



Metal Additive Goes Full Scale

White Paper / 2022 Additive Manufacturing Market Analysis

The future of the metal additive
powder materials market

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01. Introduction

Defining the AM Ecosystem

Throughout its history, metal additive manufacturing (AM) has been based on the use of powder. Metal in a powder form is core to the very nature of layer-by-layer construction at a micro level, allowing for precise feature detail and advanced geometry fabrication in additive processes, like laser and electron beam powder bed fusion (PBF).

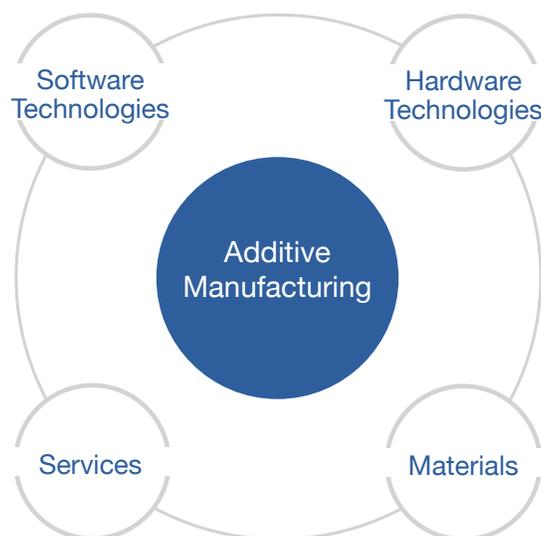
Since about 2013, AM has been one of the single most interesting production innovations since the first CNC machines were developed in the 1950s. Of course, metal additive's history dates back far before 2013, but since around that period the market for producing metal parts via AM methods really began to be explored for end-use production applications. Interestingly enough this occurred in the context of two highly regulated manufacturing industries with aerospace and medical, and a commercial ecosystem began to coalesce.

In its basic form, the metal additive ecosystem is based around four key focus areas as shown in figure 1. Over the past decade, each area of the ecosystem has evolved at varying paces, with an ebb and

flow of investments, technical progress, and business development. Materials—more specifically, metal powders—are on the precipice of entering one such period of significant growth and evolution. An exploration of the reasons behind this, and the factors impacting it, can all generally be tied back to one theme; **Scale**.

Many human mathematical systems are based on units of ten, so we often measure long periods of time in decades. Where will we be ten years from now? This is precisely the question many have been wondering about with regards to metal additive technologies since the early 2010s. If the math holds true and the current age of industrialized metal powder-based additive technologies began around 2013, we've come about ten years. What's happened in that time?

Figure 1: The Additive Manufacturing Market Ecosystem



02. User Base

Metal AM users; now and then

Much has certainly changed, but one of the most informative glimpses into how the market has evolved is to look at the typical metal additive customer.

A number of customer trends are uncovered which share the common theme of scale, and how the market has slowly and steadily arrived at the point we are at today.

Application Development Years in the Making Beginning to Bear Fruit

It didn't take long for customers to figure out that metal additive technologies, like laser and electron beam PBF or directed energy deposition (DED), had significant advantages for certain kinds of applications that were not cost sensitive. Because of the cost profiles associated with earlier iterations of these processes, the highly regulated industries of biomedical and aerospace were the leading adopters, and generally, still are today. However, it has taken years for these users to build expertise and trust in the processes on a level that they can apply to critical parts like implants for healing people, or aircraft to transport them.

Even with tireless technology development cycles from hardware manufacturers making these machines, it has taken nearly a decade for early adopters to bring many more significant serial manufacturing projects into production. Today, however, those efforts are finally beginning to bear fruit.

Many of today's metal additive users in the aerospace, defense, and medical industries now have application roadmaps that feature multiple real, tested parts and use cases entering (or already in) true production. This has led to companies like Incodema3D, which operates as a specialist contract manufacturing agent solely for metal AM parts, to go from consuming a couple of tons of powder per month with AM, to expecting to consume thirty to fifty tons per month as early as 2023.

Machines Are Consuming More on Average, and Running Longer

The average metal powder-bed based machines—and the organizations around them—are capable of much more than they were in prior years. This is also contributing to the effect of scale, while simultaneously improving the price structure of the industry. This helps create a positive feedback loop in the market, where overcoming certain technical hurdles at both machine and material levels have reduced costs. Users have been willing to invest in building the implementation organization necessary to further support a more serialized production environment—thus, further reducing part costs and adding a whole host of other benefits. This has set up a profound opportunity for the powder supply of these machines.

