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All about Additive Manufacturing

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Hello & Welcome

"The important thing is to never stop asking questions."

For the Additive Manufacturing industry, this time of the year is the one when all minds are set on Formnext; which will be held from November 7-10, in Frankfurt, and where this September/October edition of 3D ADEPT Mag will be mainly distributed. For 3D ADEPT Media, it's the time to take stock of efforts made towards the improvement of sustainability in our industry.

There are a couple of things that we have realized since the latest edition. First, a lot of efforts are focused on "Environment" when approaching sustainability in the AM industry whereas it should be a well-thought-out strategy that encompasses "Social" and "Governance" aspects.

Moreover, companies that are already engaged in this journey sometimes approach climate and emissions, biodiversity and supply chain, social and DEI matters separately, with different teams reporting on their specific areas despite them being inextricably linked.

This September/October edition of 3D ADEPT Mag questions everything – again. It goes back to the basics of what companies should know at the legislation level and how legislation may affect their business. It highlights what companies have done during the past year and strives to demonstrate that a sustainability strategy is much more than carbon footprint calculation, incremental targets and offsetting. More importantly, it recognizes that it should be about securing long-term business resilience alongside creating profit, thus generating wider value for society and the planet.

Lastly, it's an issue that urges AM companies to never stop asking questions, whatever stage they are at in their journey.

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Editorial

.DOSSIER.

AM COMPANIES MUST GET STARTED ON THEIR ESG JOURNEY. HERE IS HOW. (PART 1)

*For a long time, sustainability in our industry has been focusing on environmental concerns only. As time goes by, conversations with investors and VC companies have urged Additive Manufacturing (AM) companies to make **profit** while doing good for **people** and the **planet**. This triple bottom line is at the heart of Environmental, Social, and Governance (ESG) planning and strategies companies should implement to withstand the test of time, investor demands, and cultural shifts. So, how should they get started? The article below aims to respond to this one-million-dollar question.*

ESG is both simple and complex. To avoid drowning in the sea of information the Internet can offer, we sat down with three lawyers from Squire Patton Boggs (US) LLP: **Dr. Andreas Fillmann, Wolfgang A. Maschek** and **Valerio Giovannini**. With over 40 offices across the world, this full-service global firm operates on 4 continents with more than 1500 specialist practicing lawyers. Their Brussels-based office focuses on public policy and looks into all ESG-related legislation. Overall, no matter where they are based, the team at Squire Patton Boggs helps companies understand the business and legal implications surrounding ESG, and on the other hand, helps design, develop or overhaul policies and practices in relation to sustainability and ESG.

Together, Fillmann, Maschek and Giovannini help us understand:

- The different directives and regulations that should draw AM companies' attention right now
- The regulatory body in charge of monitoring the rules after the implementation of these directives and regulations
- And the first steps to get started

1 - What are these ESG regulations ?

Since 3D ADEPT Mag is a global digital and print magazine, it's important to mention that changing administration priorities under President Biden have amplified the need for attention to ESG in the USA but legislation may slightly differ from Europe – which will remain our key focus in this dossier.

Within the EU region, different legal requirements have passed in some jurisdictions but are being enacted at different paces. In this vein, we learned from our subject matter experts that the different regulations concerning ESG include:

- The Taxonomy Regulation
- The Non-Financial Reporting Directive (NFRD)
- The Corporate Sustainability Reporting Directive (CSRD)
- The Sustainable Finance Disclosure Regulation (SFDR) – (mostly applied to banks and financial institutions)
- And the still negotiated Corporate Sustainability Due Diligence Directive (CSDDD)

"Even across different European companies, one can observe differences in the implementation of ESG legislation. With increasing demand from investors that require companies to be ESG compliant, [technology] companies have to meet reporting requirements but also product requirements. That's why they should set up a roadmap to ensure that all the discussions around this topic continuously align with their vision and goals," **Fillmann** explains.

Simply put, the Taxonomy Regulation is a framework that indicates when a company or enterprise is operating sustainably or environmentally friendly. The Taxonomy Regulation positively recognizes green, or "environmentally sustainable", economic activities that make a substantial contribution to achieving the six climate and environmental objectives, while minimum social safeguards.

The six environmental objectives that are assessed here include climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control as well as protection and restoration of biodiversity and ecosystems.

Compared to their competitors, companies in compliance with the Taxonomy stand out positively and thus **might benefit from higher investments**. Thereby, the legislation aims to reward and promote environmentally friendly business practices and technologies.

Under the NFRD (Directive 2014/95/EU), certain large EU public-interest companies must disclose non-financial and diversity information in their annual reports. The CSRD legislation comes as a reinforcement to this one as it urges around 50,000 companies seated in the EU to report sustainability disclosures across several topics pertaining to environmental and social issues, and improve non-financial reporting.

As for the CSDDD, which is still under discussion at EU level, it would require companies to establish due diligence procedures to overcome adverse impacts of their actions on human rights and the environment along their global value chain.

*"With the EU Green Deal, one realizes that ESG is becoming a very important component of the game, as more and more legislation is coming into force. It should be noted companies have an **obligation of** disclosing environmental information from 2025,"* **Giovannini** comments.

But who is concerned and by which legislation specifically?

"Rules apply to almost every sizeable company but the level of implementation may vary from one company to another. It's a question of size," **Maschek** adds. This means that CSRD for instance will be a requirement for companies

with over 250 employees, EUR 40 million+ turnover, or EUR 20 million+ total assets (two of three criteria should be met). Even so-called 'third country' (i.e. from outside the EU) companies with a turnover of EUR150 million in the EU whose subsidiaries meet the above size criteria or whose branches achieve a turnover of more than EUR40 million will have to comply with the CSRD. Furthermore, *"the EU regulator may have defined what it wants to see at the framework level, but there are more granular rules that will apply to specific industry sectors."*

"The EU taxonomy for instance is a green classification that applies also to technology companies specifically [such as the ones of the AM industry] helping them to assess if they meet the EU's climate and environmental objectives," **Giovannini** outlines.

In the same vein, as we will see in ***PART 2 of this dossier***, the various ESG rules directly apply to the AM industry as they encompass specific points that touch upon diversity and inclusion (people) and the right management (governance) to operate responsibly.

On another note, *"the CSDDD is another puzzle piece [AM companies] will have to look into as some might operate with raw materials coming from developing countries where compliance with the future CSDDD rules might be challenging,"* **Maschek** continues. Not to mention the new EU Deforestation Regulation, which could also affect certain AM companies.

Which regulatory body is in charge of monitoring the implementation of ESG Legislation ?

To this question, **Fillmann** replies that the monitoring will be done at a national level by government bodies as described by EU law, supported by certain EU-level supervisory bodies. That being said, more and more NGOs and non-profit associations are taking responsibility in this area and pro-actively review, and at times sue, firms for incorrect corporate reporting activities.

2- So, what are the steps that will help you get started ?

Getting started on ESG is quite similar to a marketing strategy that you design as the plan needs to follow specific objectives. "This can seem complex as most AM companies do not have sufficient ESG expertise, yet they need to move from marketing promises to tangible actions and dedicated ESG teams. Acting now is the first step to avoid promising something that they can't deliver in 2025," Maschek points out.

Based on our conversation with Fillmann, Maschek and Giovannini, we came up with 4 steps that can help any AM company confidently take the leap on this journey.

1- Understand where you are headed

This very first step should be quite similar to the introspection you conduct at the end of the year. With a critical look at your activity, you can assess the areas of your business that may impact people and the planet.

2- Conduct your Materiality Assessment and related ESG obligations

Conducting a comprehensive ESG audit and materiality assessment means evaluating one's impact on the environment, society, and governance structure, and determining which of these ESG issues could influence your financial bottom line. A third-party audit firm specializing in ESG assessments can come into play here. Important is also to understand which ESG laws apply to your activities.

3- Develop & implement your action plan

At this stage, you will set SMART goals. Needless to say, this goes along with key responsibilities assigned to specific teams, the creation of a timeline and budget allocation to make things happen. Most AM companies set environmental goals like reducing CO2 emissions by x % over the next five years. This is great but there are other pinpoint areas. As we will see in **PART 3 of this dossier**.

4- Continuously monitor your progress

Regardless of the standards, frameworks, or guidance used to tell your story, what's important to keep in mind is that your report should tell your results in a concise and clear manner as well as your next areas of interest. At this level, we strongly recommend sharing your lessons/what you've learned with the trade press.

What I am hoping to see here is an ESG strategy aligned with business objectives (yes, because in the end, you're running a business that should be profitable), as well as a focus on ESG goals, metrics and programs put in place.

In a nutshell?

One thing we will keep from this conversation is that just like there is no one-size-fits-all solution with AM technologies, from regulations to implementation, each company's sustainability journey will look a bit different, depending on its location(s), value chain, investors, or partners. It is important to look for the right external partners on this journey, to ensure you are getting through this new ESG maze.

KEY AREAS OF FOCUS IN THE APPLICATION OF ESG BY AM COMPANIES (PART 2)

The first part of this dossier shed light on the importance of implementing an ESG strategy taking into account the legislation that applies to your specific situation. While each company's sustainability journey is unique and may vary depending on its location(s), value chain, investors, or partners, there are a couple of pain points that all AM companies can relate to. This article aims to highlight them. It will also shed light on a few companies that have already taken the leap on ESG.

Image: CASTOR

As a reminder, Environmental, social and governance (ESG) is a framework used to assess an organization's business practices and performance on various sustainability and ethical issues. The AM industry focuses a lot on the **"E" part of this acronym**. As per the words of **Simon Schlagintweit**, Medical Expert & Lead Auditor Additive Manufacturing at **TÜV SÜD**, the biggest impact when it comes to the environment is "the feedstock– how sustainable is the feedstock, how effective is the recycling and waste management – and energy consumption of the various machines required."

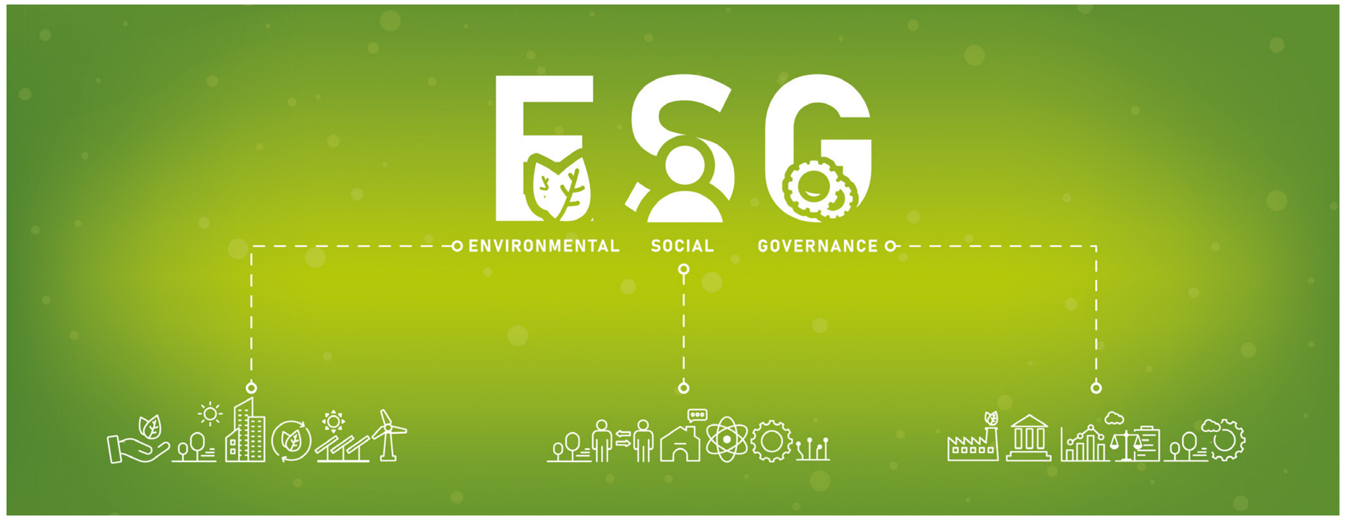
Long story short, TÜV SÜD goes in different directions to support and enhance the ESG internationally. A few examples are their core business of testing, inspection, and certification, which cover all ESG topics from product and employee safety to regulatory compliance. More in-depth examples of their services are climate neutrality services or industrial cyber security.

In the AM industry, a few software providers like CASTOR and Siemens have developed a **CO2 Emission Calculator** tool that would help manufacturers reduce their CO2 emissions. The calculation behind the CO2 analysis of CASTOR, for instance, takes into account various parameters along the full lifecycle of the product.

Image: CASTOR

While there is a great chance that many parts won't be able to be taken into account in this newly created process, the importance of CO2 measurement might create a paradigm shift for those industrials starting their AM journey as there would be a great temptation to produce AM parts that will be directly optimized for CO2 reduction. Moving forward, given the climate emergency, others will have no choice but to follow the move.

However, as you will see in **PART 3 of this dossier**, much more can be done to reduce the risks of AM activities at the environmental level.



The "S" of ESG for AM companies

The "social" or "S" elements of ESG played for a long time a secondary role to environmental and governance factors. This can be understood by the fact that environmental and governance issues are much more clearly defined.

In the AM industry, the main issue around the "S" of ESG is for **Schlagintweit**, the **workforce**. *"On the one hand, safety is important for the workforce, as AM can be dangerous in some circumstances. On the other hand, training and specialization are necessary. Comprehensive training is not yet fully available (e.g. apprenticeships or academic courses). In addition, supply chain responsibility naturally affects the AM industry, e.g. where the raw materials and/or products come from and how they were produced,"* he adds. For the expert, education and general product safety are especially pivotal when AM is leveraged in highly critical sectors like automotive, medical, and aerospace.

In a tech industry like AM, I believe the rationale behind the "S" element can go further to lay emphasis on questions of **diversity, equity**, and **inclusion** (DEI). If we look at the theory only, the first hurdle we will see is the **lack of data** that explains the current situation of each organization.

The other hurdle is **time** and **resources**. As a lead author of a previous Women in 3D Printing "Diversity for AM Report", I came to realize that going beyond a marketing promise or a marketing action that consists in highlighting a person from a minority ethnic group on one's website, requires time and money. Time to educate one's employees on these questions and money to invest in services that will help you deploy tangible actions across all departments. It should be a joint work between Marketing, HR and Management teams.

The "G" of ESG for AM companies

At this level, AM companies should focus on **transparency** in the supply chain and throughout the company.

For TÜV SÜD's representative, AM companies should provide clear answers on *"where does everything come from and where does it go (again, supply chain responsibility)? What is being produced (e.g. counterfeit products or medical devices)? Are all necessary and relevant regulations and standards being adhered to?"*

According to this expert, the governance issues affecting the AM industry are related to **intellectual property rights** and **data security** – what is printed, is it the original data and how can we make sure it is not stolen –, **quality assurance** – even though specialized QM AM standards are being published (like ISO/ASTM 52920) the industry needs to adopt them as well.

Overall, it is important to keep in mind that corporate governance is the set of rules, practices, and processes that determine how a company is operated and controlled. Its main aim is to ensure that the company acts in an open and accountable manner and that its leadership acts in the best interests of stakeholders.

ESG programs ?

