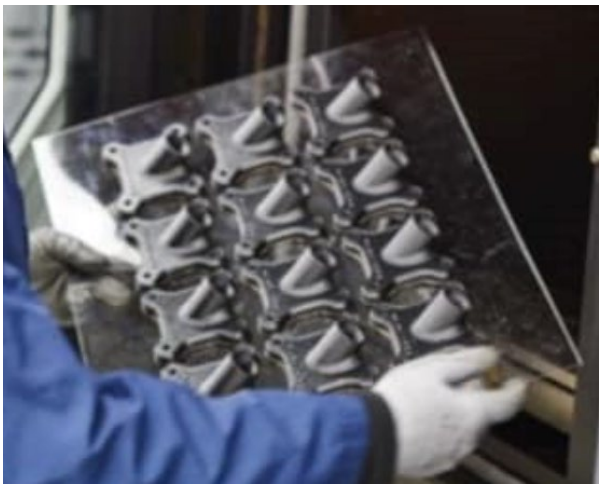

Production Scale, Low Cost, Sustainable Additive Manufacturing Has Arrived

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In an era of digitilization, global market pressure, and uncertainty on many fronts, it's more important than ever to leverage innovative technologies. Successful industrial manufacturers are replacing obsolete methodologies and adopting additive manfuacturing for more sustainable, low cost, and consistent high level production parts.

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Executive Overview

There was a time when volume production additive manufacturing (AM) was considered to be far in the future for 3D printing technology. For many years, 3D printing saw its value in rapid prototyping, design iterations and product development. However, for production applications, limitations in printing technology and material choices challenged the ability to produce consistent quality parts affordably. While some companies have indeed embraced AM manufacturing and are producing quality end user parts; the need remains to weigh up the complex economics of instances where AM makes sense.

Successful industrial manufacturers are replacing obsolete opinions about additive manufacturing, resulting in environmentally friendly, low cost, consistent production level manufacturing.

Some manufacturers may still believe that AM is a slow, expensive tool best suited to prototyping, yet this belief is fast being replaced by manufacturers successful in partaking in more sustainable, lower cost, and consistent production level manufacturing.

Some of the biggest pain points facing industrial manufacturers are industry-specific volatility, broken supply chains, acute labor shortages, and complexities around corporate sustainability. For example, the automotive industry saw a significant downturn during the beginning of the Covid-19 crisis followed by the supply chain discontinuity of semiconducor parts in 2021 (among others), which significantly lowered the number of cars produced. Forward-looking companies are digitally transforming to face these challenges, and include 3D printing as an integral part of transforming their manufacturing processes.

In particular, the advent of newer technologies like Selective Absorption Fusion (SAF) provide an opportunity to embrace additive manufacturing with consistent quality and at production level scale while reducing material waste, simplifying production, alleviating broken supply chains risks, and cutting costs.

Manufacturers Reap the Benefits of Printing Production Level Parts

A new light shines on industrialized additive manufacturing as hardware additive manufacturing innovation, IoT software, services, and material advances intersect with global uncertainty and unrest. Prototyping will continue to be an important use case. Use cases proliferate and feature higher throughput production of end use parts and products as additive manufacturing technologies have become more accurate, reliable and less expensive. Software is better tailored to additive manufacturing workflow, and material choices are become increasingly plentiful.

Use Case	Definition	Growth as it relates to overall 2021-2026 CAGR of 13.7%
Parts for New Products	Using 3D printing rather than traditional manufacturing methods for new products.	++
Parts for Aftermarket	Replacement parts not made by the original equipment manufacturer.	+
Prototyping	Fabrication of a model of a physical part in a multitude of manufacturing industries.	=

Five Year CAGR sourced from ARC Additive Manufacturing Machinery BY 2021 Report:
+ Higher Growth, ++ Significantly Higher Growth, =In Line with CAGR,
- Lower Growth

Adopting AM beyond prototyping and moving from light production into serialized production of major parts are expected to be an increasing driver of market growth. The market for industrial additive manufacturing will grow at a double-digit five-year Compound Annual Growth Rate through 2026 (Source: ARC Additive Manufacturing for Machinery BY2021 Report). As with other transformative technologies, adopters must balance short-term investments and capital expenditures vs. much needed innovation in a competitive world.

