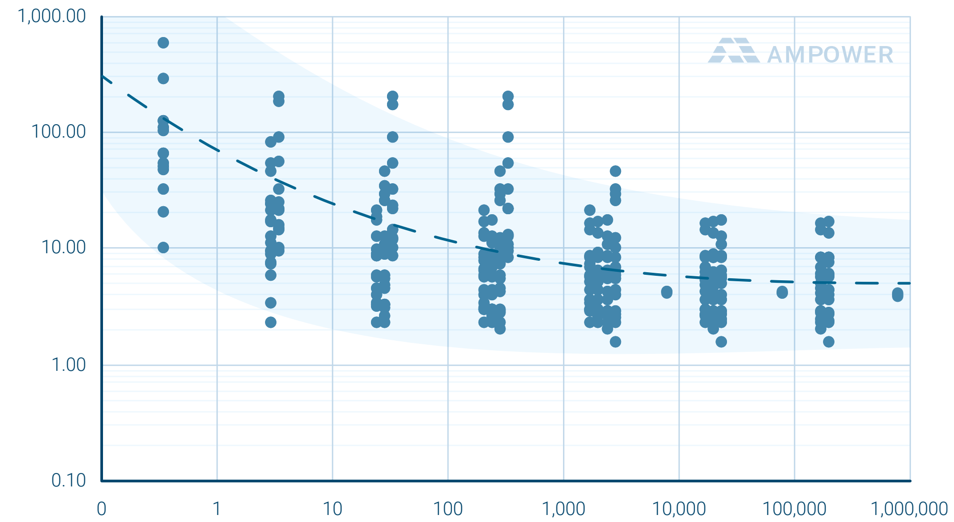


## Metal Laser Powder Bed Fusion pricing per volume in EUR/cm³ [log]

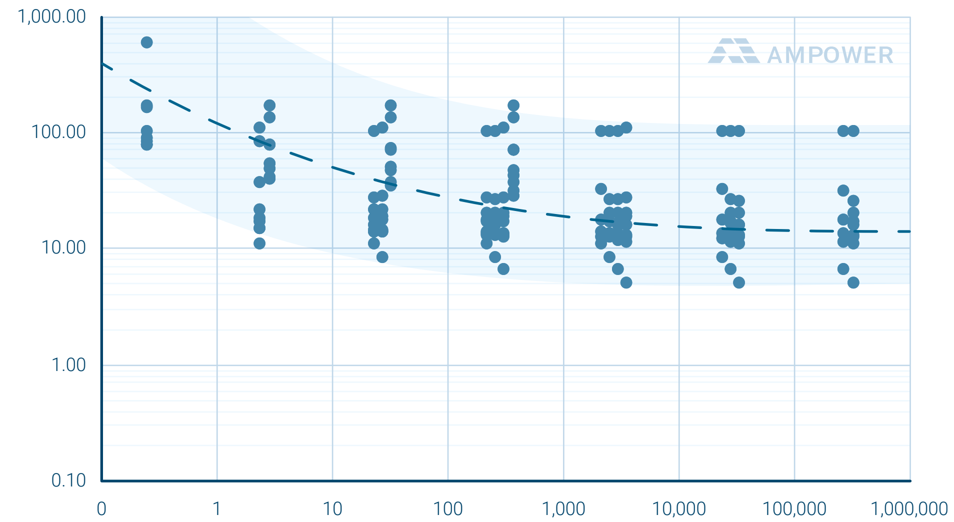
Aluminum Alloy AlSi10Mg




Stainless Steel 316L




Titanium alloy Ti-6Al-4V




TOTAL ORDER VOLUME IN CM³

Online pricing --- Average Range

# In-House vs. External Manufacturing

A comprehensive breakeven analysis is challenging due to distinct prerequisites concerning qualifying investments and organizational overheads particular to the company. For a sensible make or buy decision, cost is only one element to consider. A long-term AM strategy is recommended, where supply chain risk, value chain strategies as well as IP and know-how aspects should be evaluated.

An attractive price point for internal manufacturing can often be achieved, when a machine is fully utilized and only direct manufacturing cost such as material, machine depreciation, labor and consumables are considered. However, AM departments are often burdened with high overheads which must be added to this equation. Additionally, many companies include initial qualification efforts into their breakeven considerations, which can make especially the first AM applications unattractive from a commercial perspective.