It is too soon for us to legitimately say or recommend that a specific ESG program has already borne fruit within a specific AM company. Especially taking into account that *"the landscape of regulation and policies change regularly as new regulations and standards are being developed."* As **Schlagintweit** points out, these influences *"the AM industry, from product regulation (e.g. MDR), Data and cyber security (e.g. CRA) to supply chain regulations (e.g. European Supply Chain Act). Additionally, new standards are being developed and published on topics like EH&S, QM, or material specifications, which can support and influence how regulations need to be addressed."*

As such, ensuring the maturity of ESG programs requires *"independent (3rd party) reviews, assessments and audits of supply chains and companies, to make sure these really adhere to set policies & regulations and to have these kind of assessments and audits, clear metrics and requirements need to be defined. When we have metrics and requirements and thus more data, these can be used to analyze and interpret via AI or big data to identify issues or future trends. Moreover, these data can be used for monitoring & reporting, benchmarking, improvement loops and transparency,"* **Schlagintweit** concludes.

That being said, one should recognize the efforts of AM companies that have taken the leap on ESG. **Stratasys** is an example that is worth mentioning here as not only are they attempting to track and limit their footprint, but they also introduced renewable energy through solar panels at some factories and have dozens of additional initiatives to address waste streams and optimize operations. These initiatives are highlighted in their first ESG report published last year.

Another company that we should observe in this field is **Prusa Research**. Founded in 2012, the founder Josef Prusa and his team were able to manufacture 101 232 3D printers in 2022, delivered across 149 countries (data of 2022 shared by the company). The company started focusing on sustainability at the end of summer 2021 – being aware of the environment in which they make business, and more importantly, of the CSRD Directive that will require companies to publish their ESG report from 2025 onwards. (See more information in PART 1 of this dossier).

"We have drafted our sustainability strategy, together with our main stakeholders (employees, suppliers, academy / NGOs and 3D printing community). In June, this year we launched our first ESG report to show where we are and what we aim for," **Vladimír Víšek**, Sustainability Manager told 3D ADEPT Media.

More specifically, what have they done so far?

First, Prusa Research identified the three cornerstones of its strategy as followed: environment, 3D printing for a better world and fair relations.

At the environmental level, they calculated their carbon footprint taking into account direct emissions (scope 1), indirect emissions from purchased energies (scope 2), and partially indirect emissions (scope 3). In Prusa Research's case, direct emissions include fuel for company cars and refrigerants for air conditioners. Indirect emissions from purchase energies refer to electricity and direct heating supply. Other indirect emissions include purchased supplies and their transportation to Prusa research, transportation of finished products from Prusa Research to customers, investments into Prusa Research tangible assets, business trips, commuting, or home office – and on top of that, water consumption and waste management. The company also acknowledges that so far, they do not have reasonable data to calculate CO2 emissions of 3D printers operated by their customers and to take into account the end of life of their printer– which is fair enough, right?

"Frankly, it was a lot of work – considering and accurately identifying all the materials we use in our production, contacting suppliers and finding out from where and how a given component is delivered to us, keeping track of the energy and water consumption, or making a survey on how our colleagues travel to work," the company says in its report. The carbon footprint was calculated by **CI3** company and independently verified by **Envitrail** company. The calculation is made according to the international GHG protocol and ISO 14064-1.

Prusa Research has also introduced a **digital product passport** – as a way to strengthen their sustainability efforts by designing and manufacturing 3D printers that meet the requirements of the circular economy. To date, the Prusa Product Passport includes the origin of the 3D printer, the carbon footprint of the 3D printer, information on maintenance, repairability, and spare parts, information on upgrades, description of the materials of each part for the purpose of recycling as well as inspiration on how to reuse selected printer parts at the end of their lifespan.

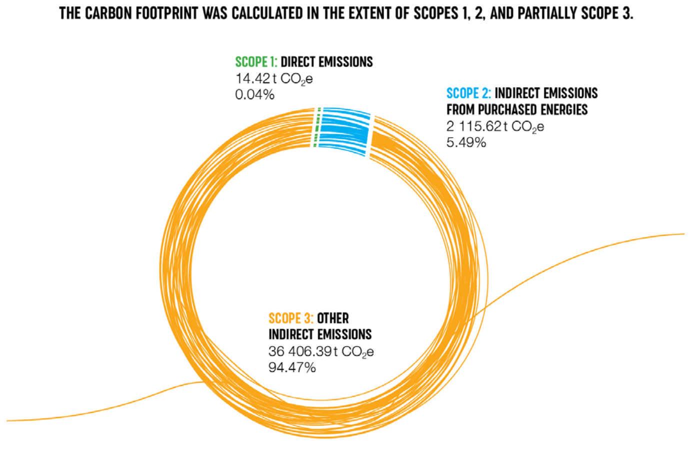


Image: Prusa Research

As said before, the social part of ESG can be interpreted in several ways. One of the actions we will keep from Prusa Research is their **Prusa Education** (Průša pro školy) program designed for all schools, universities, and other educational institutions in the Czech Republic. Launched in September 2020, the program aims to develop 3D printing-related skills in a fun way.

"We donate a free printer to each school that publishes an educational project on 3D printing. These projects are then available free of charge to all other schools. So far we have donated 1,369 printers," the report reads.

As for the G of ESG, the company describes in its report the advantages they provide their employees with to ensure an ideal work-life balance as well as measures they take to ensure a worker safety system above legal standards.

Prusa Research still has a long road ahead. As a matter of fact, their report clearly outlines what are their next plans. And that's something we are willing to follow to share examples of what can be done in the AM industry.

CAN ADDITIVE MANUFACTURING (AM) DELIVER "FAULTY" IMPLICATIONS FOR ITS "GREEN" CREDENTIALS ? (PART 3)

I remember the very first interviews I conducted in the AM industry. As a newcomer, I didn't have enough distance to analyze things. Therefore, I found myself repetitively writing the same sentences, spoken by different people, as if they were the chorus of the same song:

"AM is a sustainable technology by nature.

AM is less expensive than conventional manufacturing technology.

AM can produce parts that were previously impossible to manufacture.

AM can enable decentralized production, thus can be closer to the point of consumption. A shortened and simplified supply chain means a lower environmental impact."

And just like that, we have started building the "green" credentials of AM. Fast forward to today, I question each of these sentences as we are continuously monitoring data that demonstrate how accurate they are. And then, we came to realize that:

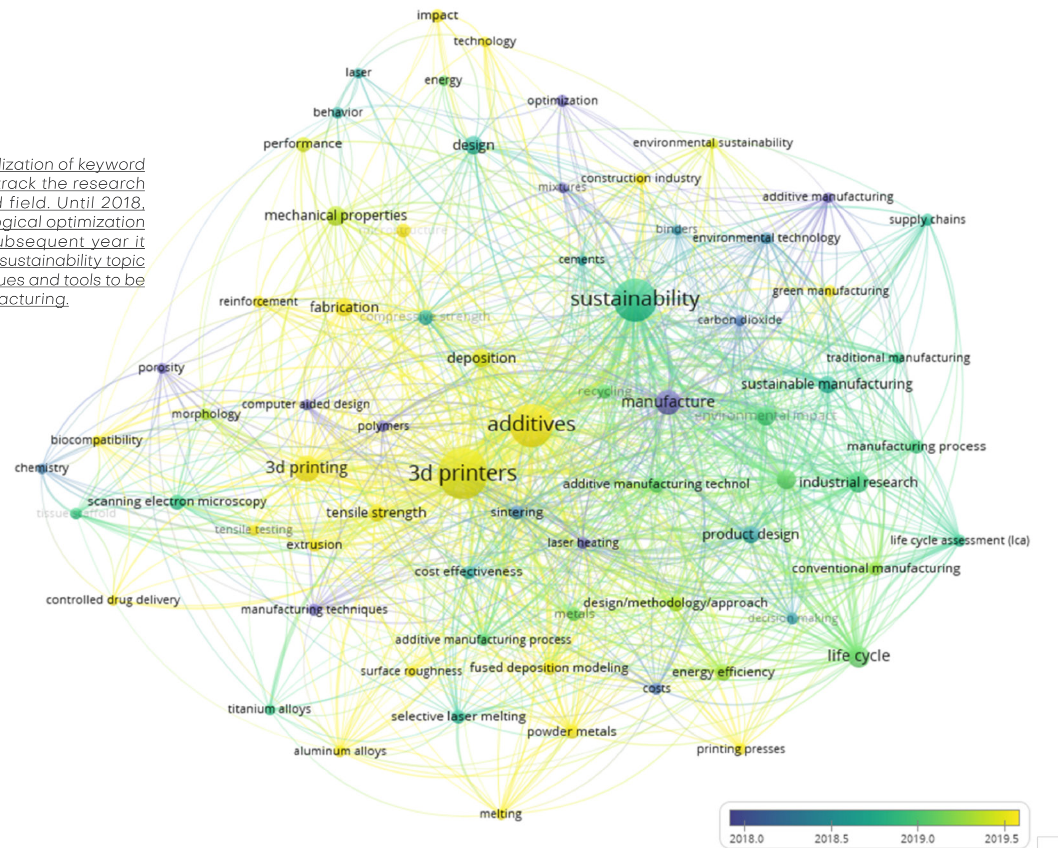
- In a mass production case, the cost of conventional manufacturing remains lower than one-off AM production.

- AM is not necessarily superior to CM processes when it comes to energy consumption.

- When we look at Desktop 3D printers only, users are confronted with the emission of toxic gaseous substances called volatile organic compounds (VOCs) and ultrafine particles (UFP) in the environment.

- Not to mention the fact that, sometimes, supply chains can be complex due to the need for secondary processes and additional supplier requirements.

This list can go on depending on each professional's experience with the technology. **So, should we say that the understanding of sustainability in AM is fairly subjective ?**



This figure shows the overlay visualization of keyword co-occurrence which is useful to track the research temporal trends of the analyzed field. Until 2018, research was focused on technological optimization and cost analysis, while in the subsequent year it evolved towards the environmental sustainability topic and the innovative process techniques and tools to be potentially used in additive manufacturing.

For **Sarah Jordan**, CEO of **Skuld**, *"It is not that it is subjective. It is that it highly depends on one's assumptions which may or may not be stated. The devil is in the details as there isn't just one AM and one conventional process. AM for metal is 25+ processes, and at least that many for polymers and even more for composites or ceramics. Conventional manufacturing is several hundreds of processes and a combination of processes. So, it highly depends on what you are comparing. What material, what process, what transportation, what energy source for the process and transportation is used, how much recycling/reuse in the process all need decided both for the baseline and for the AM option. There is also the risk of greenwashing because one can intentionally make assumptions that benefit AM but harm conventional manufacturing."*

As a metallurgical engineer, she brings a pretty metal-centric input to the table. With over 25 years of experience in conventional metals manufacturing, about 8 years in AM, and after getting her MBA, Jordan has cumulated a decade of experience in forecasting/supply chain/operational excellence. She is currently in the University of Tennessee's Spark Cleantech Accelerator and works as the founder and CEO of **Skuld**, where they are merging casting process (lost foam) with AM by replacing the petroleum-based foam with a biopolymer.

I love Jordan's insights here as she has a very critical thinking mindset and as a metallurgical engineer with experience in AM, she brings that technical expertise of both worlds that is very much needed for this topic. But it is not enough.

It was crucial for us to bring the view of a company that believes in a data-driven, multidisciplinary approach to sustainability and energy management. I found that expertise in **Foresight Management**. **Mike Troupos**, Vice President at **Foresight Management** and his brilliant team of subject matter experts confirm some of our assumptions and pinpoints where the struggle is:

"Sustainability in AM is absolutely subjective. In fact, sustainability across the board struggles with subjectivity. A prime example in the AM industry is recycled content and chemical transparency, both high values in the marketplace. However, these items are opposing. The more recycled content used in a product, the less chemical transparency. This is especially true if you are sourcing post-consumer recycled content. The most significant sustainability advantage of AM is that you have significantly reduced "waste" compared to traditional stamping/CNC manufacturing of metals - adding will inherently be less resource/waste-intensive than subtracting. Economies of scale for AM are generally the biggest drawback. It is simply longer and more expensive to manufacture using AM in most cases, especially at large scale."

The team at **Foresight Management** champions energy management, accelerates sustainability and increases profitability by working with manufacturers and consumer brands that pursue sustainability and energy management initiatives. If you are a regular reader of 3D ADEPT Media, you may have read one of the studies they conducted last year for the AM division of material producer 6K .

Where are we today ?

I can feel the willingness of AM companies that want to explore energy management initiatives, to do better to deliver a product that can legitimately be qualified as sustainable. I see the efforts of organizations like AMGTA that should not be overlooked and in the midst of these efforts, I see a strong reliance on life cycle analysis/life cycle assessments.

If you're new to this area, keep in mind that Life Cycle Assessment (LCA) is a tool that helps to assess potential environmental impacts throughout a product's life cycle, i.e., from natural resource acquisition, via production and use stage to waste management (including disposal and recycling).

To date, it's the only assessment method we have seen AM companies use – which is not bad. The problem is sometimes; we question their accuracy for certain technologies. Remember the conversation Jordan started here. **Do LCAs always help to identify the most extensive variables to compare or maybe the question to ask yourself is – what question are you trying to respond to with an LCA?**

"LCAs are not all equal." one learns from Foresight Management. "Each LCA is built to answer a specific question. An LCA done for a printable powder might help quantify the environmental impact of mining and extraction of materials to make the powder, but not address the impact that product has in replacing other materials downstream. A different LCA for the same printable powder could answer the question of how that powder replaces other products in a specific use phase but leave out other uses.

An LCA can account for the entire product lifecycle, including raw material extraction, transportation (upstream and downstream), manufacturing, product use, and end-of-life. The LCA, practitioner, the product designer, and any industry standards dictate which aspects of the product lifecycle are included in the LCA. Additionally, LCAs don't only quantify GHG intensity (generally, a product carbon footprint, or PCF, is acceptable if you only want to quantify carbon) but also account for water, waste, and other environmental impacts."

That's exactly what Jordan decries here: the fact that even though LCA makes sense, most people do not do a full cradle-to-grave assessment and consider all options. Then, it becomes easy to fall into the trap of blanket statements like *"metal 3D printing is greener than casting."*

"Are they assuming sand casting? How much machining are they assuming? Since I work in lost foam I am highly skeptical of any claim of metal AM being green compared to casting when the powder or wire feedstock is required to be melted twice. Once to make the feedstock and once later to make the AM part. Whereas casting is typically taking scrap*

and melting the material once. I am also skeptical because the vast majority of metal AM parts I see can be cast. Maybe 10% of them are designed such that they must be produced with AM.

**One of the key areas of conventional manufacturing that I am very experienced in is lost foam casting, a type of investment casting that eliminates 95% of the process steps of conventional lost wax investment casting. According to Department of Energy data, lost foam uses 27% less energy, 8% less particulate air emissions, 37% less greenhouse gas emissions, 7% less raw materials, has minimal solid waste. I actually think this data is understated because it has not been updated for process improvements in the past 15-20 years and we know that our yields are typically double conventional sand casting after accounting for the machining losses,"* Jordan adds.

That being said, other assessment methods exist. Apart from LCAs, it's possible to explore **Material Flow Cost Accounting (MFCA)**. This environmental management accounting method allocates costs to material and energy flows through a process, thereby enabling a simultaneous reduction in environmental impacts alongside an improvement in business and economic efficiency.

