WHITE PAPER

Fuse Series SLS Printers vs. Traditional Powder Bed Fusion Systems

As selective laser sintering (SLS) 3D printing systems have become more popular for applications as diverse as prototyping consumer products and end-use aerospace components, businesses are faced with a proliferation of options. There are consumer-accessible machines as inexpensive as $10,000 and large-scale industrial systems that often cost upwards of $500,000.

There are benefits to each type of system, and this comparison guide will cover the main differences between compact SLS printers such as Formlabs Fuse 1+ 30W that can easily fit into existing office or manufacturing spaces and large footprint machines that require more planning and preparation to integrate into an existing workflow.

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What Is SLS?

Selective laser sintering (SLS) refers to a type of 3D printing, also known as additive manufacturing, where a laser sinters powdered particles into a thin, solid layer on top of a bed of powder. New powder particles cover the previous layer, the laser sinters again, and the process repeats, building a three-dimensional object. There are multiple similar powder bed fusion (PBF) 3D printing technologies that use some type of binding agent, whether it's a laser's heat as with SLS, or a liquid binding agent as in multi-jet fusion (MJF) technologies. This comparison will compare compact SLS systems, such as Formlabs' Fuse 1+ 30W SLS printer, to large-format powder bed fusion solutions.

SLS 3D printers are relied upon to create stronger and more durable and rugged plastic parts than their fused deposition modeling (FDM) or stereolithography (SLA) counterparts. The self-supporting nature of the powder bed means that parts do not require supports, and thus complicated geometries and parts with internal channels or hollows require less post-processing.

Powder bed fusion 3D printing technologies also enable parts to nest inside each other, enabling printer operators to fit more parts inside each build volume, and improving print efficiency. SLS powders, such as nylon and thermoplastic polypropylene (TPU) are familiar to the design and manufacturing community, with recognizable material and mechanical properties.

Applications of SLS 3D Printing

The strength and superior mechanical properties of many SLS printed parts make a wide range of applications possible, from functional prototyping to end-use products in diverse industries.

Engineering

Take control of your entire product development process, from iterating on your first concept design to manufacturing ready-to-use products:

- Rapid prototyping
- Mockups of products for in-field customer feedback
- Functional prototyping
- Rigorous functional testing of products (e.g. ductwork, brackets)

Manufacturing

Own your supply chain and respond quickly to changing demands:

- End-use part production
- Small batch, stop-gap, and bridge manufacturing
- Mass customized consumer products
- Replacement parts, aftermarket parts, spare parts
- Long-lasting, durable manufacturing aids, jigs and fixtures (e.g clips and clamps) and tooling
- Custom automotive or motorcycle parts, marine equipment, military ‘resupply on-demand’

Healthcare

Manufacture ready-to-use, patient-specific medical devices in-house:

- Medical device prototyping
- Prosthetics and orthotics (i.e.insoles, limb replacements, braces)
- Surgical models and tools
- End-use parts (Nylon 12 Powder is biocompatible and compatible with sterilization*)

* Material properties may vary based on part design and manufacturing practices. It is the manufacturer’s responsibility to validate the suitability of the printed parts for the intended use.

Powder Bed Fusion 3D Printers Available

As the efficiency and versatility of powder bed fusion technology becomes more mainstream, many 3D printer manufacturers have developed systems at a wide range of price points. There are consumer-friendly options available for as low as $10,000 and industrial systems that can cost over $500,000 with accessories.

Traditional Powder Bed Systems

The majority of polymer powder bed systems (SLS or MJF) are designed for large-scale industrial applications. They often have larger build volumes and bigger machine footprints than newer compact SLS systems. Typical examples include the EOS P396 and HP 5210 systems, which cost about $350,000 and $500,000, respectively. These machines are often used by large aerospace manufacturers or service bureaus with advanced infrastructure and large operating budgets. These users are familiar with heavy machinery and are comfortable with paying a premium for annual service contracts and high-end accessories.

Compact SLS 3D Printers

Compact SLS printers like the Fuse Series from Formlabs have opened up new means of manufacturing for many small to medium-sized businesses. Their accessible size and affordable price point, typically from about $10,000 to $50,000, are within reach for businesses that cannot afford the cost of hardware and infrastructure investment necessary for a traditional powder bed system. The range of applications possible makes SLS 3D printing a sort of 'Swiss Army knife' tool for many startups, aftermarket manufacturers, or service bureaus.