With years of application development taken place, more users today have now achieved the critical mass necessary to support an organization that enables greater per-machine productivity and uptime. This includes things like employing in-house technicians to keep machine downtime shorter, while also maintaining a rolling supply of powder and other machine consumables on-site, so that material and machine prep work

is both continuous and less subject to interruption.

Visualizing the Scale of Consumption into the Future

The extensive additive market data models and forecasts of SmarTech Analysis can provide a quantitative look into the impacts that these trends will likely have on additive powder consumption in the future. By looking at metal PBF technology installation data and utilization rates, we see that the average metal PBF machine (overwhelmingly laser based) consumed 22 percent (or about 50 kilograms on average) more powder at the end of 2021 than it did at the end of 2014. That same increase is expected to replicate again astonishingly in just one year from the end of 2021 to the end of 2022—and this is just the beginning. As the installed base of machines shifts more rapidly from the single laser style architecture and use cases of the past to the industrialized, factory architecture of cutting-edge machines of today, average consumption per installed machine worldwide will have doubled from 2021 consumption levels.

But that, in itself, only tells half the story: the number of installations of PBF machines has grown rapidly and will continue to do so over this same forecast period. This

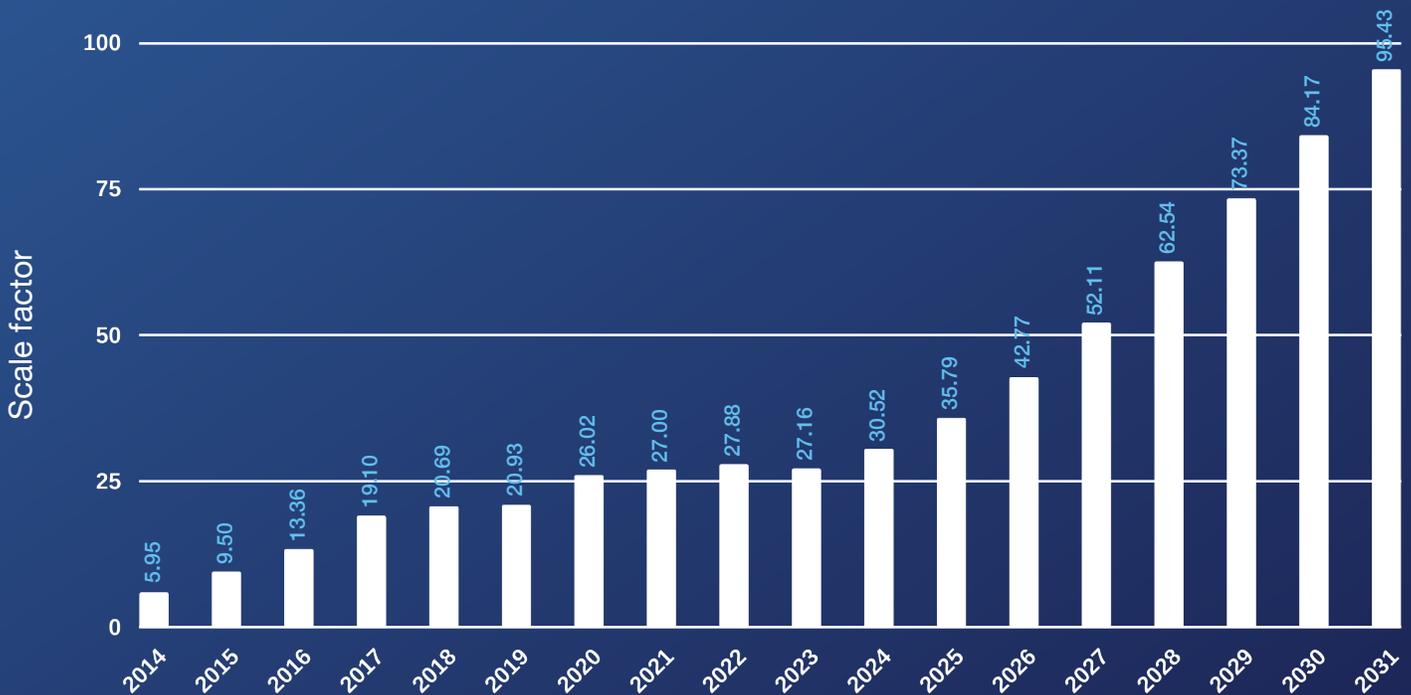
Through years of application development, users have achieved the critical mass necessary for greater machine productivity and uptime.

means many more installed machines all steadily consuming much more powder on average than before. To visualize this, we performed a 'Scale Factor' modeling, which takes the increasing annual installed base of PBF machines worldwide and divides it by the average consumption per machine (in kilograms) to provide a 'Scale Factor'

number. This data, presented for the first time below, effectively visualizes the scale up in additive powder material consumption that will be witnessed in the coming decade.