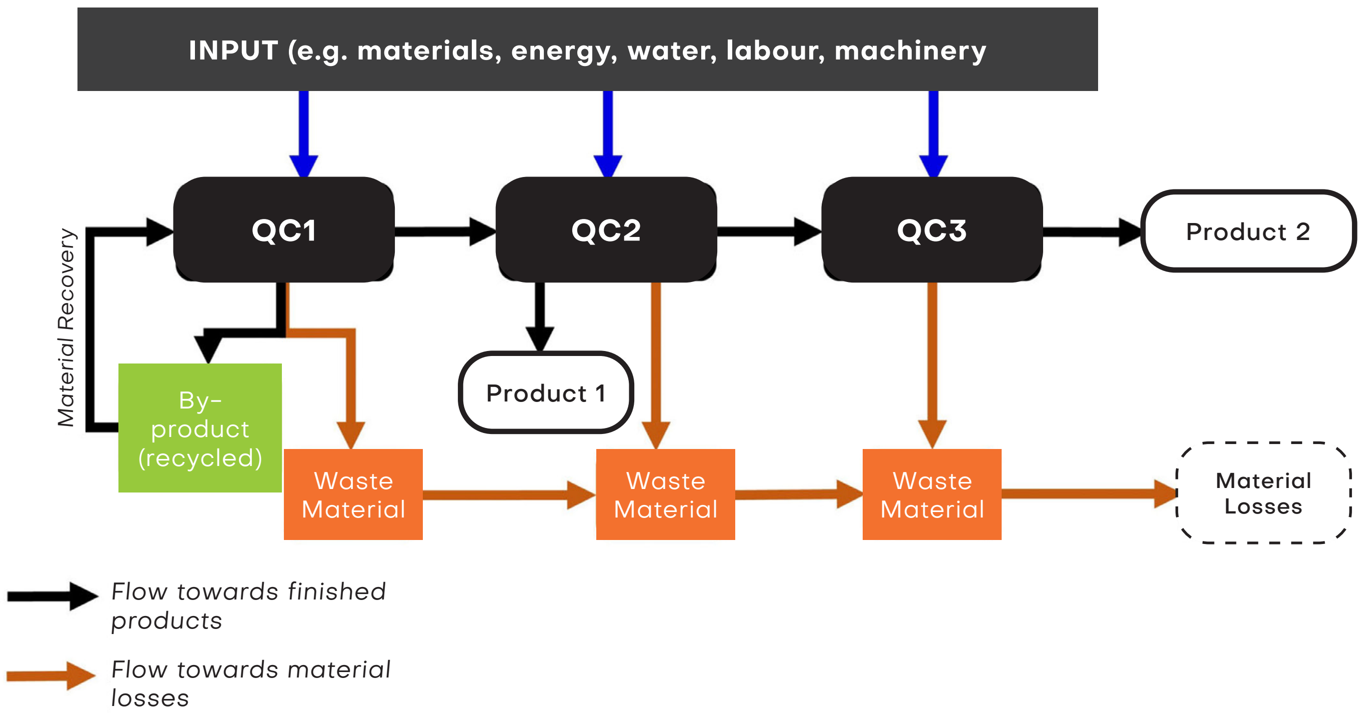


Image: Simplified material flow model for a process with three quantity centres (QC1, QC2 and QC3), one byproduct and two products (Source: Adapted from DIN ISO 14051).

Understanding how this can precisely be applied to AM technologies should constitute the subject of another article.

In the meantime, the subject matter experts from **Foresight Management** remind us that while the LCA modeling framework is the gold standard, it can only be as good as the data entered into the model. The most effective way to improve the accuracy of an LCA is to collect more primary data. Often, a product is modeled with inputs from databases that use industry averages because primary data is lacking. All site/material-specific primary data that is collected makes the findings of the LCA more accurate. This process involves working with your supply chain partners to source their specific data.

On a personal note, in my previous life, I have seen a few trade associations use LCAs as a tool to help their members quantify environmental benefits and improve their designs. Therefore, I do understand that it's not possible for every company to invest in their own LCA models – and this might become another barrier to taking the leap on their sustainability journey.

Concluding thoughts

I will be cautious with my words while trying to answer the question we asked in the title: "Can Additive Manufacturing (AM) deliver "faulty" implications for its "green" credentials?"

After these insights, I can say that AM does not deliver faulty implications for its green credentials but AM companies might, by highlighting the sustainability of their technology in a wrong way. From a strict adoption point of view, we will agree with Jordan when she says "costs, lead time, engineering design capabilities, and supply chain benefits are way more important to most decision makers."

However, for those who would like to become more responsible companies, it's important to keep in mind that the digital transformation of AM comes along with other digitized processes including design, manufacturing logistics and management. According to research, to handle, manage, and extract knowledge from such big data for sustainability considerations, the current manufacturing framework must incorporate a database infrastructure.

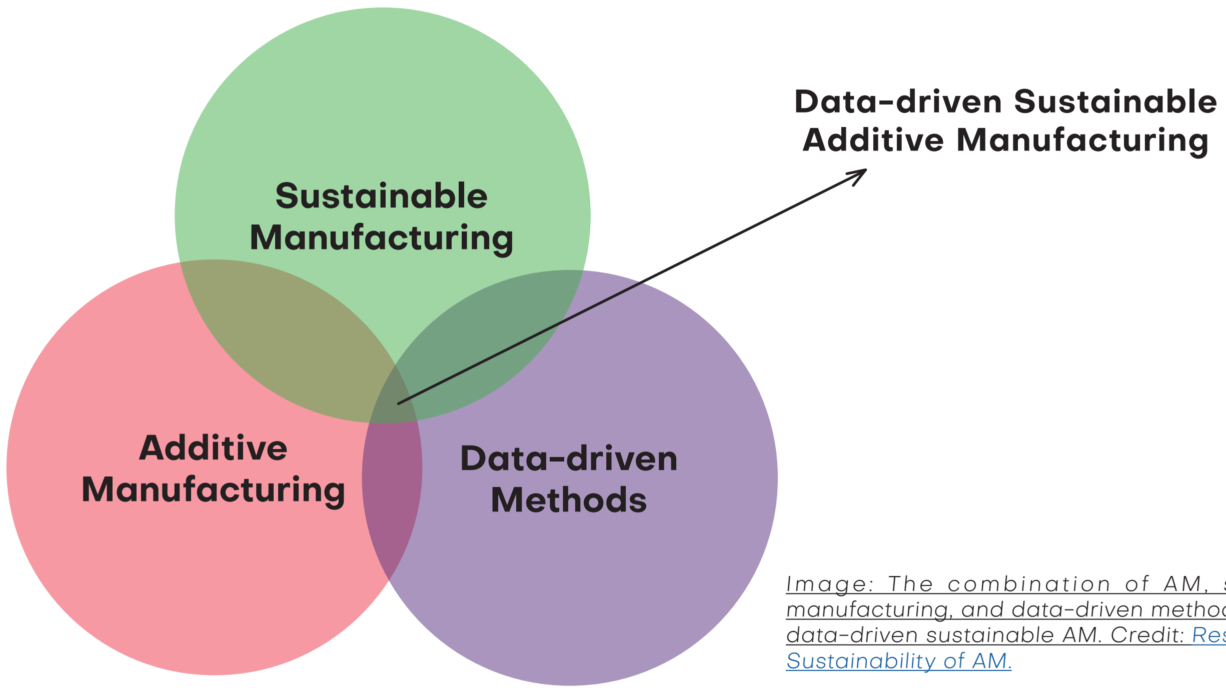


Image: The combination of AM, sustainable manufacturing, and data-driven methods constitutes data-driven sustainable AM. Credit: Research on the Sustainability of AM.

Editor's notes

Skuld is on a mission to get metal parts made in the most environmentally friendly and efficient manner which saves time, money, and the planet. The company's solution includes small-volume custom parts such as for prototypes, rapid emergency replacements, tooling all the way through developing high-volume automotive processes and the equipment to execute processes based on lost foam investment casting and additive manufacturing evaporative casting. The company has a Solar Impulse Foundation certification for its lightweight thin-walled ductile iron solution; the environmental aspect is seen by most as a bonus but not a key factor to adoption.

Foresight's job isn't only to perform an LCA, but to help companies holistically understand how to navigate sustainability across their organizations, buildings, and products at the same time. The main value the company has been pushing is transparency as it allows to improve accuracy and accountability. Foresight also helps industry associations create industry-wide models for their members and create Product Category Rules (PCR) for the industry. Having a PCR ensures there is a standardized approach and provides clarity on assumptions for all products in a given industry. Having industry PCRs increases the data quality across the board and lowers the bar of entry for those pursuing LCAs. The company believes that sustainability can mean increased profitability if you get ahead of the curve.

AM Shapers

Beyond on-demand 3D printing for supply chain with Shell

Eleven years ago, when multinational oil and gas company ***Shell*** *bought its first metal 3D printer, the company only aimed at producing prototype parts for their experimental installations. Fast forward to today, along with fellow companies of the same league, Shell is writing a chapter that could position the oil and gas industry as the fourth major adopter of Additive Manufacturing.* ***Angeline Goh****, 3D Printing Technology Manager at Shell, takes us through a journey rich in lessons, collaborations and hope for the future.*

As you probably already know, healthcare, aerospace and automotive are the major adopters of AM. If AM is continuously opening up new applications across these industries and more, the technology's ability to respond to a billion-dollar problem, at multiple levels can be enough to position the oil and gas industry as another source of growth for the technology. That problem is supply chain uncertainty.

Unused or outdated parts take up storage space, resulting in increased inventory costs. Added to that the inability to identify and track obsolete spares, operational downtime, or safety and regulatory compliance, one may understand why oil and gas industries are riding a costs roller-coaster.

Since Covid-19, AM has emphasized its ability to address these challenges, giving oil and gas companies like Shell the chance to make the most of their resources – in-house, they have powder DED, SLM, SLS, SLA, FDM, Multi-jet fusion across a fleet of about 15 3D printers in Amsterdam and India:

Image credit: Shell

"Today, we are using 3D printing to print obsolete spare parts on demand for our assets; develop novel equipment and rapidly prototype engineering designs. By developing an in-house capability, we want to bridge the gap between 3D printing manufacturers and the energy industry, and also become informed users of the service externally," Goh explains.

While these resources supported the production of medical equipment during the Covid-19 pandemic, and in some development projects like the one conducted with the OEM B.F.E Bonney Forge, Shell does not aim to become a manufacturer. Just like Equinor, the company believes in a new digital inventory ecosystem, whereby it is important that manufacturing of spare parts for their asset is done locally as much as possible, leveraging qualified 3rd party local service providers to provide true lead time reduction and sustainability gains. As such, they only use their facilities for internal R&D and asset support projects.

Angeline Goh, 3D Printing Technology Manager at Shell

Key areas of interest and collaborations

"There isn't a typical day at work for us in the 3D Printing [unit] when it comes to R&D alongside asset support, but there are 5 broad categories of work that keep me busy, and the allocation of time to the categories may vary from day to day," Goh said before listing:

- R&D work on novel designs or applications. These are projects aimed at achieving longer term objectives of AM applications to create business value for our company. Some of these are multi-year programs, such as the development we started on the 3D printed pressure vessel for 3rd party certification. It's about addressing a problem worth solving and evaluating over the course of milestones set for the project if the hypothesis holds and we are able to make the breakthrough needed.

- Asset support work can come from any part of the world and could include a simple visualization for an engineering solution, to help with an emergency requirement of an obsolete spare part. Work requests from the assets need constant prioritization due to the potential impact they can have on the asset's production.

- *Knowledge Management & Transfer – I prepare materials for workshops, and webinars, and am involved in the 3DP network calls internally to upskill our engineers.*

- The Joint Industry collaboration work for the digital inventory *with partner operators is underway too and is an exciting piece of development.*

- *Technical Assurance work – reviewing new internal guidelines and preparing technical documentation & papers on the technology."*

Needless to say, the challenges may differ from one project to another, but one common thread in their job is that given the high standards of the energy industry for health, safety and environmental concerns, the introduction of any new technology needs to be thoroughly proven by robust and comprehensive testing and adequate data points.

Taking the example of the work they are doing with **Kongsberg Ferrotech, Equinor, SINTEF, and Gassco**, to develop 3D printing technologies for subsea equipment repair and maintenance, she explains:

"This is certainly a challenge for example, when there are no AM standards for hyperbaric and mobile applications.

The team has to harmonize applicable standards for the scope of repair, and we are working in close collaboration with vendors, operating companies and the class societies to achieve that. In this process of introducing AM-based subsea repair, it is important to identify and manage the risks as we go about engaging our

Image credit: Shell

assets that are candidates as pathfinders. In this way, we then build confidence in the whole value chain. A comprehensive qualification program with participation from the inventor and manufacturer to the first user asset is required to demonstrate the quality and value of subsea AM repairs."

In this vein, in Goh's view, enhancing quality management would drastically improve the way we source 3D-printed spare parts across the industry but not only. Improved lead time, costs and acceptance for AM also require a focus on **data** and **people**.

As far as data are concerned, *"improvement leveraging online quality monitoring data for defect detection and quality control that reduces the amount of post-manufacturing testing" should be a key area of focus for the industry as it "is important to achieve higher-right-first time prints and reduce overall lead time and cost of the technology."*

Furthermore, I like the idea that Goh puts people at the heart of change. Let's be honest. Transformation is notorious for its pitfalls and challenges – but perhaps the most common mistake organizations often make is neglecting the so-called *"soft side"* of change. Goh sees the importance of focusing on people – and collaborations in particular, with end-users *"to upskill the community on knowledge of the technology, to build trust in the technology, as well as manage the changes in work processes related to [its adoption]."*

"Similarly, there are advocates for digital inventory in the supplier companies that are original equipment manufacturers. However, even these advocates need support to transform their organizations to the new ways of supplying. Strategy and processes will have to change, and these require effort and attention to be implemented effectively," she adds.

Can AM divisions of oil and gas companies do their part in this sustainability journey?

The oil and gas industry is facing increasing demands to clarify the implications of energy transitions for their operations and business models, and to explain the contributions that they can make to reducing greenhouse gas emissions and to achieving the goals of the Paris Agreement.

The increasing social and environmental pressures on many oil and gas companies raise complex questions about the role of these fuels in a changing energy economy, and the position of these companies in the societies in which they operate.

While improving the sustainability of its operations is a multi-faceted ambition, Goh reaffirms that Shell is pursuing both immediate and long-term opportunities to mitigate the impacts their operations have on people and the environments they operate in.

While the company's ESG and sustainability journey is a topic that goes beyond her scope of expertise, she remains hopeful on what AM can do – especially when it comes to going beyond the development of novel designs to reduce the emission of operations and the local on-demand spare parts production:

"More can be achieved in improving repeatability and reducing the variation of printer quality, in the development of secure and autonomous transfer of data to remote printers for manufacturing and availability of AM specific datasheet for a wider range of material used by our industry to facilitate on-demand, local manufacturing."

"Beyond the technical scope, the community can help propel growth in the adoption of the technology by sharing success stories as well as lessons learned on AM applications. There are various platforms for exchanging knowledge and experiences and I am certainly participating in a number of them and hope to see these forums grow. An example of AM community coming together to share experiences and inspire others is a book that I've read and found helpful. It is called the AM Change Management Guide and is published by the Mobility Goes Additive Group (MGA). There is a lot of effort still needed to develop new guidelines and standards requiring contributions from all partners in the AM ecosystem. Published standards would support the development of legislation to support the AM adoption," she concludes.

Image credit: Shell

AM Shapers

BEYOND LPBF : HONEYWELL ON FINDING THE RIGHT OPPORTUNITY WITH ADDITIVE MANUFACTURING

Courtesy of Honeywell Aerospace. RE220 commercial APU with the additive exhaust duct front and Center.

With a decade of experience in Additive Manufacturing (AM), Honeywell has built a solid reputation as a major developer of commercial aerospace applications enabled by metal AM. Today, the company continues to explore new avenues of technology for its field of activity. Brian Baughman and Curtis Swift took fifty minutes off their busy schedule to walk me through these avenues. They also shared what they find the most challenging in their adoption of AM and how the industrial conglomerate is ready to continue winning billions in this business.