A fleet of compact SLS printers can be scaled up for production capacity without massive investment, or a single machine can be relied upon as a workhorse for a large factory's manufacturing aids, replacement parts, and more.

Compare Compact SLS vs. Traditional Powder Bed 3D Printers

There are many factors to consider when choosing between a compact SLS 3D printer and a more traditional powder bed system, including efficiency, cost per part, scalability, versatility, cost of ownership, and performance-specific metrics like accuracy, tolerancing, and surface finish.

Efficiency

Though efficiency has been used by many manufacturers as a way of speaking about print speed, here we will discuss efficiency as the measurable ability to avoid wasting material and time. Compact SLS printers are more efficient than large traditional powder bed systems because their build chambers are more easily filled with parts, and densely packing a build chamber is more efficient, i.e., it wastes less material and finishes faster. Though these compact build chambers may hold fewer parts than maximally packed traditional powder bed fusion systems, running several compact SLS machines can be more efficient, less vulnerable to production disruptions, and produce just as many parts.

PACKING DENSITY

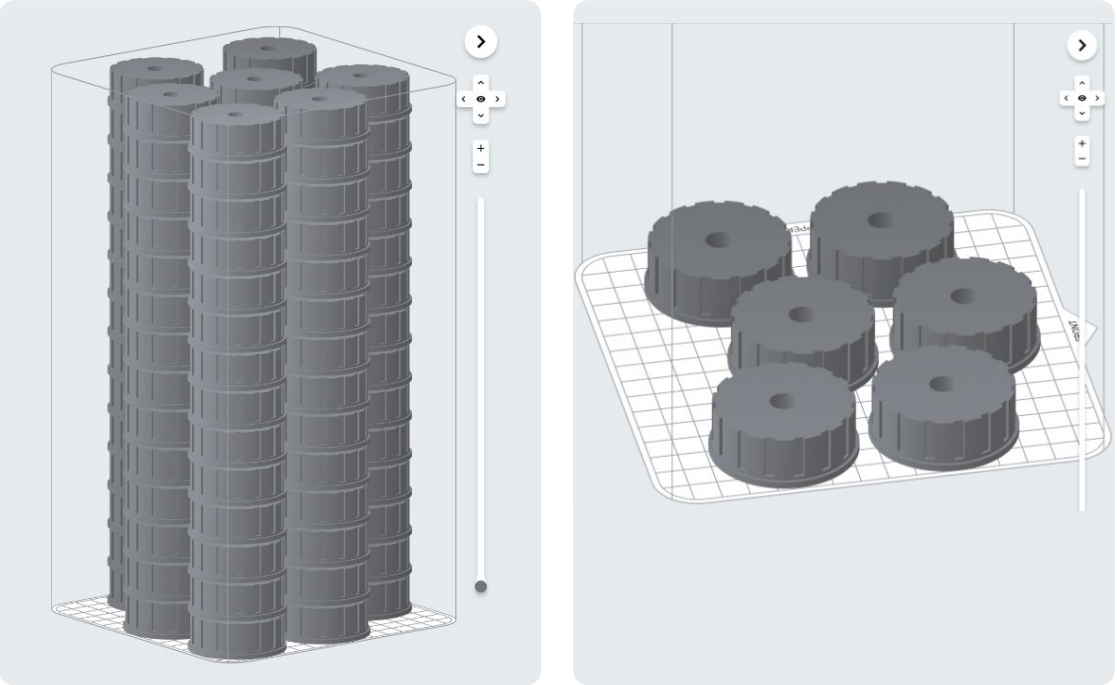
Packing density refers to how densely parts are packed within a build chamber, and the higher the packing density, the more efficiently you're using the space and material. SLS technology has a self-supporting print bed, so that parts can be vertically stacked, or even nested within each other. SLS printers can reach a higher packing density by printing with only a few inches of powder, rather than a full build chamber. However, certain large-format powder bed systems set a limit on packing density, reducing the user's ability to control efficiency parameters.

REFRESH RATE

SLS printers use a mix of fresh and recycled powder to create each print. Recycled material comes from unsintered powder that was part of a previous print job. The percentage of a new build chamber that is required to be fresh powder is called the refresh rate — so a refresh rate of 30% means that you need 30% fresh powder to achieve optimal print results.

Though large-format powder bed fusion printers can achieve similar refresh rates, their large build volumes make it much more difficult because it's harder to fully pack a bigger build chamber. Operators can wait around for the right volume of parts in order to pack it densely enough, but this can hold up operations.