And this is only for PBF-based processes, meaning that other metal AM technologies would increase this number that much more.

Figure 2: Metal AM PBF Worldwide Machine Installations/ Average Powder Consumption Per Machine



Source: SmarTech Analysis Core Metal AM Advisory Service

03. Market Dynamics

Metal Powder Market Rising to the Supply Challenge

Over the past decade, the broader metal powder market (beyond and including AM), which is sustained by traditional powder metallurgy processing, has augmented to fully ‘adopt’ metal additive processes as one of several powder-based specialty industries served.

A decade ago, the world’s largest metal powder atomizers and suppliers focused in selling to the traditional melt market were primarily just selling the scrap powders their primary clients couldn’t use to AM users because the material was too fine for their traditional sintering processes. Today, every leading metal powder provider has a specialized offering tailored to the detailed needs of AM users, and many more specialized providers have emerged targeting the AM market as their main customer for super high-quality metal

powders. Why, because they see the growth on AM and the applications being developed for production.

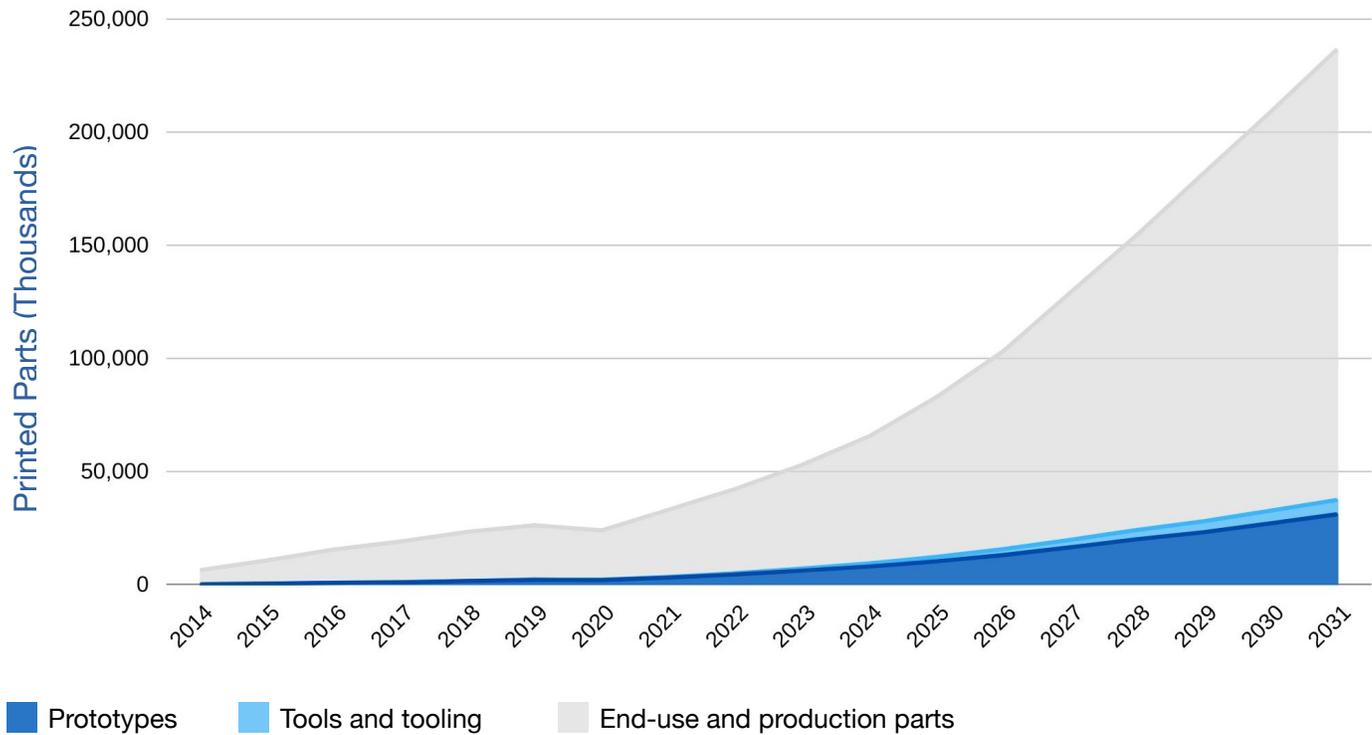
Although the growth in demand for additive powders has been relatively steady over the past decade, the writing is on the wall for most of these providers. With a number of these powder leaders having already worked closely with the aerospace or medical industries for many years, intimate collaboration and communication with customers quickly led to the biggest names—Carpenter, Oerlikon, Praxair, ATI, Sandvik, and many more—working to develop additive-optimized powder offerings. Today, powder manufacturing innovators, such as 6K Additive, have had a chance to respond quickly to the market’s challenges and develop even more unique manufacturing solutions with expanded powder offerings.