While manufacturing inhouse is often more attractive, it also involves a massive investment in know-how, equipment, and shopfloor. In the end, it often depends on the application that is considered.

While jigs, tools, fixtures, and prototypes are often more economical externally, system components with high quality requirements and a high degree of design and performance IP, should be manufactured internally or by a TIER1 supplier with a close relationship. Part manufacturing service bureaus and online marketplaces might offer a fast lead time and wide choice of technologies, build volumes and materials. However, IP protection and quality standards that comply with the requirements of high demanding and regulated industries such as aviation, energy and medical are not easily achieved. This is why most end parts we see today in the market, are manufactured internally or by industry related TIER1 supplier.

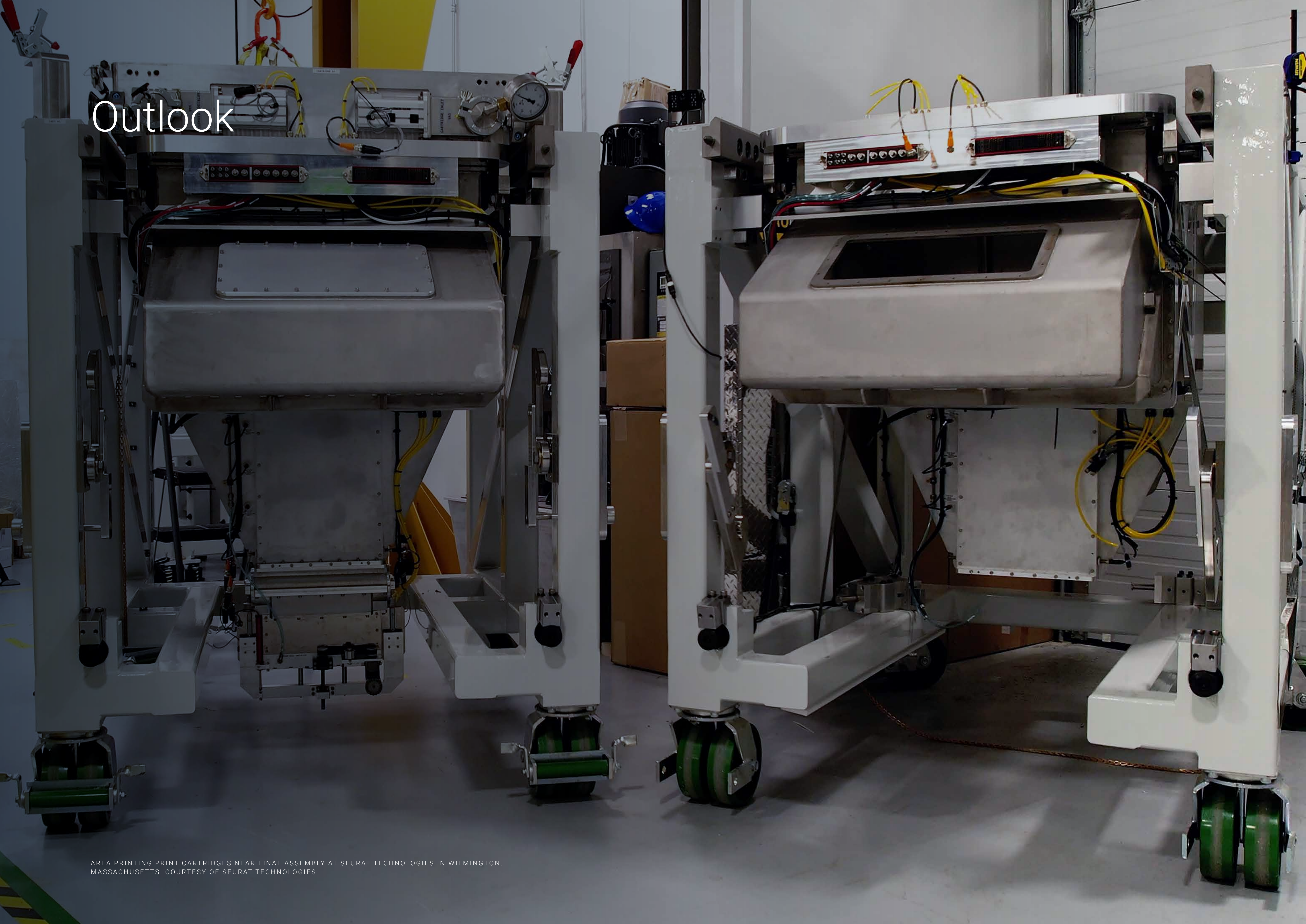


| | Make | Buy |
|---|---|---|
| + | • Development of protected material parameters<br>• IP on industrial production and quality assurance process<br>• High production integration increases quality | • No investment in infrastructure<br>• Know-how transfer synergies between partner supplier<br>• Wide choice of materials and processes especially in early application development phase |
| − | • Large internal overheads increase production cost<br>• High initial investment and risk<br>• Limited material and technology flexibility<br>• Low equipment utilization during introduction phase | • IP protection and transfer insufficient<br>• No developments in machine or material<br>• No increase of internal know-how |

### Knowledge increase with in-house capacity

A significant challenge in achieving successful AM implementation is the lack of knowledge. The complete understanding can only be gained with in-house machine capacity. When new AM designs are being tested, it's essential to have direct feedback from the manufacturing process to optimize the part fully for AM. In the initial implementation phase, while identifying promising business cases, using an external supply chain can help reduce the investment risk.