Compact SLS printers like the Fuse Series make it easy to pack the build chamber densely, matching the refresh rate to the packing density. This ensures all unsintered powder can be recycled into a new build chamber.



These build chambers both achieve a high packing density and are very efficient. The tall build chamber (left) stacks 98 parts vertically and uses the entire build chamber. The short build chamber (right) only needs to have an inch or so of powder in the build chamber, but the small area is still densely packed. Both print jobs will produce very little to no excess, unsintered powder that will then need to be recycled.

When users can match their packing density to their refresh rate, they avoid having any used powder left over and are more efficient. Achieving a high packing density with traditional powder bed systems is very difficult, and so operators typically have a lot of unsintered powder left over from jobs that they cannot recycle.

Because compact SLS printers have the flexibility to print either higher volume production runs or just a few parts at a time, both with a high packing density, they are more efficient than the traditional systems that are difficult to fully pack. Users do not need to wait for many parts to be ready to print in order to optimize their use of a large-format machine. Compact SLS printers can be run continuously while maintaining close to optimal packing density, even for low volumes of parts.

EXPLAINING EFFICIENCY: COST PER PART FOR TRADITIONAL SLS VS. FUSE SERIES

When comparing the cost per part of different technologies, it's important to consider that the cost per part can vary even when calculating for the same part on the same machine. Consider the example of the Fuse 1+ 30W SLS printer and a round two inch diameter wrist unit.

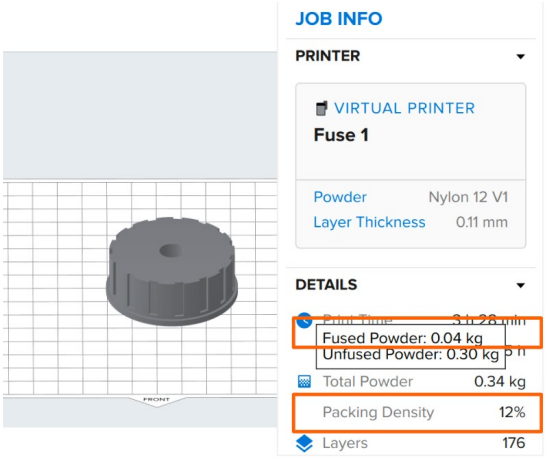
Chamber 1: A single wrist unit surrounded by unused, unsintered powder, creates a packing density of 12%. There is 0.04 kg of sintered (Fused) powder, and 0.30 kg of unsintered (Unfused) powder. Total powder used is 0.34 kg of powder and Nylon 12 Powder has a 30% refresh rate. The cost of new powder is $99 per kilogram.

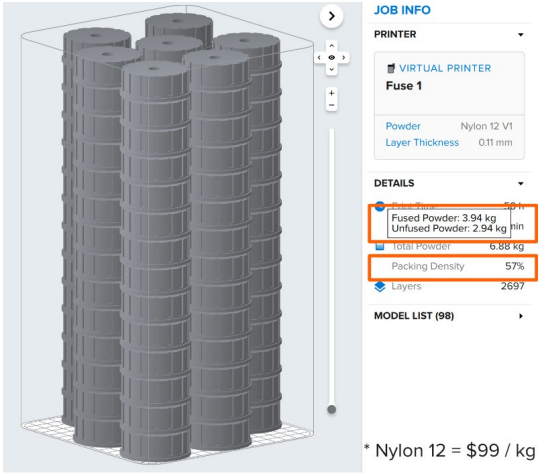
Because packing density (12%) is lower than refresh rate (30%), not all the unsintered powder will be recycled into the new part — it's waste. *This means that cost per part should include unused powder only when packing density is lower than refresh rate.*

Chamber 2: 98 wrist units are efficiently stacked to optimize powder usage and build chamber packing density. There is 3.94 kg of sintered (fused) powder and 2.94 kg of unsintered (unfused) powder. The cost of powder is $99 per kilogram.