Additive manufacturing at the production level isn't meant to universally replace traditional manufacturing methods such as machining, injection molding or casting. In some use cases, market segment volumes will never

justify traditional manufacturing. Spare parts printing is a compelling example. Careful analysis of volumes, benefits and cost savings is required before simply recreating existing traditional manufacturing using 3D printing. The biggest benefits are realized when manufacturers design for 3D from the conception of a product. Design for Additive Manufacturing (DfAM) takes advantage of the design freedom that comes with 3D printing. DfAM allows manufacturers to reap the benefits of complex geometries and the use of tools such as generative design to create parts that would otherwise be too difficult or costly to justify with traditional manufacturing methods.

Generative design is an iterative process that generates multiple design outputs meeting predefined constraints and requirements for fit, form, and function. Design engineering can augment the output by manipulating the values of the constraint variables. This allows for many design solutions to be presented in a very short period of time.

Today, manufacturers face supply chain disruptions, material shortages, labor shortages, order backlogs, rising prices and shipping and logistics issues. Local or global supply chain disruptions and vulnerabilities have been brought to light by the Covid pandemic and current geopolitical tensions. Delays and inefficiencies are further exacerbated when one supplier is the sole source for a part, or when one geographic area holds most of the options for a particular supply. Container shortages and port delays create material shortages, forcing business leaders to rethink standard sourcing practices such as low-cost sourcing and just-in-time manufacturing.

Additionally, more recent challenges include an acute labor shortage and an increasing complexity in the demands of manufacturers as well as a need to understand and measure the impact their actions have on global sustainability initiatives. More than ever, companies are facing a manufacturing labor shortage, which is driving many organizations to accelerate investments in technologies to help boost the performance of their existing staff.

The pandemic, political unrest and climate disruption has completely changed the global economy and market dynamics across many industries. Industries that are already adopting additive manufacturing are also affected by vertical-specific trends. For example, the aerospace and defense sector has faced huge headwinds. During the early part of the Covid-19 pandemic, investment stalled. But as the industry began to recover, capex spending has focused on digital innovation. Historically, spending is driven differently by the defense vs. the commercial sector. The commercial sector is heavily tied

to passenger traffic, which is trying to creep back to pre-pandemic levels. But airlines themselves are struggling to meet demands amid staffing shortages, and reduced flight schedules. The demand from the defense sector remains solid as geopolitical tensions result in increased defense budgets.

Like the automotive industry, the aerospace and defense industry is driven by increased energy efficiency and manufacturing optimization. This in turn will continue to push the market to employ innovative manufacturing technologies and advanced materials, as can be provided by additive manufacturing. The automotive industry has its own set of unique challenges. Increasing vehicle electrification, tighter networking across the automotive value chain, the entrance of new competitors, and chip shortages are pushing this industry toward transformative technologies.

The automotive industry has been the largest industry for additive manufacturing but has dropped in both size and year over year growth. Despite the drop in demand for cars, innovations surrounding additive manufacturing continue to be adopted by the industry. The automotive industry use cases for AM initially had been for new product development prototyping, but now include tooling, jigs, fixtures, and parts. Additive manufacturing is expected to continue to produce product differentiation and competitive advantages in this and other key industries.

Successful Manufacturers Lower Costs While Mitigating Supply Chain Risks and Becoming More Sustainable

Implemented properly, additive manufacturing can reduce material waste, simplify production, reduce lead times, alleviate high inventory costs, and optimize product design. With the advent of powder bed fusion processes driven by industrial printhead technology such as Selective Absorption Fusion (SAF), manufacturers are achieving accurate, consistent production at competitive part costs. An example is 3D printer manufacturer Stratasys. The company's SAF technology uses an infrared-sensitive high absorbing fluid to fuse particles of polymer powder together in discreet layers to build parts. Quality, consistency, and reliability are achieved through a proprietary technology that includes powder distribution across a bed, where industrial-grade piezoelectric print heads jet the fluid in prescribed areas to create each layer of a part. This is followed by exposure to infrared energy, which causes the areas with high absorbing fluid to melt and fuse together. Careful thermal control throughout the build volume leads to more consistent part

production. The system uses renewable, biosourced PA11 which is not only durable, but is also known to fit well as part of a sustainability program.