Honeywell may have dedicated facilities in five countries, but the true magic happens in their Phoenix Additive Manufacturing Center. If every year brings its share of joy and lessons, Baughman drew our attention to 5 important dates that have been pivotal in Honeywell's AM journey.

2008: Like many fellow aerospace companies, Honeywell started investigating the potential of AM through prototyping applications.

"Our goal was to learn about AM, what it could do and what it could not do," Baughman said. These years saw the development of prototype parts produced in collaboration with external vendors. These years were decisive as they also helped the team understand the economics of the technology and what applications it should tap into to make the most of the technology.

2014 marked the purchase of their first laser powder bed fusion machines– which have remained the primary AM process of the company so far. The purchase comes along with the opening of their AM facility in Phoenix.

2015 saw the completion of the first functional metal 3D printed part.

2016 saw the expansion of that AM facility with an aluminum 3D printing laboratory in Phoenix. As you will see in the "Materials segment" of this edition of 3D ADEPT Mag **(pp 30-33)**, aluminum is a preferred metal for aerospace parts due to its lightweight and anticorrosive qualities.

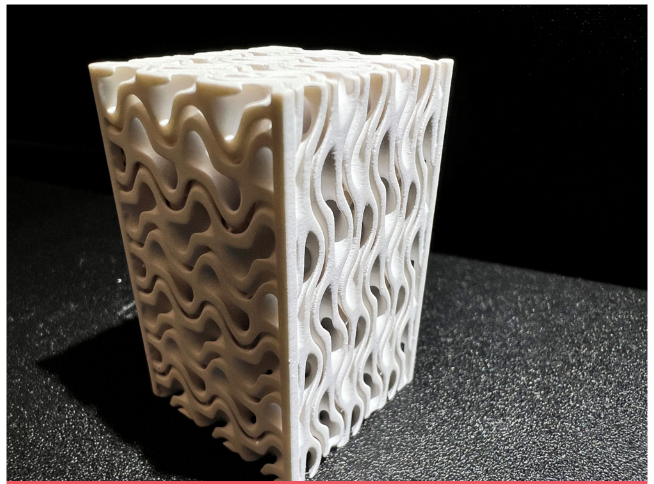
2018 saw the completion of production applications for specific use cases.

The rationale behind the choice of AM technologies

Not surprisingly, laser powder bed fusion technology is the primary AM technology of Honeywell but the company makes use of other technologies like DED, Electron Beam Melting and polymer 3D printing technologies. The main reasons that justify the focus on LPBF are the ability to achieve production-scale manufacturing and consistency in material properties. Baughman explains while making a short comparison with DED – a technology that I believe is also quite advanced for aerospace parts, and for which he had first been hired:

"At the Phoenix metal AM Facility, laser powder bed fusion is the primary focus. We use other technologies like DED but not as extensively as LPBF. The reason for that is that DED is a hard process to control when you're building up different geometric features. And you tend to have different grain sizes in these features which translate to different material properties. And that's not great for aerospace. The consistency aerospace requires at the material properties level can more easily be achieved with LPBF. That being said, in our repair business, DED is used to repair the impellers on our engines."

As for polymer 3D printing, *"we don't have any production parts made in plastics,"* Swift acknowledges. *"polymer 3D printing is used to support the design of next-generation cockpits, fixtures and testing. When you work in AM, it's easy to assume that everyone knows about AM but that's not always the case. Polymer 3D printing is one of these technologies that can help you raise awareness on the potential of AM – whether it is for a customer need or a life sciences project that is not directly related to commercial aerospace applications."*



Ceramic gyroid 3D printed part. Courtesy of Honeywell Aerospace.

In addition to these technologies, Honeywell representatives pleasantly surprised me when they said one of the technologies they are currently exploring right now is ceramic 3D printing. If you remember, during the first quarter of the year, we discussed in one of the first editions of 3D ADEPT Mag if ceramic AM can add value to the automotive and aerospace industries. One thing we realized is that the challenges and opportunities are reflected at the materials level, and when it comes to the *"High Value vs High Volume"* decision. Indeed, the difficulty that comes with creating dense ceramic materials may often limit the applications in this sector to the exploration stage.

"Honeywell uses ceramic 3D printing to create molds for casting. The technology is designed for a specific process.It allows us to cast turbine blades that have extremely accurate dimensions and features," Swift explains.

"We focus on making hot section turbine components," Baughman emphasizes. While he didn't mention what type of ceramic 3D printing they use specifically, he did say the technology had already helped them achieve better efficiency for the production of engine-quality single crystal castings for a blade. *"When you perform the casting with a traditional process, it takes about two years to make the tooling and about a million dollars per blade mold. With ceramic 3D printing, we were able to shorten that time to 6 weeks. To achieve that, we spent a lot of time developing our ceramic materials to make them stable so that they would work seamlessly with the casting process."*

"We're at the forefront of the ceramic 3D printing technology. I don't know another company that does better than us," Swift adds.

Overall, one learns with our subject matter experts that the team at Honeywell has been able to find the right opportunity for tooling, production parts, and obsolete parts. Given the number of examples mentioned during our conversation, our guess is that an important ROI lies in the fabrication of production parts.

Challenges across the adoption journey

Among the many things I can learn from adopters of AM technologies, I am often keen to discover what they consider the most challenging in their learning curve. Responses obviously vary from one another, but they eventually often help AM technology providers know what they can

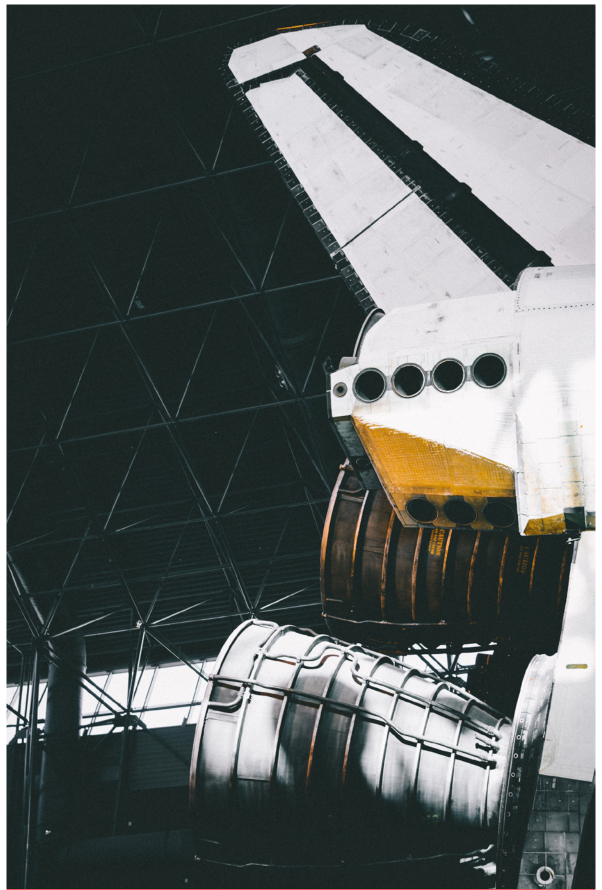


Image: white rocket ship inside warehouse do better in the way they develop their solutions.

In Honeywell's case, I came to realize one thing: challenges are also inherent to individuals. In Swift's view, *"3D printing is the easy part. Post-processing is very difficult. Getting a part through to production is lengthy. It's longer than what people think. But in the midst of all of that, I would say the biggest challenge for me is not having a full library of material properties. As Brian mentioned to me a long time ago, there is an entire library of material properties when you look at casting for traditional processes. In comparison, you only have a couple of boxes with AM. Trying to compete with that difference in material characterization is very difficult."*

For Baughman, this lack of a library of material properties is one of the top three challenges he encountered. *"The qualification aspect of AM is also a big challenge. With so many regulatory bodies in the aerospace industry, we have to be able to make products that everyone is comfortable with."* For a given production part, approval must first be made internally, then by the customer and thereafter by the FAA which will certify the part meets the desired criteria.

Baughman also mentioned the cost of the process in this top three. When one compares the traditional manufacturing of a single part vs. its production via AM, AM remains expensive. *"There are so many people who want to use AM but the key in using the technology today is not just about finding the right combination between qualification, process and costs; it's about finding the right opportunity".*

With these two challenges, the Chief Engineer brings to the table two considerations previously discussed by Boeing VP of AM, Melissa Orme. As far as qualification is concerned, we have shared our lessons on how to approach it in the July/August edition of 3D ADEPT Mag. As for the costs, there are a number of tips AM providers have already shared to address the cost consideration, but that's something we will discuss in another article.

Concluding thoughts

Aerospace might be a major adopter of AM but its progress remains slow for obvious reasons – strict regulations but also materials. Swift opened my eyes to the importance of understanding how the material will perform to be efficient in one's production and this takes a lot of time.

Furthermore, the rationale behind the choice of every AM and the challenges across the adoption journey might be the main points discussed here but it should be noted that Honeywell has created opportunities across several other crucial areas: enabling supply chain transformation with AM is one that I would like you to keep in mind as the need for flexible supply chains became more pressing with the Covid-19 pandemic.

In the end, no matter what those other areas are, keep in mind Baughman's strategic thinking if you work in the aerospace industry: your opportunity lies in the right combination of qualification, process and costs.

Editor's notes:

Both Swift and Baughman work with Honeywell Aerospace, in the Additive Manufacturing Technology Center located in Phoenix, AZ. Swift is the Senior Additive Manufacturing Engineer whereas Baughman is the Chief Engineer in the AM technology center. Swift started his career in the automotive industry, working with active and passive safety systems, before switching to a Design Engineer role in avionics, as well as plastic 3D printing with the Honeywell Deer Valley location, and is now a Manufacturing Engineer for LPBF Metal 3D printing. Baughman, that I first discovered as the co-author of "Additive Manufacturing of Metals: The Technology, Materials, Design and Production (Springer Series in Advanced Manufacturing)", held several roles of increasing responsibility in the Aftermarket Repair and Overhaul, Materials and Process Engineering, and Advanced Manufacturing Engineering groups. In a recent role, he was the Manager of Phoenix AM facility, ensuring the prototyping and production applications with AM. His work consists in introducing manufacturing technologies into the company's manufacturing value chain.

Materials

DRIVING CIRCULAR PLASTICS ECONOMY IN ADDITIVE MANUFACTURING

We have grown up in an environment where plastic, once used, is considered waste. This burden has prevented generations of consumers and industries from capturing the economic benefits of plastic. With Additive Manufacturing and circular economy at the top of Europe's agenda, waste that was considered a burden before has now turned into gold. The only thing is that it's up to each company to find the right way to make it glitter. We asked difficult questions to Evonik's Dominic Störkle to understand their strategy.

Why specialty chemicals company **Evonik**, you may ask? Because I strongly believe that a circular economy strategy for 3D printed plastics starts with **material**. More importantly, material producers have the right expertise and can leverage the right resources to put in place a circular economy or a system that avoids waste and limits resource consumption by recirculating existing materials. Such circularity would mean recapturing and reusing existing polymers when and where possible, as well as controlling or restricting the development of new, virgin materials made from non-renewable fossil fuels.

To do so, material producers have to understand the specific market they operate in. Indeed, each material producer will have unique objectives when it comes to circular economy.

The article below aims to help you understand:

- The specifications and the challenges for a material producer operating in the AM industry
- The decisions made at the manufacturing level to produce 3D printing materials with circular economy in mind
- Where Evonik is in its sustainability journey

The specifications and the challenges for a material producer operating in the AM industry

The mindset around plastic waste pollution is usually one of the first barriers to companies dealing with plastics. Interestingly, this mindset is not really the problem in the AM industry because the technology itself has cultivated **an attitude towards recycling materials.** One of the first challenges, according to Evonik will be to determine how to materialise this know-how.

"There are good examples already of well-working recycling concepts like in the case of PET bottles. In the next step which is already ongoing, we have to transfer this know-how to other application areas in order to circulate high volumes and thus improve the economics of plastic recycling. The plastics industry understands the need to force innovation in mechanical recycling but also in chemical recycling technologies," **Dominic Störkle**, Head of Additive Manufacturing Innovation Growth Field at Evonik explains from the outset.

Despite this good attitude from the AM industry, recycling rates remain small across industries in general. In Europe for instance, which tends to take the lead on environmental issues, the recycling rate is about **32.5 wt%*** (Plastics, 2019) in general. To increase this recycling rate, Störkle calls on legislation:

"Legislation will play an important role in driving circular plastics economy like, for instance, the EU's directive on end-of-life vehicles, which will trigger significant demand for recycled materials from the industry. In this regard, EU legislation on recycled content target in automotive is looking at 25% recycled content in the near future. This target is also supported by the Plastics Europe Association.

Dominic Störkle, Head of Additive Manufacturing Innovation Growth Field at Evonik

Application Technology-INFINAM PA Polyamide 12 Powders - Evonik

Driving circularity for special polymers such as polyamide 12 requires close collaboration across the entire value chain to find out the right concepts. As a market leader for PA12 materials, we are at the right point of contact for key market players to get this started."

That being said, one needs to recognize that improving global recycling rates can also be challenging because of **poorly functioning markets.** Indeed, the raw feedstocks for most plastics remain fossil fuels, which are currently cheaper to use than recycled materials. The question then, is to know how far you are willing to go to propose an alternative that is more environment-friendly.

Answering this question will help AM users understand the decisions you made at the manufacturing level to produce materials.

Producing 3D printing materials with circular economy in mind

Traditionally, the philosophy of the circular economy has been structured around the **3Rs: reduce, reuse, and recycle**. As someone who is well familiar with organizations providing ESG services, I know it's more than that because each company tackling this topic defines its own terminology. Evonik is no exception.

"In our terminology, reusability of materials refers to the refresh rates over several printing cycles, defined by the replacement of just the powder that was used to form the part created during the previous job. In this regard, our PA12 grades exhibit the market's best reusability rates while evidencing high surface quality and stable mechanical properties of 3D printed parts over several printing cycles. When it comes to recycling, 3D printing is a great technology because it enables a toolless design for recycling of highly complex parts and structures that are manufactured next using only one type of material. These practices help bring end-of-life parts into a second life cycle, creating an optimized closed-loop ecosystem," the Head of AM explains.

So, **how do we define a strategy that aims to reduce plastic waste and greenhouse gas emissions in the plastic value chain while delivering market returns?**

That's a tough question even for the most experienced experts – because of the versatile use of plastics. Some of us may use 3D printing plastic materials for implants that enhance the quality of life of millions of patients worldwide, while others leverage them for high-performance applications in the automotive industry. And these materials will continue improving so many aspects of our lives in the future.

"That's why today's shift from a linear to a circular plastics economy is crucial to safeguarding the

INFINAM Polymer powders-Evonik

quality of life for next generations," Störkle adds, before attempting to respond to the question: *"Establishing an efficient circular economy, however, is a complex thing: every single step in the production cycle must be re-evaluated, supply chains must be reorganized, sustainable materials like* ***our footprint reduced PA12*** *with a high reusability rate are needed and eventually new way of parts design is necessary. For material producers like Evonik, living circularity might not be so self-evident for everyone. However, the more aware and transparent the sustainable journey becomes at the beginning of the additive value chain, the more impact these effects will have in the final application. Yet material manufacturers bear a great responsibility here because the sustainable result of an application stands or falls with the sustainable performance of the materials used."*

In this vein, Störkle agreed with us: moving away from fossil resources is a must and this can be done in several ways. For Evonik, this means acknowledging the importance of biobased raw materials in sustainable manufacturing.