# Outlook



AREA PRINTING PRINT CARTRIDGES NEAR FINAL ASSEMBLY AT SEURAT TECHNOLOGIES IN WILMINGTON, MASSACHUSETTS. COURTESY OF SEURAT TECHNOLOGIES

# Cost scenario 2030 for metal AM

The market for metal components and the selection of production technology are fundamentally influenced by the production cost per kg. Given its existing cost structure, AM for aluminum components presently addresses exclusively the high-end component market, characterized by an annual volume of 3,000 kilotonnes. Nevertheless, ongoing advancements and innovative strategies hold the potential to substantially reduce costs. As highlighted in a recent study conducted by AMPOWER, this trajectory is anticipated to expand the addressable AM market by a factor of 2.

Currently three approaches promise to significantly reduce cost per part compared to L-PBF, the most established metal AM technology. The foremost and most mature approach is metal Binder Jetting. Although the technology principle is as old as L-PBF, it has garnered heightened interest in the past five years, largely catalyzed by DESKTOP METAL. Subsequently, key industry players like HP and GE ADDITIVE have also unveiled machines rooted in this technological segment.

The primary advantage of Binder Jetting lies in its utilization of presumably more economical powders, the potential for high packing density within the build box, and the rapid speed achievable with the combined recoating and jetting process. When paired with a highly efficient continuous furnace, this technology stands to yield substantial cost reductions, particularly for stainless steel and alloys that are easily sintered. However, it is worth noting that mechanical properties often lag behind those attainable through L-PBF for the same alloy.

The other two approaches are variations of L-PBF, yet significantly amplify its productivity. Both innovations originated from startups situated in the Boston region and have recently secured substantial funding rounds surpassing USD 50 million.