At some level, all of this investment is being driven by metal additive’s move into production—not only in the core markets of aerospace and medical, but also in other industrial opportunities. Visualized below is the growth in metal additive parts produced worldwide, with the forecasted scale-up in production looming.

Figure 3: UniMelt microwave plasma system at 6K Additive



Figure 4: Global Production Volume of Additive Metal Parts by Profile



Powder prices have fallen significantly, primarily via the vast expansion of competition, but also in part through further optimization of the processes involved in creating powder from feedstock material. Instead of buying what’s available from atomization processes adapted to AM from serving other technologies, today’s metal additive users can now often specify their powder requirements up front, identify the proper type of manufacturing processes that can produce those specifications, and then select from an array of possible partners.

Plasma atomization processes have long since been the leading method for producing super high-quality titanium alloys with extreme spherical shape and minimal oxygen content, but at very high costs. Today,

plasma atomization or spheroidization techniques have both expanded into producing many different alloys for AM powder while also reducing costs through the benefits of scale-up and a competitive market, alongside process-level innovations that have increased efficiency. In 2022, users like Incodema3D noted that materials that used to cost more than \$400 per kilogram of powder can often be purchased for less than half that historical price.

Although AM users will always appreciate lower costs for materials and a greater diversity of a qualified selection, the users of tomorrow also will reap many more benefits from a robust domestic additive powder supply chain that is less reliant on foreign sources such as Russia or the Ukraine.