"An unreflected use of biobased raw materials as a more sustainable choice for so-called eco-friendly manufacturing is changing at the moment. Fact-based decisions should be made. There are other biobased raw material alternatives available on the market today like bio-circular oils or rapeseed oil grown in closer proximity to our production site. Transparency is key," the expert points out.

More than cutting CO2 emissions, it's about determining *"a holistic analysis that includes other important factors, such as water consumption or land use along improved overall eco-balances. Evonik drives the circular plastics economy by contributing to both footprint and handprint values. Alongside factors such as production efficiency or the reusability of materials, our circularity approach includes the total life cycle assessments of our materials and their consistent improvement. We look not only at carbon footprint as well as other important factors such as water consumption and land use. Through the use of renewable energy sources and renewable or recycled feedstocks for production, we are significantly improving the overall eco-balance of our materials. Looking ahead, we are working on end-of-life opportunities for our polymers,"* he adds.

Where is the company headed ?

As the first tangible and publicly announced step to back words with action in the AM industry, Evonik introduced a **new grade of PA12 powders with significantly reduced CO2 emissions**. We caught up with the company at Formnext 2022 to learn more about the cornerstones of their sustainable manufacturing approach (carbon footprint, saving fossil resources, reusability rate and recycling). While other releases have marked this year, we were keen to discover what specific progress has been made in their sustainability journey. **Störkle's** response did not disappoint:

"Since introducing our carbon-footprint-reduced PA12 materials for powder bed fusion 3D printing technologies last year, we have been developing an ***eCO grade of our nylon powders that is aligned with Evonik's mass-balanced approach****. At this year's Formnext trade show, we will be launching a new PA12 grade that exhibits the highest circular benefits available on the market for additive manufacturing today.*

The product will be called ***INFINAM® eCO****, and it will be the world's first PA12 powder material for 3D printing that substitutes 100 percent of fossil feedstock with bio-circular raw material from waste cooking oil in a mass balancing process. By using 100 percent renewable energy for production, the new ready-to-use PA12 powder features a carbon footprint reduction of 74% – in comparison to our castor seed oil-based INFINAM® Terra grade. Furthermore, INFINAM® eCO will offer the market's best reusability rate to eliminate production waste even further. It can be reused over several cycles by only replacing the powder needed to form the part created during the previous job."*

What's next, you might wonder?

The growing need for environmentally friendly manufacturing has emphasized the need for assessments like LCAs that demonstrate the environmental impact of one's technology. Evonik is aware of that and strongly believes that true circularity leads to a successful business.

"As a pioneer for polymer-based 3D printing materials, we will follow our formula for our PA12 powders to drive circular plastics economy in additive manufacturing by improving the efficiency of our production processes and the overall improved of eco-balances of our materials," **Störkle** comments.

As the company is currently exploring new end-of-life opportunities for its polyamide 12 powders, we hope to share their progress in the next edition of 3D ADEPT Mag which focuses on sustainability.

"We are always on the lookout for companies to collaborate with in the field of additive manufacturing in order to establish material collection schemes and promote the reuse of polymers," **Störkle** concludes.

This content has been produced in collaboration with Evonik.

Materials

THE USE OF ALUMINUM IN ADDITIVE MANUFACTURING: CHALLENGES AND OPPORTUNITIES

Metal Additive Manufacturing applications are filled with examples that involve the use of titanium, inconel and recently, pure copper. As we are exploring the next phase of growth of this segment, we need to consider aluminum and aluminum alloys as the range of materials AM users can capitalize on. The only thing is that the benefits one can get by processing aluminum alloys with AM are underrated, even overlooked and the weird part of it, is that I understand why.

It's been centuries that aluminum and aluminum alloys have been serving the needs of industries such as aerospace, automotive or packaging, due to their mechanical properties: high strength-to-weight ratio, malleability, electrical conductivity, corrosion resistance and recyclability. The processing of these materials has long been associated with conventional manufacturing processes such as casting, sheet metal forming or machining.

"There are excellent options for making high-performance aluminum parts. For example, aluminum alloys can be machined much more readily than other metals (titanium, stainless steels…). We can cast aluminum into complex shapes, we can form sheets into beverage cans or automotive body panels. Many assembling processes exist (welding, brazing, mechanical assembly, adhesive bonding… And of course, aluminum is infinitely recyclable. This is why aluminum is the material of choice in many packaging and transportation applications, particularly when light weight and/or recycling are the drivers," Alireza ARBAB, Head of Additive Manufacturing at Constellium told 3D ADEPT Media.

Furthermore, when we look at costs, aluminum is less costly than copper, stainless steel, titanium, and other metals – even if its raw form tends to cost more than the common grades of low-carbon steel and low-alloy steel.

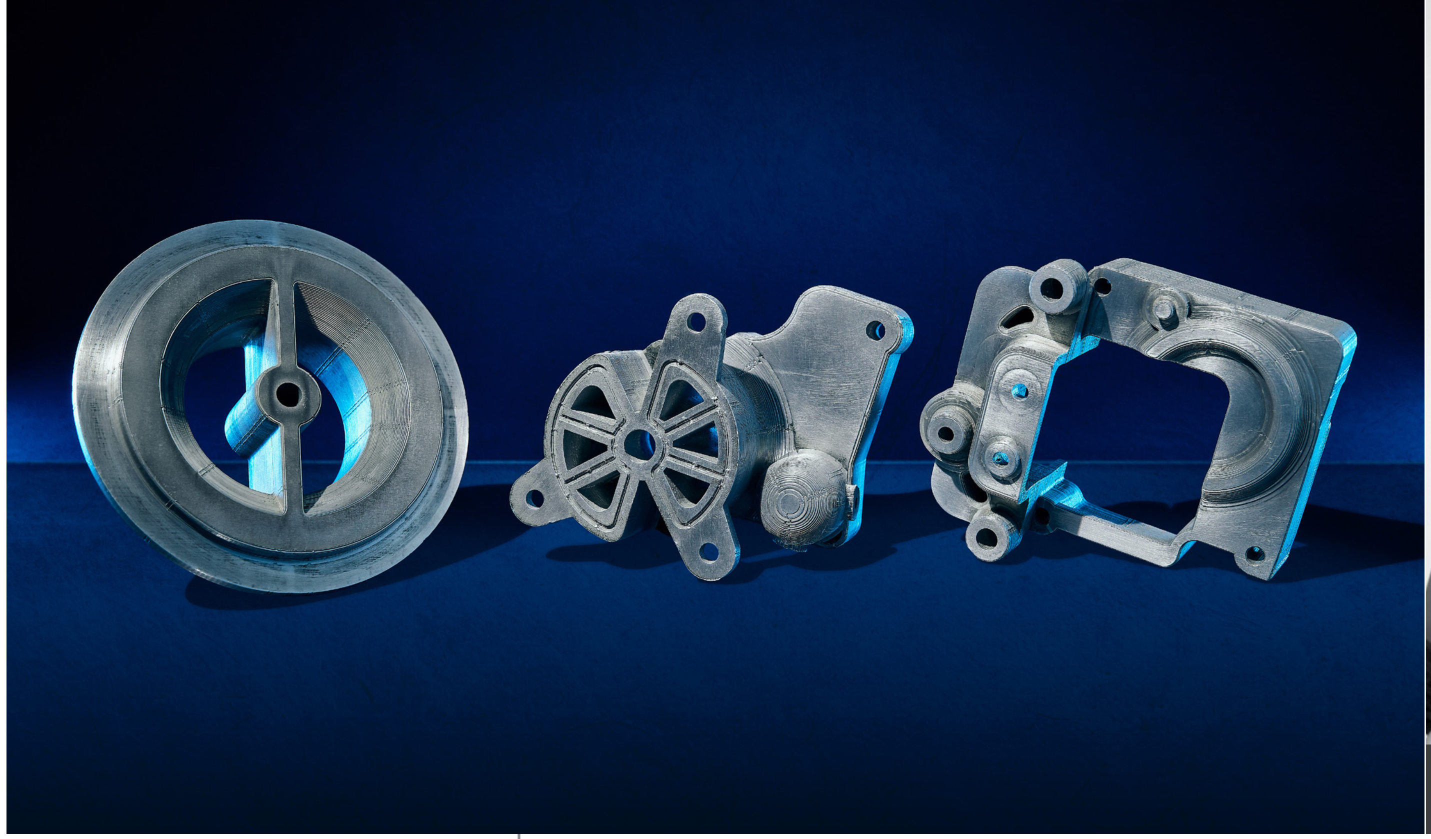
These favorable properties and these cost considerations have raised the interest of AM users and AM solutions providers that have started exploring how they could combine these advantages with the ones of AM, providing this way another manufacturing option to vertical industries adopting AM.

The article below aims to understand the opportunities and challenges of aluminum AM. To do so, it will highlight:

- First, aluminum or aluminum alloys?
- The different AM technologies that can process aluminum: key focus on LPBF and a manufacturing process specifically designed for aluminum components
- The AM applications that will drive the use of aluminum alloys across the metal AM segment
- And the considerations that one should take into account to explore a sustainability route.

1 -First, aluminum or aluminum alloys ?

If you're new in the materials industry, one question that may legitimately come to your mind is: why are aluminum alloys used rather than pure aluminum? The answer obviously varies from one application to another, but it should be noted that for most industrial applications, pure aluminum is often reported to be **expensive, too soft and weak** to act as a structural material – despite its many winning properties.



Alison Forsyth - CEO of Alloy Enterprises

To the best of our knowledge, USA-based Elementum3D and Germany-based m4p (metals 4 printing) are two material producers that have been able to develop pure aluminum powders for L-PBF.

"Aluminum is almost always alloyed and heat-treated or work-hardened to increase strength. The alloy depends on the application. Casting and PBF both require melting and flow, as such they commonly have high levels of silicon and the resulting parts are prone to porosity. This reduces the strength of the parts. Alloy's Sheet Forging process does not require melting or flow, and as a result a wider array of aluminum alloys is possible and porosity is not an issue. Our first alloy is 6061 - fully dense," Alison Forsyth, CEO of Alloy Enterprises explains.

Moreover, it can be alloyed with many other elements to overcome its low strength. According to Arbab, aluminum can be combined with elements such as Magnesium, Zinc, Copper, Silicon, Manganese, to name a few. The key is to be able to design the right aluminium alloys for different markets and production processes.

2- The different AM technologies that can process aluminum and aluminum alloys

Among the wide range of AM processes that are available on the market, this may come as no surprise to you to read that powder-bed fusion (PBF) is the most-widely used process for aluminum. Other processes include WAAM, binder jetting, DED, EBAM and Kinetic. Each of these technologies can process a specific type of aluminum alloys.

Alireza ARBAB, Head of Additive Manufacturing at Constellium

Compared to other metals, the high reflectivity towards the typical fibre laser wavelength, the high thermal conductivity and tendency to crack during solidification are items that make it difficult to process aluminum with a laser beam process. That's why conventional casting alloys such as AlSi10Mg and AlSi12 have been mainly used for LPBF. They are relatively easy to process compared to high-strength Al alloys.

Among the aforementioned processes, Laser Beam Powder Bed Fusion (LPBF) and Directed Energy Deposition (DED) can use a laser beam - the latter of which can use powder or wire as a feedstock.

Let's focus for a few minutes on laser powder-bed fusion.

Constellium's Head of AM told 3D ADEPT Media that *"the many alloys developed for existing applications are not optimized for production using AM technologies, in particular Laser Powder Bed Fusion (LPBF)."* For the expert, a look at the big picture is necessary to understand the full process - from powder management to the final parts, including printing, post-processing and quality control - and the areas that may require specific points of interest.

"Our Aheadd® CP1 alloy [a material specifically designed for AM] uses the advantage of the extremely rapid solidification rate of LPBF allowing Constellium to use specific alloy design rules to create a much better solution. As an example, CP1 contains 1% of iron as a key alloying element. In most aluminum alloys, iron alloy is limited as impurity", he points out.

On another note, in addition to high reflectivity and low laser absorption that may result in defects, the properties of certain aluminum alloys may also result in defects like **porosity, cracks, poor surface finish, shrinkage, oxidation and residual stress**.

Furthermore, each 3D printer comes with a set of unique parameters. This means that an issue observed in machine X may not necessarily be the same as the issue observed in machine Y.

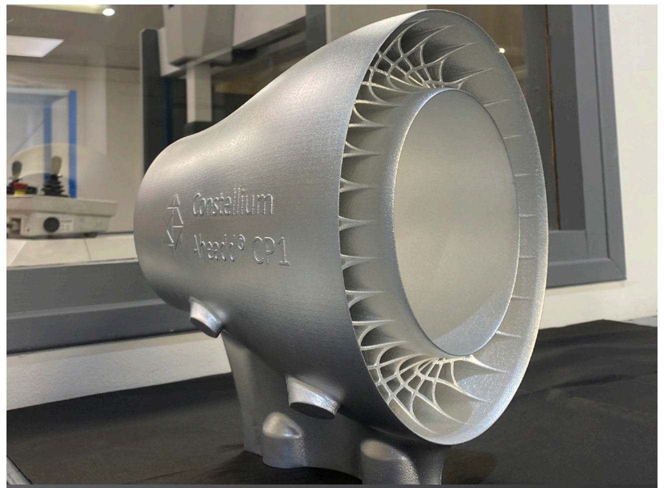
Among the solutions that can be explored to overcome these defects, one notes the **use of additives, laser power, scanning and powder drying.**

Researchers from the Norwegian University of Science and Technology explain in a research that the category "additives" refers to solutions that include the addition of additives to the Al alloy powder or new alloys. This means that alloy blends can be created to enhance the desired properties. Laser power refers to solutions where it is proposed to either increase or decrease the laser power. This is often combined with other solutions such as changing the scanning speed. The category scanning includes solutions, where the scan parameters are changed, such as changing the scan speed or performing a double scan. With powder drying, it is possible to pre-dry the Al alloy powder before melting the powder.

What if we consider a process specifically designed for aluminum parts ?

Alison Forsyth opened our eyes to a new way to fabricate aluminum parts and materials using high-speed manufacturing. For Forsyth, aluminum is different from other metals because it *"forms a robust oxide layer in milliseconds. This makes it difficult to bond or print, particularly in processes with a high surface area-to-volume ratio which maximizes the amount of oxide. Alloy's Sheet Forging process has been designed to overcome this challenge."*

Speaking of their Sheet Forging process, she explained that *"Alloy Enterprises is transforming how aluminum components are made. Alloy manufactures fully dense aluminum components, enabling customers to scale from prototype to production. Unlike powder-based additive manufacturing processes, Alloy's Sheet Forging process is high-throughput and produces components with superior material properties. The process starts with digitally slicing the 3D component into discrete layers. The layers are then laser-cut from Alloy's custom feedstock and an inhibiting agent is selectively applied to create in-situ supports. The full stack of registered sheets is then diffusion-bonded together. Finally, the parts are removed from the block and heat-treated. Alloy's process provides the flexibility of wrought material properties and the geometric complexity of additive manufacturing to produce lightweight components with optimal strength, durability,*



3D printed heat exchanger produced with Constellium's Aheadd CP1. Image, Courtesy of Volum-E. Shared by Constellium.

and thermal conductivity."

We are not aware of any limitations of the process yet, but if it works well, this process could yield a significant speed advantage over LBPF as it does not need to move point by point through the entire area.

3 - The AM applications that will drive the use of aluminum alloys

Among the vertical industries mentioned above, one industry that may see the increasing use of aluminum alloys is the EV industry. The more EVs will be developed, the more OEMs in this sector will need strong, lightweight materials such as aluminum.