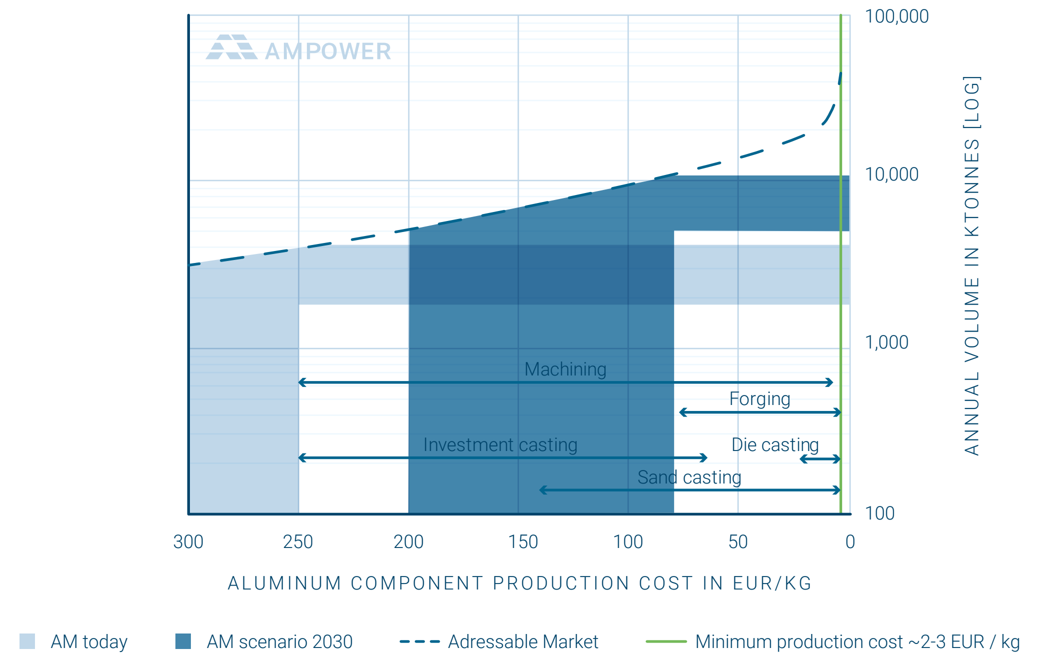
One technology principle stems from SEURAT TECHNOLOGIES, which employs a novel technique to expand a single laser beam over a designated area. The company employs an intricate array of laser sources and beam shaping apparatuses. This results in what is termed as "Area Printing", wherein the laser spot is expanded into a square field spanning multiple millimeters. Each area is exposed for a brief interval in contrast to the continuous movement characteristic of conventional L-PBF technology. Moreover, the area beam spot is shaped to mirror the combined pattern of all exposed areas within a given layer, effectively replicating the sliced geometry. This method touts melting speeds exceeding 10 times the rate achievable with conventional multi-laser PBF machines.

The third approach involves pushing the multi-laser concept to its extremes. VULCANFORMS promises exceptional build speeds and reduced cost per part, through the simultaneous use of 1,000 lasers, with 1kW each. However, very little information on the exact specifications, current state of development and machine and process maturity is publicly known.

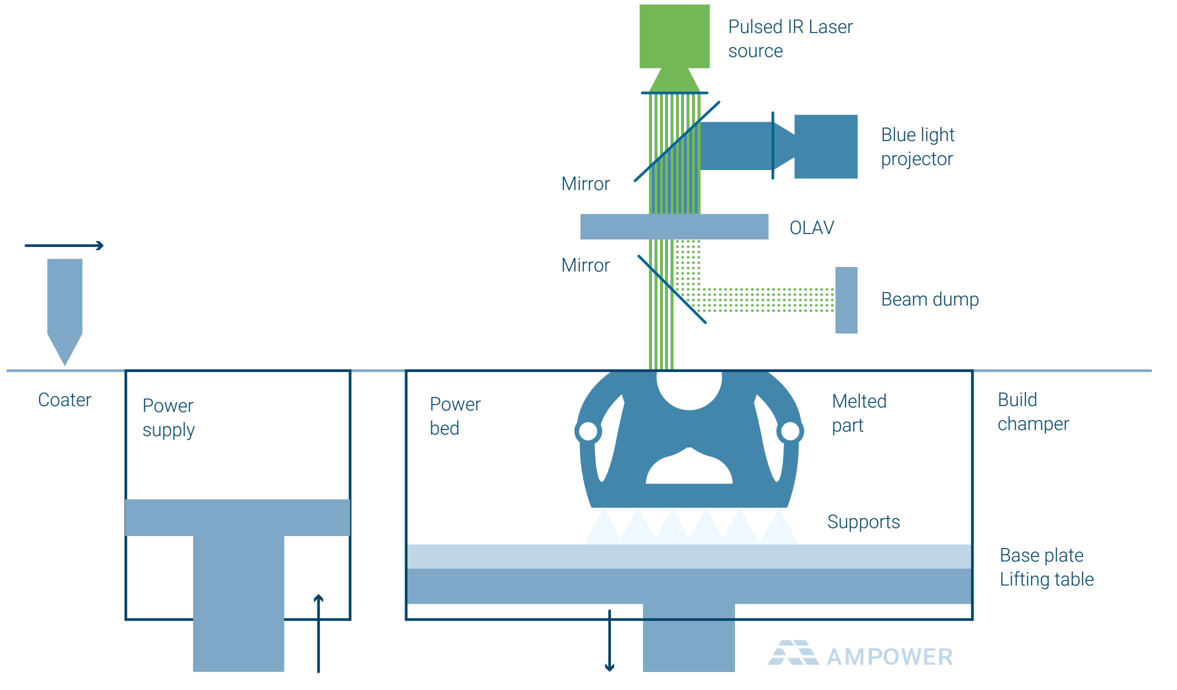
Owing to the proprietary nature of both these approaches and the absence of comprehensive insights into their developmental status, the ultimate physical limitations and consequently the cost per part of these technologies remain uncertain. While heightened productivity holds significance, the cost of equipment and ensuring hourly rates will determine the competitive viability of these emerging technologies.