Because packing density (57%) is higher than refresh rate (30%), you do not need to factor in the unsintered, recyclable powder to the equation. For this equation, you do not use total powder for material, but rather only sintered (fused) powder. The unsintered (unfused) powder will be recycled by the Fuse Sift and used in another print, so it doesn't affect material cost for this build.

$$\frac{(\text{Sintered Powder Full Build} + ((\text{Refresh Rate} - \text{Pack Density}) \cdot \text{Total Powder})) \cdot \text{Powder Cost}}{\text{Number of Parts}}$$





* Nylon 12 = $99 / kg

Packing Density (12%) < Refresh Rate (30%)

Total Powder x Cost of Powder x Refresh rate / Number of Parts = Cost Per Part

0.34 kg x $100 x 0.3 / 1 part = $10.2

Cost Per Part: $10.2

Packing Density (57%) > Refresh Rate (30%)

Fused Powder / Number of Parts = Cost Per Part

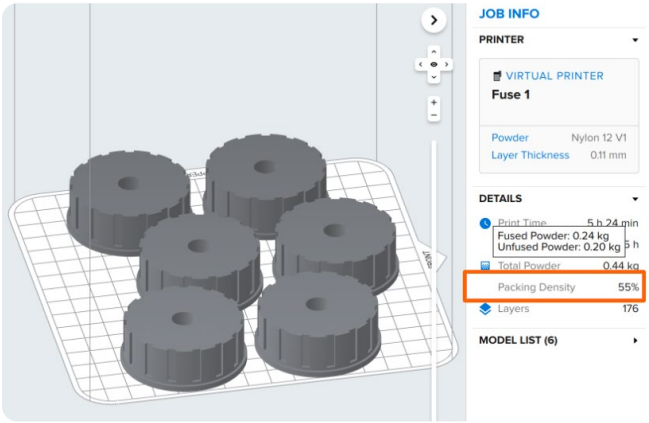
$100 x 3.94 kg / 98 parts = $4

Cost per part: $4

Of course, equalizing refresh rate and packing density is the goal, but not the everyday reality for most Fuse Series users. These two examples show that the higher your packing density, the easier it is to match refresh rate, and the more likely you'll be able to reuse all unsintered powder in your next build, driving down material costs.

Because the Fuse 1+ 30W printer is compact, it's easier to fill the build chamber. Some large-format traditional powder bed fusion printers are not only difficult to fill, but actually prohibit users from overpacking, and this can lead to lower densities and higher cost per part.

Additionally, printing efficiently with the Fuse 1+ 30W doesn't always require users to wait until 98 parts are ready to be printed. Users can create a build chamber in PreForm with only a few parts and an adjusted height, so that only the amount of powder absolutely necessary for the print is used. In the example below, a build with only six parts can still reach a packing density of 55%.



Scalability and Redundancy

Users who rely on large-format industrial powder bed fusion printers know that when the printer requires maintenance or needs service, the whole production line or design process stops. The high price and infrastructure requirements of traditional powder bed fusion machines preclude the users from purchasing multiple units, so there is no alternative when the machine isn't running.

SIZE AND INFRASTRUCTURE

In contrast, compact SLS printers are easier to scale and offer redundancy. They are small and light enough to move around a lab if necessary, they easily fit into existing spaces without the need for complex electrical infrastructure, and together with post-processing machines such as Formlabs Fuse Sift, they are clean and safe to use in a variety of environments.

Traditional SLS and MJF printers require a three product set-up: the build chamber, which slots into the printer, and the post-processing station. Together, these three parts cover substantial footage and require multiple power sources. Compact SLS printers, like the Fuse Series, enable an efficient, streamlined workflow with the inclusion of the Fuse Sift, an all-in-one powder reclamation, cleaning, and recycling station. Fuse Series printers do not require specialized wiring either and can run on a typical AC power outlet.

PRICE POINT

The accessible price point, ranging from under $25,000 for a Fuse 1+ 30W printer to around $37,000 for the complete solution that includes an all-in-one, efficient powder recovery system, means that even startups and small to medium-sized businesses have the means to bring SLS printing in house, or even build a fleet of multiple machines for less than the price of a single traditional powder bed fusion 3D printing solution.

For companies that have a central 3D printing lab, the affordability of multiple compact SLS machines helps organize operations and allocate printers to different areas of the business. An internal printing lab can easily designate one printer for the prototyping division, two or three for production, and one for manufacturing aids or tooling. The printers can share a post-processing machine like the Fuse Sift, and the cost of all five machines is still lower than some of the largest traditional powder bed systems.