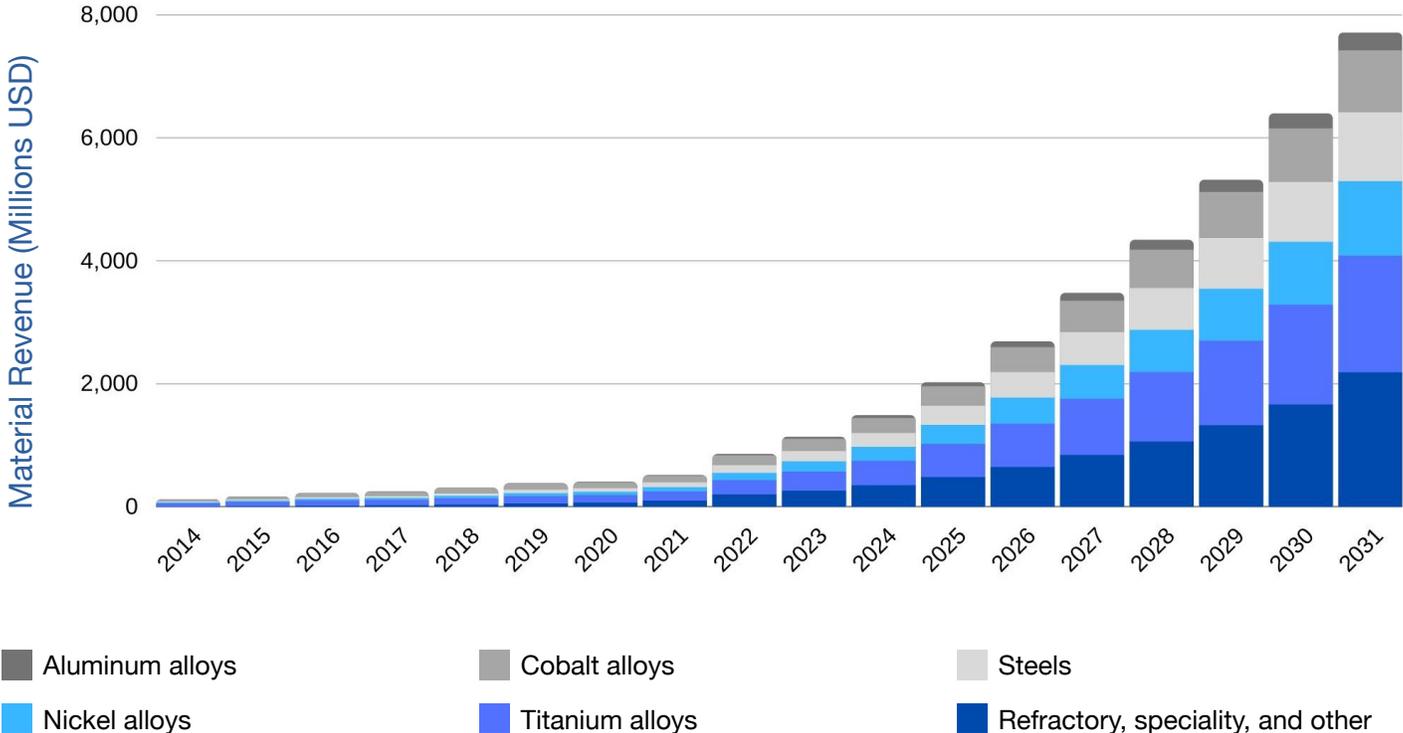
04. Market Opportunities

Unlocking the Full Potential of AM Through Materials

The next generation of AM powder suppliers face opportunities to move the needle for additive even further. That is, they will not just support the scale up but supercharge it through innovation and partnership. The current outlook for additive metal powder markets is shown in the below graph from SmarTech’s metal additive market advisory services.

There are three core ways that powder suppliers can add value to the future of metal additive even beyond the constant battle to bring down costs of materials. This could power the market even beyond the current forecast to grow to \$7.7 billion in 2031.

Figure 5: Global Additive metal powder revenues, all industries and technologies, 2014-2031(f)



Source: SmarTech Analysis Core Metal AM Advisory Service
 Metal Additive Goes Full Scale

Enabling New Applications by Creating New Materials

One of the most exciting ways users are looking to exploit AM is by using it to create parts that couldn't exist with another manufacturing process. This has been discussed at length for the better part of a decade by AM experts largely in terms of geometric design freedom. Executing this dream is a little more challenging than is often stated. However, there are other ways to get there using additive that relies not on geometric freedom but on the powder supply chain and its material experts. Advanced materials like high entropy alloys, figure 8, certain refractory metals, and metal matrix composites, can be very difficult to convert into a powder form—and, in some cases, might be practically impossible to

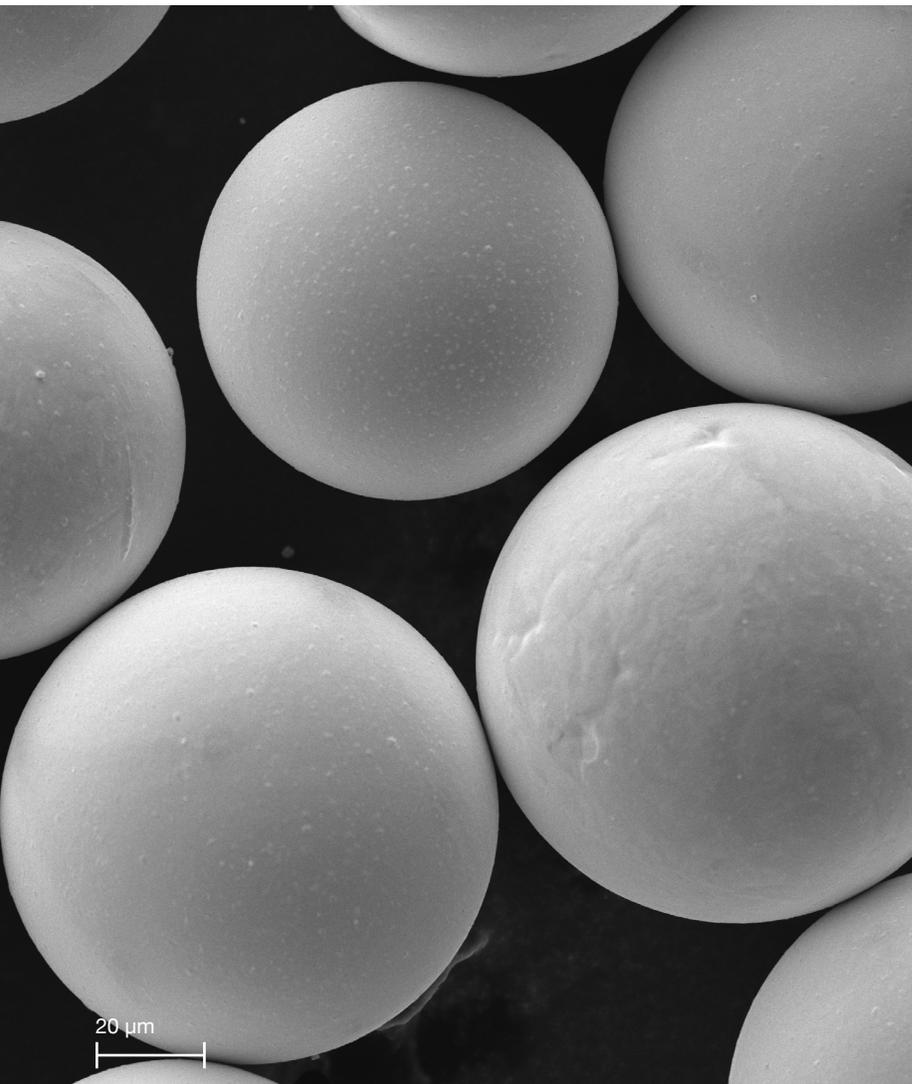
do so using traditional methods. These are often materials that also are rarely, if ever, processable by conventional manufacturing methods in terms of forming real components.