Sustainability has become a hot topic. Investors and consumers are expecting business to take steps to address its environmental impact on the planet. To meet the ever-pressing sustainability goals, industry is taking the lead wherever it can. The eyes of the world are looking for companies to produce green solutions to fight climate change and additive manufacturing is providing solutions to make this more attainable. AM has recently seen a major uptick in recognition as being more sustainable, in some cases over traditional manufacturing methods. High marks for sustainability are not only achieved with renewable materials such as PA11, but also in the higher yield of parts and material reuse. Other potential benefits include reduced waste inventory, and reduced energy expended in transporting parts across long supply chains.

The ability to produce high-volume parts with accuracy and repeatability from build to build and machine to machine combined with the ability to minimize waste by recycling powder, boasts a very attractive return on investment.

Broken supply chains have been brought front and center the past few years. Supply chains are fragile due to political turmoil, climatic events, pandemics, and economic uncertainty. Additive manufacturing mitigates supply chain risk with a "design anywhere, produce locally" strategy. Ultimately, this can alleviate expensive complex manufacturing, shorten lead times, and reduce inventory. Producing locally also mitigates high import/export costs and risky sole sourcing. Growth in the adoption of manufacturing-scale 3D printing helps manufacturers address their supply chain challenges.

Today we have a manufacturing labor shortage, which has caused many organizations to accelerate investments in technologies to help amplify the performance of their existing staff. In addition to an aging and retiring workforce and difficulty in finding people with the right skills, the "great resignation" remains a hallmark of the labor market today. With demand for labor historically high and more workers quitting their jobs, there is no better time to transform business processes to retain best talent and optimize processes to do more with less. Embracing production-level SAF additive manufacturing can result in an increased revenue per headcount when choosing a printer that is easy to use, consistent, high yielding and scalable.

What a Production Level Additive Manufacturing Solution Looks Like for Top Tier Innovative Manufacturers

Making the decision to utilize additive manufacturing for production is not a trivial decision. Incorporating innovative technologies into existing business process flows typically requires a cross-collaborative culture. Successful manufacturers who have integrated end-to-end solutions often involve multiple constituents within an organization.

Cross-functional collaboration between manufacturing, IT, research & development, and engineering is prevalent in the most successful additive manufacturing production level programs. Research and development were the earliest adopter and still may be the "champions" of 3D printing within an enterprise.

Historically, when 3D printing's goal was to simply transform manual prototype techniques to digital, it was common and effective for this to be in the hands of R&D, but this is no longer true with a digitized manufacturing process from design to end use parts. Successful manufacturers need to integrate an end-to-end solution workflow connecting software, hardware, and post processing solutions. Not all companies are able to connect the dots to implement an end-to-end production process using additive manufacturing. Some successfully turn to third party 3D printing services manufacturers for a variety of reasons. These may include a desire to try before buying, access to a breadth of technologies that can't be justified in house, location flexibility, skills gap, financial limitation, or cultural limitation.

Recommendations

Industrial customers interested in exploiting additive manufacturing to enable next generation manufacturing digital transformation strategies have numerous issues to consider. Based on ARC research and analysis we recommend the following actions to industrial manufacturers:

- **Expand use case mindset beyond prototyping:** While prototyping and proof-of concept will still make up an important part of the 3D printing landscape, the true benefit is in exploring new use cases such as parts for new products and aftermarket parts where value can come in the form of operational efficiencies, creation of new products, or even the transformation of the customer experience.

- **Understand the benefits of Selective Absorption Fusion (SAF) technology:** SAF is an industrial-grade powder-based additive manufacturing technology which brings the realization of higher levels of consistent quality end-user parts to production. Often this can be done at a lower cost and sustainably.

- **Weigh outsourcing vs. in-house:** Uncertain global macro-economic conditions have constrained budgets in some industries. Rather than be left behind in the additive manufacturing revolution, some companies are weighing outsourcing as their entry into 3D printing. Factors to consider include budget, in-house expertise, identification of applications, and use cases and volume. For those exploring high volume production, a service bureau has proven to have the capacity and knowledge to help test production hypotheses before making more permanent capital expenditures.

- **Design for additive manufacturing:** Utilize generative design tools to create parts that would otherwise be too difficult or costly to justify with traditional manufacturing methods. This will result in a multitude of design solutions to be presented in a very short period of time. Redesigning an existing part or creating a new one with production-level additive manufacturing in mind, when done correctly, provides the opportunity for design improvements, material advantages, speed and cost savings.

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Acronym Reference:

AM Additive Manufacturing
DfAM Design for Additive Manufacturing
SAF Selective Absorption Fusion

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