## Addressable market of aluminum components today and scenario forecast 2030




## Area printing technology principle by SEURAT TECHNOLOGIES



# Outlook on pricing for polymer AM

As the utilization of polymer AM expands across a diverse range of industrial applications, the need to achieve greater cost reduction remains high. As a result, we are continuing to witness significant efforts from various players to enhance productivity and reduce costs in product development and part production.

An increasingly prominent strategy involves harnessing multiple smaller and more affordable desktop systems to achieve high-volume part production. This approach proves particularly advantageous for part manufacturing services, as it offers improved flexibility and the potential for large-scale manufacturing. MERIT 3D serves as a noteworthy example of this approach, utilizing PHOTOCENTRIC desktop systems for significant part production volumes. Similarly, NEXA3D targets this market segment with its XiP Pro development. These systems share the benefits of a compact footprint and open environment while delivering comparable quality to "industrial" systems with a relatively modest hardware investment.

Conversely, other participants in the market have directed their efforts towards creating large industrial systems that boast high productivity capabilities. Over the past few years, EVOLVE, CUBICURE, INKBIT, and EOS have introduced such systems. While all these technologies aim for high-volume part production, most of these systems are still in early stages and must demonstrate their scalability proficiency. AMPOWER emphasizes the importance of managing system investment and material costs to remain competitive with injection molding.

Although established powder bed technologies like Selective Laser Sintering (SLS) and Multi Jet Fusion (MJF) already rival conventional manufacturing methods, injection molding retains its prominence for larger volumes due to cost considerations. The principal cost driver for powder-based technologies is the material itself, often coupled with refresh rates ranging from 30% to 90%, depending on the specific material used. This leads to substantial expenses and notable material wastage. One approach to address this challenge involves increasing packing density and reducing the refresh rate of powder-based systems, thus mitigating costs and minimizing waste linked to material consumption.




COURTESY OF CUBICURE


# The Additive Manufacturing cost calculator is now available!

As the utilization of polymer AM expands across a diverse range of industrial applications, the need to achieve greater cost reduction remains high. As a result, a collective endeavor persists among various players to amplify productivity and lower expenses in both the realms of product development and part manufacturing.

- **7 major metal AM technologies and 4 material groups included**
- **3 major polymer AM technologies and 3 material groups included**
- **Market pricing range for major metal and polymer technologies included**
- **Productivity data based on independent research**
- **Covering the cost of the complete process chain of Additive Manufacturing**
- **Dashboard for fast comparison of 10 different machines and technologies**
- **Fully customizable with own parameters and processes**
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AMPOWER Cost Calculator available at ampower.eu/tools

# About the authors

## Matthias Schmidt-Lehr

Matthias successfully led multiple projects in Additive Manufacturing with focus on business case and strategic development for AM users as well as system and material supplier. With a history in management consulting, he has a wide experience in business development, strategy development and communication. At AMPOWER he led multiple projects concerning DED, BJT and Metal Material Extrusion as well as a wide range of polymer AM technologies.

## Dr.-Ing. Eric Wycisk

Since 2008 Eric successfully supports OEMs from aerospace, medical and automotive to identify Additive Manufacturing applications and implement production capacities in their regulated environments. With a background in topology optimization, titanium alloys and fatigue he is focused on achieving the maximum part performance with the right AM technology. As Managing Partner at AMPOWER, Eric focuses on technology evaluation and benchmarking, AM material and part properties as well as sustainability.