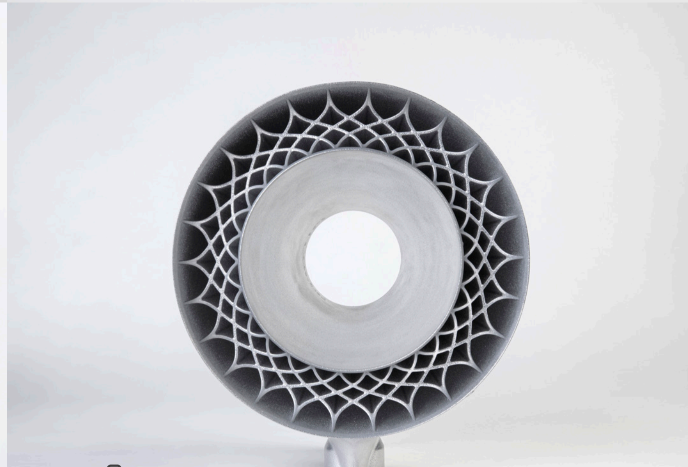
According to Alloy Enterprises's CEO, aluminum will be part of the electrification journey of everything that moves, and flexible on-demand cost-competitive fabrication will be essential to this transition. Speaking of their Sheet Forging process especially, she explains: *"Automotive, EV, heavy and industrial equipment can all be served by Alloy's Sheet Forging process. Additionally, some aluminum alloys have high thermal conductivity relative to its weight. Cooling and thermal management applications, as we pack more batteries or electronics into vehicles, machines, and computers, will continue to drive*

3D printed heat sink produced with Constellium's Aheadd CP1. Image, Courtesy of GMP Group. Shared by Constellium.

CP1 satellite RF antenna (courtesy of Burloak Technologies) - Shared by Constellium.

3D printed semiconductor heating plate produced with Constellium's Aheadd CP1. Image, Courtesy of GMP Group. Shared by Constellium.

3D printed part produced by Fraunhofer using Constellium's Ahead CP1 material



Heat exchanger. Courtesy of Volum-E. Shared by Constellium

adoption of Alloy's Sheet Forging process."

For Arbab, there are already many exciting LPBF applications that can be achieved with aluminum alloys. They include, for instance, satellite components, defense, heat-exchangers, and high-end automotive parts.

"As costs come down and designers become more aware of the new possibilities brought by specific alloys such as Aheadd® CP1. We already receive many requests for application studies in areas such as on-demand spare parts, semi-conductor industry applications…The current business is just the tip of the iceberg," he adds.

4 - Which considerations should be explored on the sustainability route?

At present, apart from reusability of powders, one realizes that material producers mostly focus on sustainability factors that are inherent to the manufacturing process of their material.

Forsyth told 3D ADEPT that the feedstock used in Alloy's Sheet Forging process has been designed to reduce carbon emissions by 15X compared to powder. Scrap from the Sheet Forging process can be reused without requiring energy-intensive and costly recycling processes.

In the same vein, Constellium's powder can be recycled multiple times in the AM machines and without any physical limit. Arbab said the team is currently working on optimizing powder production yield, quality and recycling with their atomizer pilot line at the Research & Technology Institute IRT M2P in northern France which is entirely dedicated to optimize production processes including recycling.

That being said, understanding the full lifecycle of a material is probably the first step to take for companies that are looking to produce more sustainable products and this should be the main topic of another article.

Materials

Eckart GmbH on the use of high-strength alloys in Additive Manufacturing

By definition, an alloy is a mixture of two or more metals or of a base metal with non-metallic additions. By integrating various elements into a pure metal's lattice structure, materials properties can be enhanced far beyond those of the base element. Alloys such as bronze (e.g., copper with additions of tin) and steel (e.g., iron with additions of carbon) have been used by humanity for thousands of years to increase the mechanical performance, or strength, of structural parts and tools. In the AM industry, **many AM end-users do not realize the tremendous potential of high-strength alternatives to standard materials such as AlSi10Mg and Ti6Al4V.** In what has become our traditional annual catch-up, **Dr. Ulrich Schmidt** and **Dr. Moritz Roscher**, respectively Global Head of Technical Marketing and Head of Additive Manufacturing Alloys of the Business Line Functional Applications at ECKART GmbH, share that the company broadens its portfolio **of high-strength Al- and Ti-based alloys for Additive Manufacturing**.

As a reminder, ECKART GmbH is a division of speciality chemicals group ALTANA headquartered in Germany. After an acquisition of UK-based Aluminium Materials Technologies Ltd. (AMT), the company has positioned itself in the AM market, as the developer and provider of A20X™, a lightweight aluminum-based powder derived from the aerospace-approved (MMPDS) A205 alloy.

As one of the most widespread AM processes, it made sense for material producers to design high-strength aluminum alloys that are compatible with **Laser Powder Bed Fusion** (LPBF). The problem is, the susceptibility of conventional high-strength aluminium alloys for hot cracking and a general poor processability have often made the processing of high-strength aluminum alloys by L-PBF difficult.

ECKART GmbH addressed these issues with its aerospace-approved material. **A20X™** unique chemical composition contains ceramic TiB2 particles which modify the solidification mechanism, resulting in fully equiaxed and fine-grained microstructures. The material is not susceptible to solidification cracking and can be processed on any commercial LPBF machine.

The company is now pushing the capacities of its material to allow processing by other AM technologies. *"Currently, the main driver for the use of A20X is LPBF. However, in feasibility studies, A20X was successfully used in laser-based DED. We are actively pushing A20X in DED applications as we are convinced that the properties are also a perfect fit for this field of use,"* the experts say.

Furthermore, as **costs** and **recyclability** remain key considerations for AM users who are scrutinizing any means by which they can alleviate the final cost of the 3D printed part and make the most of each AM equipment, it is important for material producers to ensure that the properties of their material make it possible to reuse the leftover material at the end of the production.

Indeed, as you may know, there are often two types of powder that are left in the powder bed at the end of a manufacturing process: one that is affected by the build process and includes powder that was partially-melted or heated during the process but was not fused in the fabricated part and another type

of powder recovered after a build.

Schmidt and Roscher confirm that the *"A20X powder is reusable, with the provision that critical parameters like oxygen content or removal of spatters are considered. There is no general guideline as the complete individual printing process needs to be taken into account. Scientific projects aiming to use excess A20X powder show that there are ways, e.g. the FAST process, that enable to recycle the material successfully."*

New developments at ECKART GmbH

"If in the field of Aluminum alloys, Eckart's strength is the well-known A20X alloy – a unique material with aerospace approval. At Formnext, Eckart will show for the first time high strength ***Titanium alloys like Ti-5-5-5-3, Ti-6-2-4-2, or Ti-6-2-4-6****, which are standing out by their mechanical performance,"* Schmidt and Roscher enthuse.

Titanium alloys often need complex casting and thermomechanical processing to perform the high strength required for some critical applications. Thanks to its capabilities, L-PBF remains one of the technologies that can enable the production of these much-needed strong and thermally stable 3D printed parts in commercial titanium alloys.

Given its decades of experience in the manufacturing of pure, spherical and nodular aluminum powders, zinc and copper-based metal powders, as well as various titanium alloys, I trust ECKART has built on this experience to deliver a material worthy of the AM industry.

From a strict business standpoint, despite a challenging market environment marked by harsh price fluctuations, supply chain and raw material shortages globally, the industry insiders report that the metal powder segments profit from the above average growth of the AM industry. "To keep pace with the growing markets, Eckart is already considering capacity expansion for its AM powders," they add.

The next rendez-vous?

We can't wait for our experts to share more about the development and applications of its new high strength alloys for AM. The next rendez-vous is definitely the one of **Formnext 2023**, where the company will be showcasing its latest metal powder portfolio and customizing capabilities in **Hall 12.0, booth A101**.

"On the booth we will be showcasing an automotive racing part from a formula student racer car. This part was deliberately LPBF printed with A20X powder due to the exceptional mechanical properties which enable the use as critical component, specifically a wheel carrier. Face-to-face meetings and inspiring talks with industry experts will help us to continuously improve our services and offerings", Schmidt and Roscher conclude.

TRUMPF focuses on industry-specific needs to deliver productivity and automation

Making Additive Manufacturing (AM) a more common process for serial production requires taking into account the specific challenges of vertical industries using the technology. In the medical industry for instance, being able to achieve surface roughness for spine cages, or a very high surface quality and level of detail in dental applications are a few production requirements that may help medical device manufacturers meet the most stringent standards of their industry.

High-tech company TRUMPF has understood the importance of delivering industry-specific solutions and will be presenting the new TruPrint 2000 at Formnext, ideal for the needs of the healthcare and medical industries.

With over 17,900 employees and generated sales of about 5.4 billion euros (preliminary figures) in 2022/2023, TRUMPF's superpower consists in helping industries drive digital connectivity through consulting, platform products and software. The OEM believes that Additive Manufacturing (AM) is the interaction of four components: laser, machine, monitoring and powder, hence the expertise it has built in each of these fields.

Key specifications of the new TruPrint 2000

Designed for medical engineering and other applications with lofty standards and quality demands, the TruPrint 2000 can serve the production of removable partial dentures, spine cages or even knee implants. First unveiled in 2019, the 3D printer has been enhanced to reflect the latest developments of TRUMPF's core technologies.

With its so-called motorized beam expander, the TruPrint 2000 automatically adjusts the spot diameter of the laser to the task at hand. Depending on the application, the spot diameter is 55 or 80 micrometers. The 80-micrometer spot enables higher productivity. Users can use the 55-micron spot when special metal powders require a higher energy density. The machine comes with a multilaser option and a powder bed monitoring option. This means that OEMs of highly regulated industries such as medicine can improve their productivity with two TRUMPF fiber lasers. The high-tech company has increased the power of the integrated fiber laser to 500 watts as an alternative to the 300W laser in the basic configuration. In such case, a 55-μm beam diameter can be exposed simultaneously in the build area and generate up to 80% more parts in the same time with flexibility.

Furthermore, the scope of materials the machine can process has been extended to include various metal powders for welding such as stainless steels, tool steels, and aluminum, nickel-based, cobalt-chrome or titanium alloys, and amorphous metals.

In addition to automated powder bed and melt pool quality monitoring, the inert machine concept of the 3D printer with powder preparation station, facilitates powder and parts handling under shielding gas.

The TruPrint 2000 works with TruTops Print, the company's proprietary software that has also been further enhanced throughout 2023.

"Users can now print parts with extreme overhang angles as low as 15 degrees without requiring support structures. In the past, users had to print support structures together with the part to anchor the part to the platform. These structures also serve to dissipate heat from the printed part and prevent internal tensions and deformations during printing. But TRUMPF's innovative new technology means that many 3D printing applications can now be carried out without those supportive structures, even when tackling hard-to-process materials such as stainless steel," the company explains.

While a key focus is made on medical engineering here, it should be noted that 3D printers from TRUMPF are often used in a wide range of industries such as tooling, molding, aerospace and automotive.

Other applications where TRUMPF has delivered productivity

One sector where TRUMPF has shined this year is the bicycle industry. A plethora of examples have demonstrated how AM continuously stands out in this industry as bike manufacturers are continuously looking to unlock new designs, and most importantly to manufacture with lighter materials.

If you're a cyclist, you probably know that with a light bike, you can ride faster, and easily on hills. With titanium and titanium alloys, it is possible to produce light, strong and durable parts – compared to carbon fiber which may be damaged under certain strains.

TRUMPF and bicycle brake manufacturer Trickstuff have been presenting 3D printed titanium brake levers for bicycles for the first time at the Eurobike bicycle trade show in Frankfurt.

"3D printing is what makes the cost-effective processing of titanium possible in the first place. Manufacturers can use 3D printers to customize brake levers. This does not only apply to the design of the titanium components. Manufacturers can also customize the lever forces of the brake to suit the cyclist. TRUMPF 3D printers also allow companies in the bicycle industry to speed up their prototyping," the company comments.

What's next?

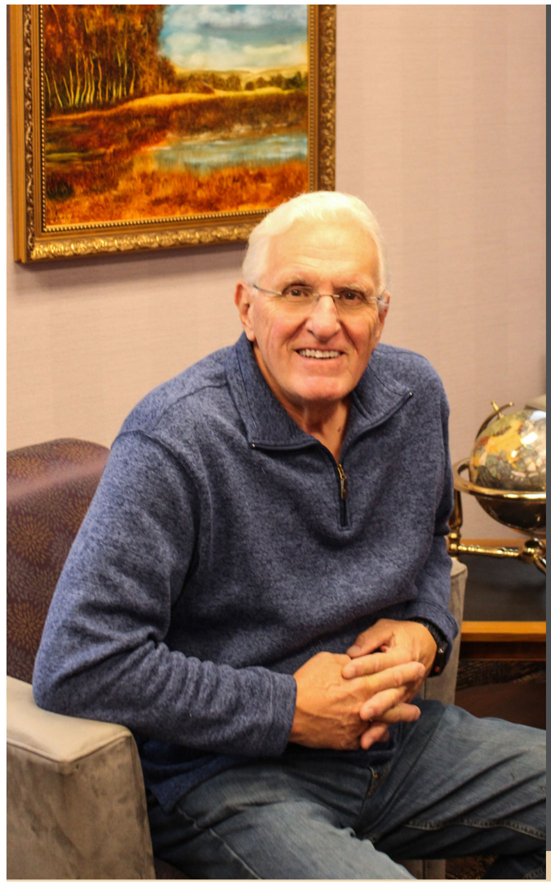
One thing we have learned from the company is that it focuses on the entire process chain to further enhance productivity. A key success to achieving true productivity lies in improving the process speed. While its 3D printers are already one of the fastest in their league with significantly reduced non-productive times, for example, due to the outsourced unpacking station and the multilaser principle, TRUMPF continues to commit to improving with automation solutions for the upstream and downstream work steps.

3D printing also makes TRUMPF's own series parts production more sustainable.

When asked what makes it stand out from the crowd, TRUMPF says that it has built up expertise in laser, machine, monitoring and powder and relies on its own value chain for 3D printing.

"TRUMPF is one of the world market leaders in industrial laser technology. As one of the few suppliers of 3D printing, TRUMPF develops and produces the beam sources, including optics and sensor technology, itself. The components of TRUMPF printers interact perfectly and have been tested for industrial series production. Machine tools for flexible sheet metal have been TRUMPF's core business for almost 100 years. As such, TRUMPF brings industrial expertise to the table like no other company in 3D printing. TRUMPF machines impress above all with their high robustness and reliability, and this also applies to 3D printing. When it comes to 3D printing, TRUMPF customers receive a complete solution that covers the entire additive manufacturing process chain. Everything from a single source is better than solutions thrown together," the company concludes.

TRUMPF will showcase its production portfolio and applications at Formnext 2023, in Frankfurt, in hall 12.0, booth D81.



Focus | Thermwood

Thermwood's Cut Layer Additive is an Additive Manufacturing process that does not 3D print. CEO Ken Susnjara explains why.

Thermwood has rolled out a new manufacturing approach that brings together its history in CNC routing and its work in large-format additive manufacturing. Named ***Cut Layer Additive****, the new manufacturing process does not 3D print parts, yet it remains an additive process. How is it possible? The company's CEO* ***Ken Susnjara*** *takes us through the how and the why of this latest development.*

Thermwood, based in Dale, Indiana, is one of the first companies to develop CNC router technologies. During the past years, the company made a name for itself in the additive manufacturing world with its Large Scale Additive Manufacturing machines.