Versatility

Compact SLS - Fuse Series

Price: ~$210,000

Nylon 12 Powder

Nylon 11 Powder

Nylon 11 CF Powder

Traditional Powder Bed Fusion System

Price: ~$500,000

Nylon 12

Traditionally a single powder bed system is locked into printing with only one material. Because SLS and MJF powder particles are so fine, it requires a thorough cleaning process in order to completely clean a machine of powder. For large systems, that process is too labor intensive, so trying a new material is out of the question. With compact systems, a company can run multiple units on the most popular material, generally nylon 12, and also have other units on more niche high performance materials, like glass or carbon-filled nylon — all at a fraction of the cost of a single traditional PBF system.

Additionally, the complexity of many traditional, large-format machines makes it difficult for new operators to learn, and it falls to a single technician to manage the printer. This type of workflow, though helpful for some scenarios like high volume service bureaus, is not ideal for small to medium businesses where a machine might be printing prototypes, jigs, end-use components, and tooling, all for different teams or members of the company.

Compact SLS machines are more versatile, both in their ability to switch between different materials if necessary and in their ease of use, which makes it easy for new operators to start printing. Printers like the Fuse Series can switch between materials after a cleaning process of only about two to four hours. If the business needs to try a new material but cannot afford a new machine, they aren't locked into their first choice. As new materials are released, users can try out different mechanical properties to find one that best suits their needs.

Print Quality

One major concern for many businesses that are familiar with traditional SLS systems is that compact SLS systems have less powerful lasers, and therefore create lower quality parts. Though larger powder bed systems may have more expensive laser systems, advances in laser technology and materials development have enabled compact SLS systems to deliver parts of similar, if not better accuracy, tolerance, and surface finish. The compact Fuse Series uses a powerful laser that, combined with an advanced galvanometer system and the patent-pending Surface Armor technology that creates a semi-sintered shell around the surface of each part, results in highly accurate parts with tight tolerances. As the three examples below show, the Fuse 1+ 30W (right) creates a highly accurate part with tight tolerances and a similar surface finish as the machines that have 10x the cost.

Comparison photos of parts printed on two traditional large-format powder bed fusion systems (left and center) with the Fuse Series (right).

3D Printing Industry created an in-depth engineer's report that includes a review of Formlabs' first generation Fuse 1 SLS 3D printer and detailed results of accuracy testing.

Download the 3D Printing Industry's In-Depth Review

Download

Build Volume

Traditional powder bed fusion systems have a much bigger footprint than the compact SLS systems available on the market today, which does translate into larger possible build volumes. However, when evaluated against the size of their footprint, the slightly larger build volume is not proportionate. Additionally, a larger build chamber translates directly into a lower packing density and more unsintered material.

Let's consider how the following applications could benefit from either a large build volume or a compact SLS workflow.

	Prototyping	Jigs and Fixtures	End-Use Parts
Traditional large volume	★★	★	★★★
Compact SLS	★★★	★★★	★★

Need and Throughput

HOW MANY PARTS DO YOU NEED?

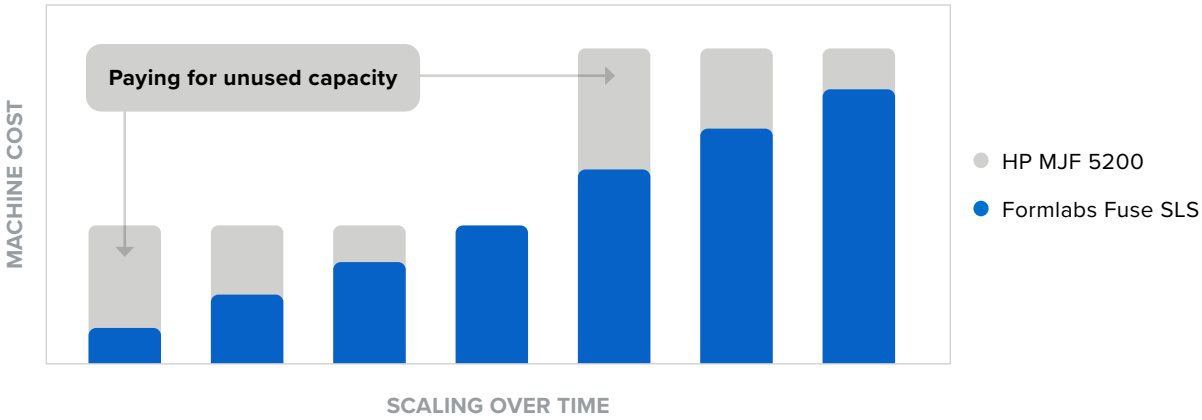
Before choosing to scale up to a fleet of compact SLS machines or rely on one large-format machine, first, determine the target volume of parts. For prototyping applications, jigs, fixtures, tooling, or even customization and low volume production, a fleet of compact Fuse Series printers makes sense. For large volumes of the same or very similar parts, with predictable pack density and refresh rate, a large-format traditional powder bed fusion system might perform best.