## Dr.-Ing. Maximilian Munsch

Maximilian is a professional user of Additive Manufacturing since 2007. After finishing his dissertation on reduction of residual stresses in metal Additive Manufacturing in 2012, he acquired extensive hands-on experience with different Powder Bed Fusion processes in regulated industry before co-founding AMPOWER in 2017. As Managing Partner at AMPOWER, Max focuses on data analysis, market intelligence and due diligence investigations.



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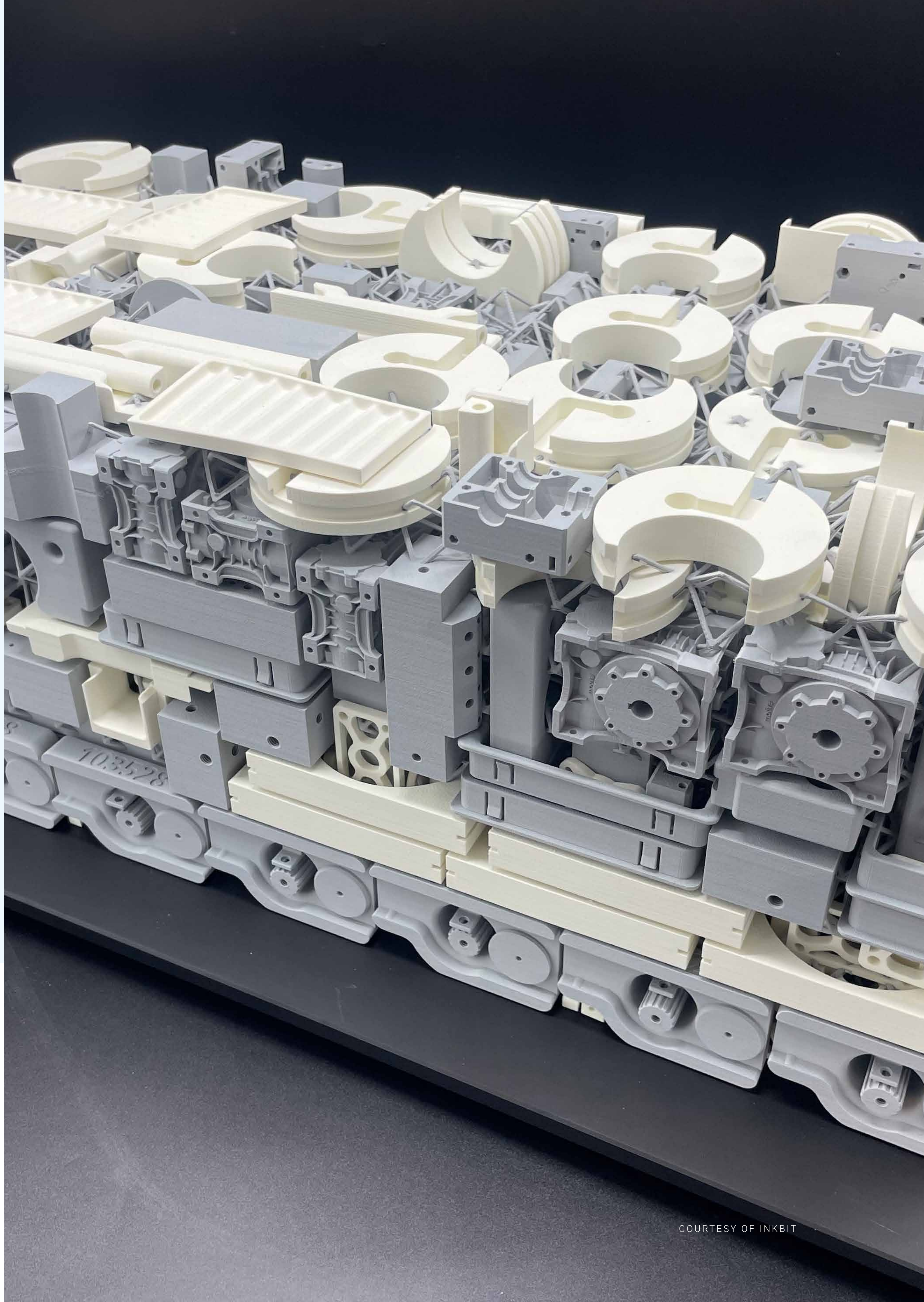

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