As you may know, 3D printing typically means extruding a soft material in layers. "That is how LSAM works but it is not how Cut Layer Additive works, so it would be confusing to call them both *"3D printed parts"*," Susnjara says. Therefore, *"Cut Layer Additive does not print, it cuts parts. It is still an additive process since it makes parts by adding layers, but it is not a "print" process in the normal sense,"* he adds.

These first differences between an LSAM 3D printer and Cut Layer Additive might easily prompt any user to think that the Cut Layer Additive machine was created to solve problems the LSAM could not. I, myself fell into that trap until Susnjara laid emphasis on the reason why this process has been created:

First and foremost, *"this process was trying to create something new"*: giving users the ability to produce parts with the benefits of the additive process using materials one cannot print.

"One way to do that is to make a part by laminating layers of material cut from sheets. We decided to try to do just that, but to also make the final product similar in structure to the rather successful large format printed parts our customers are currently making. This means that the parts that make up each layer, although thick, would not be all that wide, with walls, just like printed layers. This meant they could be nested on sheets and cut out on a CNC router. The only problem with this is that programming all those parts would be a nightmare, so we came up with a unique approach where you don't necessarily program, but instead, define the part you want and send it to an intelligent machine which then programs it for you. LSAM and Cut Layer Additive are different processes using different types of material-producing parts for different applications. Both work well, they just make things from different materials," the CEO explains.

A closer look at Cut Layer Additive: how does it work?

The machine cuts out each layer of the build, separating the layers into different segments to allow for optimized nesting on the sheet the parts are being cut from. The segments are then fit together with puzzle joints to form each layer of the build, which is typically put together by hand, layer by layer, using dowel alignment holes for faster assembly.

Thermwood says this process can be done with almost any material that can be CNC routed, including metals and porous materials that can be treated with resin to make a thermoset composite part.

In one of the first videos released on Cut Layer Additive, product manager **Jody Wilmes** says that the system can speed up the build by ordering the cutting to allow users to start assembly while the rest of the build prints, if it requires multiple sheets.

However, *"build rate depends on the material being processed,"* Susnjara outlines. *"On a large aerospace tool which was both printed using LSAM and made using Cut Layer Additive, Cut Layer was several hours faster creating the near net shape part, but there were some post operations needed for Cut Layer, to make it into a thermoset composite part, which made the two processes quite similar. Typically, if you are processing material that cuts easily, such as plywood, MDF, foam sheet or the like Cut Layer Additive will be significantly faster, even when you add assembly time. If you are processing aluminum, it will be slower but it will still be faster than about any other way of making the same aluminum part,"* he continues.

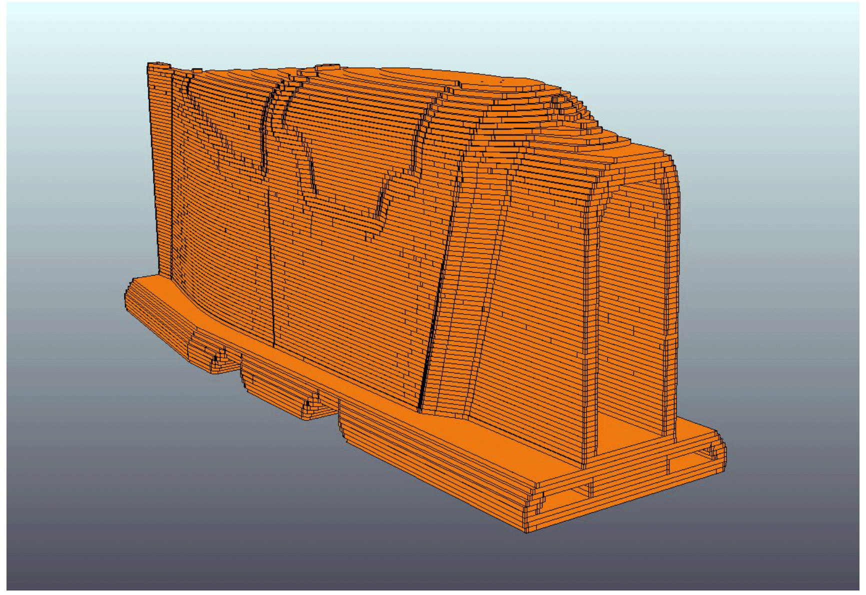
Compared to LSAM, the Cut Additive Layer process would take the same amount of time and labor as needed to additively print the same part, and it can even be faster with some materials.

Moreover, the whole process is made possible by a **programming software**, which allows users to skip the hours of work that would be needed to program out the CNC specs for each segment of each layer of the build.

This means that users just need to provide the machine with a CAD file of the shape of the build, and details about how it should be made, including the material you are using, and the wall thickness. In an interview given to 3D ADEPT Media, Susnjara also points out the capabilities of this software solution as one of the key strengths of the manufacturing package:

"Software and part processing is actually the key to the process. It is not only highly advanced but it is actually a fundamentally different approach. Instead of trying to program all the components that make up the part, we simply tell the machine what we want and it makes it. This is done in basically two steps. First, you show it the shape. You do this by sending it a CAD file of the basic shape you want. Then, you tell it how you want it made. This is done by answering questions such as the dimensions of the material you want to use; and the thickness of the walls you want. The kind of joint you want between layer segments and the like. The machine then slices the part, creates the individual layer segments, nests them on your material, creates the program and then cuts it all out. The process is fast, often taking minutes instead of hours or days.

This capability is expanding to make things that I'm not sure can be made any other way. We will be putting information out about this shortly."



3D ADEPT MAG

So, prototyping or production applications?

A manufacturing solution that can help create an additive part from a CAD model, slices the part into layers, splits each layer into segments, adds connection geometry between segments, offsets for trim stock, staggers joint between layers, adds alignment holes for dowels, efficiently nests all the parts on your sheet material, and creates a multi-tool CNC program – all of this automatically looks like a dream come true but for which end goal: **prototyping or production applications**? At the end of the day, the answer to this question is what OEMs are looking for.

"Large format near net shape parts," the CEO answers. *"These parts can be used as any large format additive parts. The additive process is normally used to produce a single example, a production tool or initial pattern or prototype, for example. It can normally produce a new design faster and at a lower cost than any other way of making it. If a part needs to be produced in volume, it is normally preferable to build production tooling and use that to make parts."*

Achieving large format near net shape parts that are not 3D printed is the result of the combination of several competencies: their CNC and additive approaches on the one hand, and on the other hand, their CNC and *"machine intelligence"*, which they've been working on for almost a decade.

When asked about the key factors that would drive a customer to go to the new Cut Layer Additive product over Thermwood's LSAM line, **Ken Susnjara** says: *"If you want to make large format parts from thermoplastic composite material, LSAM is the logical choice. It works great for that application running that type of material. If you want to make parts from other materials, such as wood or aluminum, which you can't print, you need Cut Layer Additive."*

That being said, while there isn't a real limitation in terms of build volume for Cut Layer Additive – since each layer can be broken down to a number of segments to fit on the cutting table –, it should be noted that once the near net shape part is assembled, the operator will need a five-axis machine to trim it to the final surface. This machine needs to be big enough to accommodate the assembled part.

The new product is available now, anywhere in the world where Thermwood does business.

Thermwood believes executing this simple idea with cutting-edge technology can have a profound impact throughout the large-scale manufacturing world, allowing producers to build new designs faster and at a lower cost.

Focus

3DCERAM sinto Global Advanced Ceramics

CERAMIC 3D PRINTING ROLE IN HYDROGEN PRODUCTION IS MORE TANGIBLE. 3DCERAM DEMONSTRATES IT IN THE HYP3D PROJECT

When we started discussing what a renewable energy transition with Additive Manufacturing (AM) looks like, a key focus was unconsciously placed on the role of metal 3D printing technologies like LPBF. Interestingly, various projects have popped up this year across Europe and have demonstrated the capabilities of ceramic 3D printing as an ideal production candidate that could bring the hydrogen economy closer to effective implementation. 3DCeram demonstrates the how and the why of these capabilities through the European HyP3D project.

From a manufacturing standpoint, the role AM can play in hydrogen production has often been hard to demonstrate. In theory, the capabilities of AM in any production can easily be outlined; in practice, applications of this specific segment are not really known, making it difficult to appreciate the tangible role of the technology.

This article aims to highlight:

- The European HyP3D project and the link with hydrogen production

- How 3DCeram's SLA 3D printing is utilized to help redefine the landscape of hydrogen production

- What does that mean for the energy industry?

The European HyP3D project and the link with hydrogen production

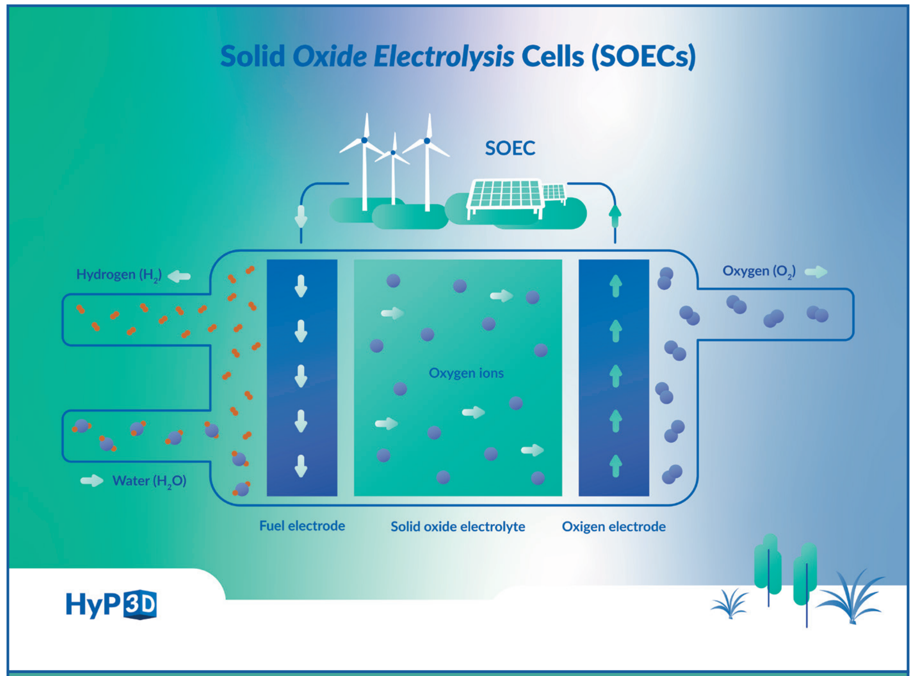
To date, one of the promising methods to produce green hydrogen from renewable sources would be to rely on **electrolysis**.

The electrolysis process consists in using electricity to split water into hydrogen and oxygen. Among the different types of electrolysis systems that can be used to enable this reaction, those based on **high-temperature Solid Oxide Electrolysis Cells** (SOECs) are often the most efficient ones. The problem is that their adoption is often slowed down by their stable operation at atmospheric pressure.

The **European HyP3D** aims to address this limitation by demonstrating the viability of a disruptive high-pressure **Solid Oxide Electrolysis Cell** (SOEC) technology. At the heart of the project, one finds a wide range of research and industry experts: IREC, DTU, PoliTo, and BSC as well as VAC-TRON, H2B2, SNAM and 3DCERAM on the industry side*.

To develop **an ultra-compact, high-pressure standalone SOEC stack** that can turn electricity into compressed hydrogen, this consortium will harness the power of several technology solutions including 3D printing. A key milestone of this research will be the development of **3D-printed SOEC cells** with a substantial active area of 70 cm², embedded functionalities, and the capacity to achieve hydrogen production at remarkably high current densities exceeding 0.90A/cm² (~1.3V) under conditions of 850°C and 5+ bar pressure.

So, how exactly is 3D printing used at this level?



Courtesy of 3DCeram.

How 3DCeram's SLA 3D printing is utilized to help redefine the landscape of hydrogen production

Founded in 2001, by Richard GAIGNON and **Christophe Chaput, 3DCeram** has built up extensive expertise in the manufacturing of ceramic 3D printers based on SLA technology. Over time, the company's offering has evolved to support customers throughout the entire value chain

"When it comes to industrialization, stereolithography becomes a significant asset as it is a top-down construction process. This means that the layers are built from the bottom to the top, foregoing the use of many supports. This is a crucial point to consider. After printing, the parts are cleaned, and the fewer supports there are, the easier and faster the operation becomes, while also reducing the risks of waste due to possible breakage during support removal," the company says.

As part of this project, 3DCeram's role will be to define and implement the application scenario established at the research level. This means developing an intricate optimization process encompassing printable feedstock Zr8Y, 3D printing parameters, and thermal treatments.

To achieve their ultimate goal – **producing complex-shaped parts mirroring the final cell dimensions** – the team will go through a number of different steps: from designing optimal procedures to studying the rheological behavior and printing tests by formulating specialized slurries for SLA 3D printing utilizing commercial YSZ powders.

The production will rely on the company's **C1000 FLEXMATIC 3D printer which aims to drive automation throughout the process.**

This semi-automatic production line features a 320*320 mm build platform that aligns with the project's industrial ambitions. Unveiled last year, the 3D printer has been designed with two laser options that could meet different production needs. Its automation capacity ensures the recycling phase of the uncured material as well as the cleaning phase of the parts and the trays. The printing process enables us to save time as the 3D printed parts require little or no support.

Fig 1. C1000 FLEXMATIC 3D printer and the recycling station work in an automatic line

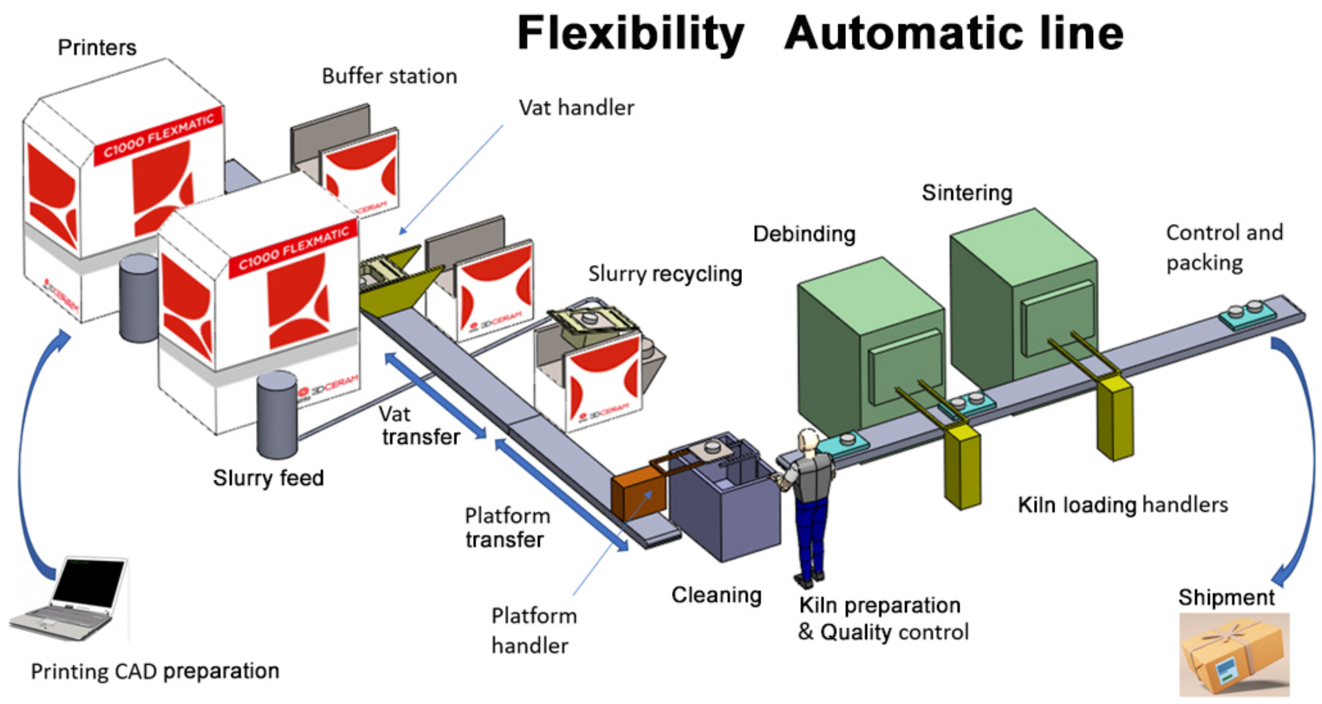
Fig 2. Two lasers increase productivity on C1000 FLEXMATIC. Courtesy of 3DCeram

Why is 3DCeram's SLA 3D printing the ideal production candidate for the project?