This photo represents 1kg of parts (laptop included for scale representation). If you needed to print this amount each day, you'd be on target for about 240 kg of printed powder each year.

This photo represents about 4kg of printed parts. If you needed to print this amount each day, you'd be on target for about 960 kg of printed powder a year - enough to justify an HP 4200 operating at 21% utilization or about four Fuse Series printers.

One Fuse 1+ 30W compact SLS printer, with an up-time of five days a week and a moderately packed (12%) build chamber, will print just over 240 kg of parts each year. The utilization rate, as shown below, is about 99%, meaning that the machine will constantly be running (compared to a much lower utilization rate for the large-format printers). However, the Fuse Series' high utility still only accounts for weekdays, and includes four total weeks of downtime or vacation.

There are few applications in which the situation demands high volumes of parts (> 2 kg of powder per day). Traditional methods of manufacturing like injection molding are still the methods of choice for mass production. For certain situations, like mass customization or situations such as service bureaus where demand is more steady and reliable, a traditional large-format machine may begin to make sense at volumes of 5-10 kg of parts a day.



Total Cost of Operation: Not Just Material Pricing and Output

Of course, as any engineer evaluating a new printer will point out, the cost of operating a printer is not limited solely to the cost of material. Though simple calculations of powder cost and number of parts possible on each machine can be helpful, the total cost of ownership also takes into consideration the hardware, software, and operating expenses.

A printer that has a cycle time of 20.5 hours requires hands-on labor, or 'touches' once a day, whereas a larger machine will require touches only during changeover and maintenance, which will happen only every few days. However, during that changeover to a new build, there is more labor involved in the cleaning, pre-print preparation, and maintenance operations.

COST OF OWNERSHIP

The purchase price of an SLS system is just the beginning of the costs associated with the workflow, the following factors must also be considered:

	Traditional Powder Bed Fusion	Compact SLS
Materials	Require proprietary, expensive materials. Lower packing density leads to more material waste.	Material purchase price commensurate with hardware price. Higher packing density leads to higher utilization.
Hardware and Software Investment	Typically $200,000+ for hardware and similarly expensive software for multi-year contracts.	Typically between $10,000-$50,000 for hardware and software is often free, such as Formlabs' software PreForm.
Service and Maintenance	Required annual service contracts with dedicated service technicians.	Intuitive workflow, multiple users can learn and operate easily.
Overhead and Infrastructure	Printers often require their own room and dedicated operator, as well as industrial HVAC and power	Printers can slot into existing office or lab spaces, scale up to fleets, and require one standard circuit.
Operators/Training	Requires dedicated operators and extensive training of new personnel.	User friendly, 'plug-and-play,' but requires more hands-on time for changing out build chambers, more frequent post-processing.
Space	Typically requires a dedicated room	Operating area of under 200 cm x 200 cm

Which Solution Is Best for Your Workflow?

As estimated kilogram output per year increases (X axis), a large-format machine is cost-efficient only at certain points. As shown here, there is more flexibility with a scaled fleet of Fuse Series printers — a single large-format powder bed printer has a high cost per part for very few parts, but becomes more efficient as volume increases. Users that have very predictable output and projections can consider large-format powder bed printers.

For users that have variable outputs, or whose estimates change based on demand should consider scaling as necessary with a fleet of Fuse Series printers. Compact SLS printers enable more flexibility while keeping the cost per part low.

Compact SLS Grows With The Business Need

There are very few scenarios where a traditional powder bed fusion system is the cost-effective option for a business. One production case may be for high volumes of small, repeatable parts, where build volume is efficiently used, maintenance and service are standardized and carried out by a single operator, and a facility is purpose-built for that workflow.

Conversely, compact SLS 3D printers fit into existing workflows and facilities, providing an agile means of production for prototypes, manufacturing aids, and end-use parts. These machines are designed to provide immediate value and deliver high-quality parts. They are more affordable and have a lower cost per part due to their efficient use of material and easily packed build volume. As the demand for more parts grows, these compact machines can scale easily, without heavy investment into new space, electrical requirements, or hardware.

To learn more about compact SLS printers and discover which type of technology will work best for your unique business, contact the Formlabs SLS sales team.

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