Advanced powder production processes now available from companies like 6K Additive using advanced plasma spheroidization can convert nontraditional feedstock material into uniform, high-quality powder at costs that other methods simply cannot. Given AM's penetration into super high-value markets including nuclear energy, defense, and space, the ability to create entirely new powder materials not previously possible also means pushing AM even further into the conversation when it comes to revolutionizing these and potentially other industries.

Figure 6: 6K Additive's Global Manufacturing Center, Burgettstown, PA, USA



As the AM metals market continues to mature and scale, three specific opportunities are available to materials vendors; broadening the number of functional metals, optimizing material for productivity or cost, and improving sustainability.



Optimizing Powder Material for Downstream Benefits Like Machine Productivity

Although AM powder costs have fallen significantly compared to levels a decade ago, most users still agree that there are still some cost challenges remaining in AM. Morf3D is one such user who recognizes that, while the industry has collectively solved a number of challenges with direct impact on part costs, more should be done. Other users recognize that, even at this stage of early production, current powder material costs are a secondary concern in the overall cost profile of additive manufacturing. However, it's unlikely to stay that way for long.

In the short term, leading innovators in powder supply are pushing the envelope of materials development to help further solve cost challenges in a downstream manner. Companies such as Uniformity Labs are creating ultra-dense powders that allow for significant reductions in shrinkage during sintering for binder jetting applications (among a host of other benefits).

Figure 7: Scanning Electron Microscope image of 6K Additive tungsten powder

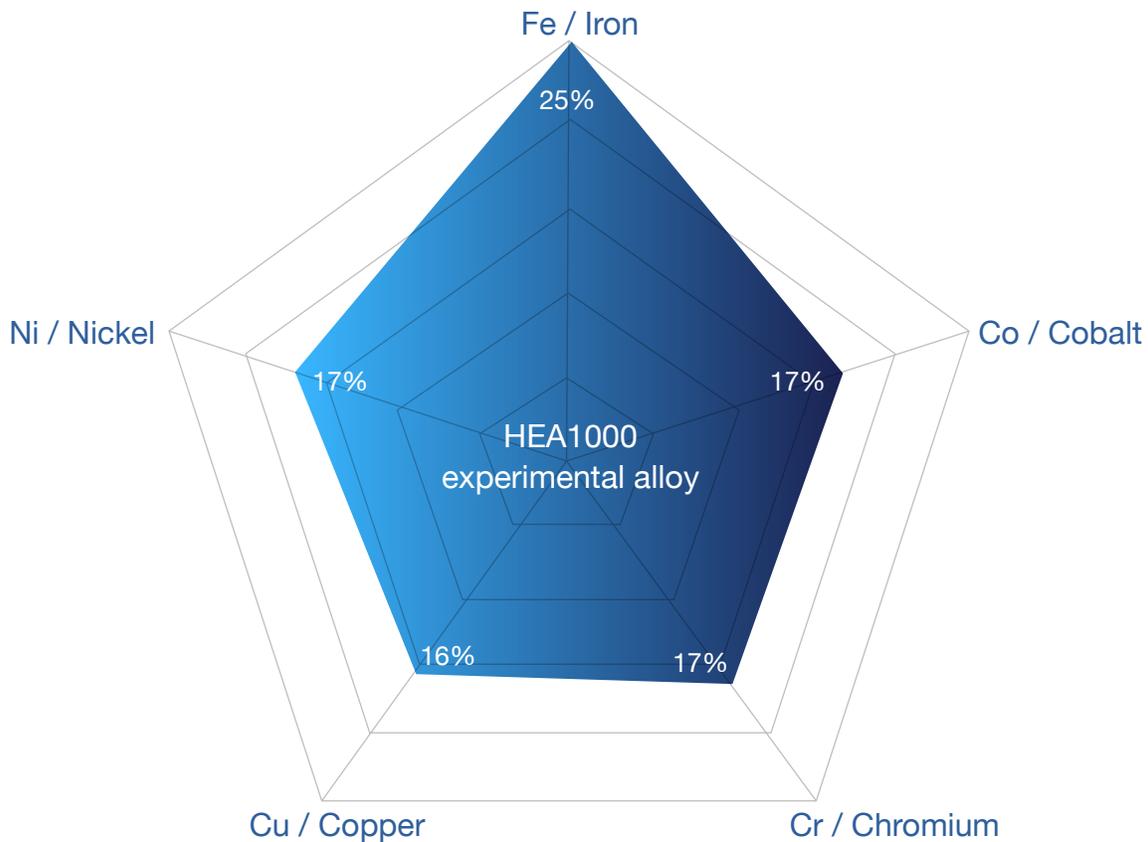
Equispheres claims the energy absorption of its aluminum alloys can increase print speed in laser PBF processes by 300 percent. 6K Additive’s plasma technology can produce 100 percent yields of very specific particle size distributions for the highest quality and fastest throughput machines. All of these benefits, in some form or another, reduce costs per part by improving the throughput of the technology overall.

Improving Sustainability

In the last few years, sustainability has attracted a lot of attention to additive technologies as various government standards and programs have either incentivized or mandated a push towards more sustainable manufacturing practices. Additive technologies, of course, possess certain inherent advantages due to their efficient use of material, among other things.

Powder manufacturers focusing on supplying AM users have a unique opportunity to bring sustainability benefits to their customers’ operations, though not all are well-positioned to do so. 6K’s microwave plasma-based technology now deployed at production scale for the AM industry is able to utilize recycled build powder— otherwise typically discarded into landfills— and upscale it for use in the build process once again, further bolstering efficiency of material use and recyclability, even for users with extremely stringent standards. 6K Additive takes this approach even further by leveraging a proprietary milling technology to reclaim other forms of scrap material and convert it into the highest quality powder for use in AM.

Figure 8: Profile of High Entropy Alloy (HEA)



05. Vendor Strategies

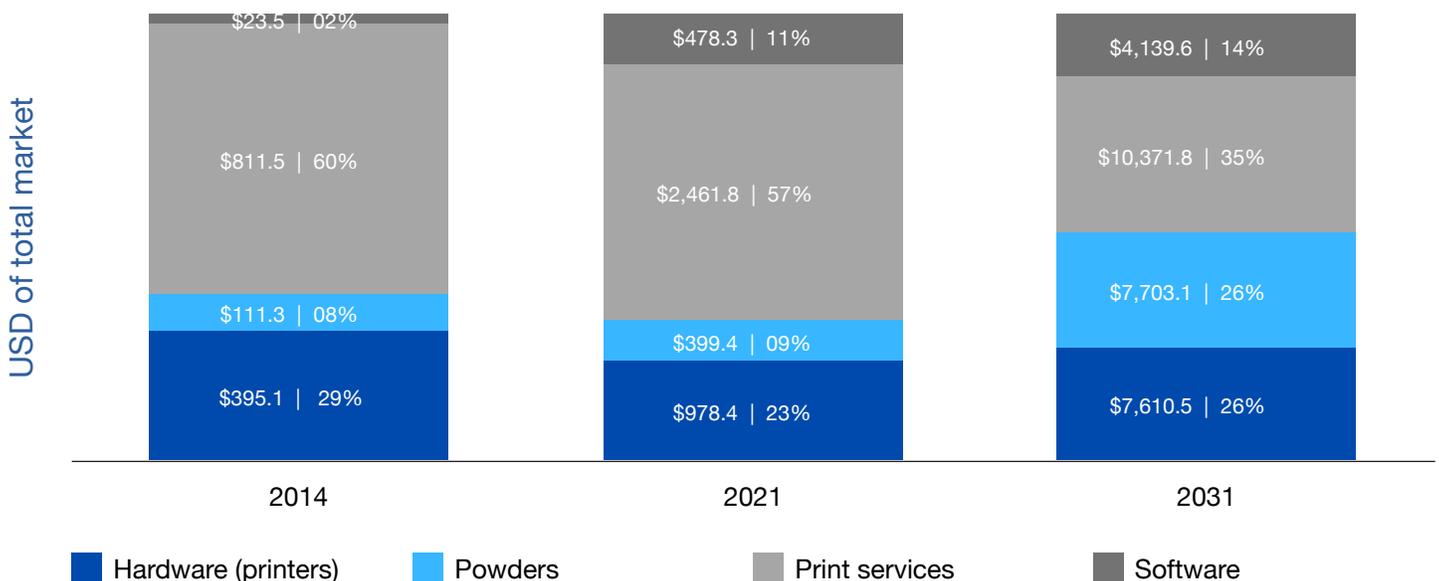
Differentiation Through Execution in the Age of AM at Full Scale

In the age of metal additive at full scale, metal powder suppliers will be thrust into a central role in the market's structure in a multitude of ways. With the number of potential competitors having exploded over the last decade, there will be a stark contrast between those who thrive in this position and those who fade into the noise of a slew of hopefuls. Make no mistake, there's plenty of opportunity to go around. However, execution on a few key elements could mean the difference between padding

corporate numbers with a few dozen accounts and establishing entirely new multi-million-dollar corporate entities for additive powder supply.

In order to be a leader in the segment that is projected to grow from about 9 percent of the total market to more than 25 percent, materials specialists must execute on the following three elements based on the evolving requirements of the market in the face of full-scale production.

Figure 9: Metal additive revenues by segment, 2014-2031(e)



Mitigation of Powder Supply Delays

Pandemics, geopolitical disruptions, labor market swings, and changes to weather patterns, all of these elements and many more continue to lengthen the timeline for supply chain disruptions. Delays for powder supply have impacted metal additive users significantly in the COVID-19 era and have become a top identifying characteristic for bringing value to customers as a powder supplier.

Although, to a certain degree, delays will be inevitable for the short term, providers differentiate themselves through availability of powder and good communication with their AM customer base. This deep collaborative approach with customers is critical today. Because AM powder users are now finally seeing the fruits of their labors in application and business case development, not being able to secure powder—or consistent pricing—has the potential to derail years of progress and set the industry back.

Establish Localized Supply of Key Materials Through Innovation

Due to the potential for negative impacts from supply disruptions in powders, the best and most successful providers will innovate to introduce localized supply, thus creating insulation from disruption to key customers.

The challenge associated with this can't be understated. With raw material supplies of certain metals very centralized in various spots across the world like Russia, China and the Ukraine, which are also less stable than ten years ago, the ability for users to have a solution they can leverage that removes these risks will be a competitive

advantage, and suppliers who can provide this capability will thrive.

The ability to scale up these offerings as customers require, while keeping powder availability high, results in a perfect scenario for success for both end user and powder supplier.

Giving Customers Competitive Advantage Outside the Norm

Powder quality is still the number one criterion by which suppliers are evaluated in today's metal AM market, at least by the largest customers of today. However, users also note that powder quality issues are no longer a common occurrence in the market for AM powders, which indicates that many providers are capable of producing quality materials. What then separates suppliers, among the other characteristics already mentioned, is the ability to provide qualified research to back up quality claims. Eventually, the common practice of users extensively qualifying powders internally for each project will need to be eliminated to move beyond the projected short-term boom.

Enabling sustainable production via AM will also separate the best from the crowd in the eyes of major OEM users of metal additive, and this is another area where the proof will need to be quantified so that burden is not squarely on the shoulders of the end user.

06. Summary

Powder Companies Should Adapt to Ensure They Don't Fail the Industry

The age of AM at full scale is here, but its full scope won't come to pass if the leaders and innovators in metal powder supply don't continue to evolve. AM's most advantageous quality is that it can be very agile at a process level, eliminating traditional bottlenecks and imbuing a degree of that agility to its users' manufacturing and product development operations.

Powder suppliers should strive to do the same with their technology, increasing efficiency and agility to keep supply flowing and accommodate those customers who have the opportunity to scale additive production as they need it—not with months of delay because feedstock material isn't available.

The additive industry, as a whole, has evolved extremely rapidly in the last year and a half of the COVID-19 era. If the powder supply chain does not also evolve with equal speed, then the industry suffers. Powder production technologies must continue to make efficiency gains, while bringing materials to market from more input sources, all while not sacrificing the current quality standards.

The future of metal additive has never been more exciting. While metal powder suppliers stand to gain significantly in the current trajectory of the market, they will have to do much more to help the industry realize the dream as it is unfolding.