To better understand the capabilities 3DCeram's technology is bringing to the table, it's important to keep in mind that these parts are still manufactured through conventional manufacturing techniques such as **tape casting**. The challenges of this manufacturing process are the difficulty of ensuring the rheological properties of green tape slurries that will enable electrolyte performance. Added to this is the fact that the manufacturing process produces a flat, non-functionalized cell, so one ends up with a process that is not always ideal for production.

On the contrary, SLA 3D printing provides the cell with a complex geometry that allows the surface shape to be changed and adds gas paths to optimize the parts where it is needed.

3D ADEPT MAG



3DCeram reports that the 3D printed ultra-high-power density SOEC stacks deliver a 2.14kW power output within a compact 630 cm3 volume. This translates to a threefold rise in specific power per unit volume to 3.4kW/, and a fourfold increase in specific power per unit mass to 1.10 kW/kg. These results currently exceed any benchmarks of the industry.

What does that mean for the energy industry?

As a key partner in the HyP3D project, 3DCeram is pushing the boundaries of its technology by demonstrating automation capabilities that will be needed for industries looking to scale production of **3D-printed SOEC cells**.

At present, the company has demonstrated the potential of ceramic 3D printing for a critical sector like energy. With robots and automated production systems that can handle all stages, from design to firing of parts, 3DCeram is ready to help the energy industry scale production with its technology.

While with the **C1000 FLEXMATIC 3D printer**, 3DCeram already allows **automation throughout the process** (from scraping to lasering strategies to the quality

Pic ceramic component IREC. Courtesy 3DCeram.

of ready-to-print ceramic formulations to recycling and post-processing), it should be noted that the company's production line includes 3D printers such as the C3600 ULTIMATE with bigger volumes. Our guess is that these 3D printers will also be appropriate for industrial production but that's a topic we would be happy to discuss in another article.

In the meantime, it's important to keep in mind that HyP3D's vision doesn't stop at materializing dense, mechanically robust components. 3DCeram is currently going the extra mile to develop and model a stack for producing hydrogen. By closely working with IREC, a center of excellence in applied energy research, the company will now focus on optimal printing strategies, ensuring reliability and maximizing production yield.

If the project is successful – and it's likely to be given promising first results –, it will help achieve the objectives of advancing the hydrogen economy, reducing time-to-market significantly, slashing raw material consumption by 76%, and minimizing the initial investment by 42% compared to conventional manufacturing processes.

"With this groundbreaking HyP3D initiative, the energy sector witnesses a convergence of 3D printing prowess and hydrogen innovation, propelling the world toward a more sustainable energy future," 3DCeram concludes.

*Editor's notes:

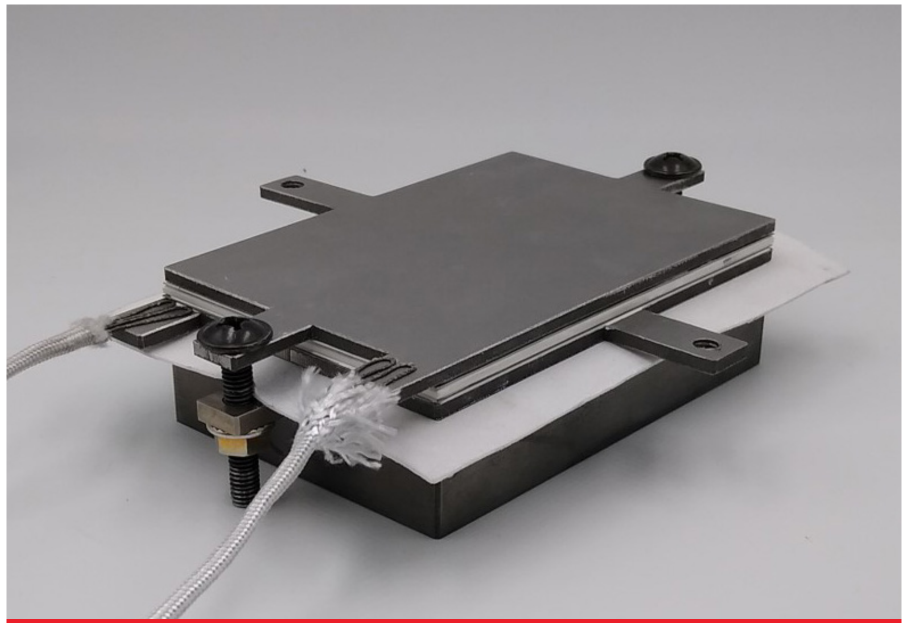
At the heart of the project, one finds a wide range of research and industry experts: IREC, DTU, PoliTo, and BSC as well as VAC-TRON, H2B2, SNAM and 3DCERAM on the industry side. While we focus on understanding the capabilities of 3DCeram's SLA 3D printing in this article, it should be noted that each of these partners brings valuable expertise to the project.

IREC is a centre of excellence in applied energy research. The Catalonia Institute for Energy Research (IREC) leads the HyP3D project and serves as a key coordinator. The Catalonia Institute for Energy Research (IREC), located in Barcelona, Spain, takes the helm in leading the HyP3D initiative and acts as the project's principal coordinator. IREC holds a pivotal role in the realm of energy research. The Department of Nanoionics and Fuel Cells at IREC brings substantial proficiency in crafting and assessing solid oxide cells for both electrolysis and power generation, using cutting-edge 3D printing techniques.

DTU is a technical university in Europe with over 20 years of experience in developing and up-scaling advanced functional ceramics.

Politecnico di Torino (PoliTO) is a top-ranking university in Italy and Europe, with a focus on technical-scientific research, and a leader in materials. Their expertise will be combined to produce high pressure resistant joining for HyP3D.

The Barcelona Supercomputing (BSC) is a national institution in Spain dedicated to high-performance computing (HPC). It is managing MareNostrum, one of the most powerful supercomputers



Courtesy of IREC. Stack for producing green hydrogen

in Europe. BSC will carry out high fidelity fluido-dynamic, electro-thermo-chemical and mechanical models for HyP3D technology, in parallel with the creation of a digital twin of the HyP3D stack.

VAC-TRON is a SME specialized in glass-to-metal sealing technology for high demanding application such as aerospace and oil and gas industry, and will bring important expertise to the HyP3D project in the areas of joint design for high pressure and high temperature, also creating reliable mass-scale sealing procedures.

H2B2 is an organization specialized in hydrogen production systems utilizing water electrolysis at different levels: development, financing, design, integration, construction, operation, and maintenance. They offer end-to-end solutions for green hydrogen production, encompassing every stage of the process. They will provide HyP3D with their deep knowledge of energy efficiency and cost-reduction strategies of the designed systems. In addition, H2B2 is the owner of the manufacturing pilot line that will be used to produce HyP3D cells.

SNAM is a leading operator in natural gas transport and storage in Europe, with an infrastructure that supports the energy transition. Drawing upon its 80 years of experience in managing and developing networks and plants, Snam ensures the security of energy supply and drives the energy transition across various territories by investing in green gases, such as biomethane and hydrogen, as well as energy efficiency. SNAM will contribute to the balance of plant of the HyP3D system.

FARSOON ON CUSTOMER-CENTRIC METAL AM SOLUTIONS : TRENDS AND LATEST APPLICATIONS

Current trends in Metal AM industry today

While the widely publicized Metal AM market growth would likely be considered to be advancements in materials, certifications, sustainability, generative design and even use of AI, Farsoon has observed the deeper currents of the market are pushing in different directions. Based on we have seen in the industrial manufacturing market today, the three dominating markets are **manufacturing efficiency of large-format parts, integration of Metal AM with traditional manufacturing to push in cost reduction, and last but not least, the customized equipment in sporting & consumer products.**

As Metal AM has already grown into a variety of manufacturing industry from prototype toward end-use application and high-volume series production, the pressure is in a totally different class in terms of production yield, cost per unit value, and factory integration. One standard Metal AM system can no longer fit all. We are seeing a strong demand of Customized Metal AM solutions and machines requiring special build size, optic systems, scanning strategies and application-specific processes; running customer-sourced engineering materials.

With over a decade of 3D Printing experience in Laser powder bed fusion systems, Farsoon technical team has work alongside industrial customers from multiple aspects from machine design, process development to application. Now the eve of **Formnext 2023**, which runs from November 7-10, 2023 at Frankfurt am Main, we are glad to share our scope and real-world customer stories on our customer-centric Metal AM solutions.

Farsoon's "Open for Industry" philosophy and Our Core Value

Farsoon is the leading supplier of industrial Laser Powder bed fusion systems with increasing growth in the global market. Farsoon was founded with the vision of creating an innovation-based company that brings truly open, high-quality industrial additive systems and value-added customer-centric solutions to the market.

Our **"Open for Industry" philosophy** simply means that the users of Farsoon systems have access to all key parameter sets (with an integrated, advanced parameter editor) in the system to customize the solutions based on specialized applications and material requirements to meet their specific production or development needs. And of course, the material choices are unlocked – It's all your call.

Figure 1: Rocket engine combustion chamber produced by FS621M (courtesy Deep Blue Aerospace)

Our Core Values for customer-centric solutions also include:

- **Customizable machine solutions:** With a comprehensive technology know-how, and a deep understanding in customers' pain points and demands, Farsoon is open to work closely with industrial partners with customizable machine solutions and configurations to best suit their needs.
- **Tailored services for your needs:** With a customer-centric service and technical support infrastructure, Farsoon offers professional and local support, as well as a tailored services and training experience, to help customers reduce operational cost and achieve business success.
- **Best Cost-to-performance:** Taking great pride in its quality products, Farsoon also strive to offer industrial market with best cost-efficient solution on the market, with customer-specific application support that can achieve a good competitive edge for series production and scalability of future manufacturing.

Real-world Customer Success Stories:

1. Improving manufacturing efficiency of large-format parts in aerospace:

Being one of the first commercial rocket manufacturers in China to use industrial metal 3D printing for key components engineering, **Deep Blue Aerospace** invested in Farsoon's large-format metal system **FS621M** (build envelope 620 x 620 x 1100 mm) in 2022 to explore innovative manufacturing solutions for rocket engines.

In 2022, Deep Blue Aerospace enhanced their batch production of single-piece, large-sized rocket engine combustion chambers using Farsoon's FS621M system. The additive manufactured Inconel combustion chamber measures **780mm (30.7 inches) in height and 550mm (21.7 inches) in diameter.** Major challenges include the size of the build, function integration, and detail resolution. The advanced additive manufacturing enabling many new innovations from Deep Blue engineers including consolidated design, light-weight lattice structures, and complicated geometries. Other features such as complex geometries with many hundreds of internal cooling ribs and channels are designated to promote combustion efficiency of the rocket engine.

With FS621M quad laser system, this large-format part production takes **327 hours** – a much accelerated cycle compared to the conventional process. In 2023, Farsoon metal application team worked together with Deep Blue Aerospace on the "Olympic" project targeting even higher production speed, while ensuring the build quality of this part. Multiple improvement items are tested and verified, including customized machine updates, advanced processing parameter development, scanning strategies, recoating and machine control. With months of joint efforts, the "Olympic" Project achieved an expedite printing time of **96.5 hours** – a significant production efficiency improvement of **338%**.

2. Integration of Metal AM with traditional manufacturing to push in cost reduction

Borton Precision Technology Co., Ltd. is specialized in customized vaping molds & tooling solutions by metal 3D printing, offering comprehensive design-to-market services including conformal cooling channel & venting design, mold flow simulation, additive manufacturing, heat treatment, and post-processing.

In 2021, after 6 years' deep dive in metal 3D printing, Borton Precision adopted 5 Farsoon FS273M Dual laser systems for rapid production of highly-complicated tooling, such as injection molding, die-casting, silicone molds, and fixtures. But when looking at the bigger picture of the mold-making, additive manufacturing is just one step amongst the multiple processes. The positioning and leveling when transfer between the processes are extremely time consuming while requires high accuracy for alignment. For advanced designs such as conformal cooling channels, the accuracy tolerance under 0.1mm is required for a functional mold product.

Taking these pain points from the customer, Farsoon metal application team worked closely with the customer to develop the **Automatic Alignment Solution** integrating Metal AM with traditional process. Equipped with high-resolution in-chamber cameras and optimized visual analysis layout, the new alignment system is able to extract the union outline of the bottom section, as well as the internal channel features for best accurate positioning of the 3D printed section. The whole grafting process takes only **4 minutes**, compared to previously hours of laborious manual alignment work; the accuracy tolerance can achieve **under 0.05mm** which easily meet the industry standards. Take the example of the vaping molds, the application of Automatic Alignment Solution can help **improving manufacturing efficiency by 70%, also reduce the powder material cost by 69%.**

3. The customized Equipment in Sporting & Consumer products

In the realm of consumer goods, the enormous pressure of efficiency and cost has keep driving technology innovation in 3D Printing. Futai Technology is dedicated to R&D and additive manufacturing of titanium alloy sports equipment especially in golf industry. Incorporated 7 medium-sized Farsoon metal AM systems including **FS200M** and **FS273M**, Futai Technology is able to deliver over **15,000** 3D printed golf club heads to extended markets such as Japan, Korean, Europe and U.S.

The application of additive manufacturing enables the true **economy production** of customized designs in streamlined forms, light-weighting and personized options. Featuring one-of-a-kind sound window design and lattice structure, the titanium alloy golf heads showcases both durability and improved performance.

One major concern from the customer is the dominating cost-pressure that requiring **sustainability of materials.** Especially dominating consumer goods companies are pushing for material savings for cost savings, marketing opportunities, and carbon reduction. While additive provides many great opportunities to reduce energy usage, the material consumption rate is key. We'll see a much larger focus on that in the coming years tied to marketing language around sustainability, carbon footprint, and total energy consumption.

*Farsoon strives to push the application of Metal additive manufacturing by working with industrial partners to offer high-quality, customer-centric 3D printing solutions. During November 7-10th, 2023, Farsoon will be showcasing its latest innovation and applications at **booth C11, Hall 11.1** at Formnext. Inquires and interested customers are welcome to contact wehelpyou@farsoon-eu.com for more information.*

Industry events

2023 / 2024

Stay up-to-date with the latest additive manufacturing industry events, conferences, exhibitions and seminars.

GERMANY	USA
FORMNEXT 7-10 NOVEMBER 2023 FRANKFURT www.formnext.com	**MIM 2024** 26-28 FEBRUARY, 2024 RALEIGH, NC www.mim2024.org
SPACE TECH EXPO EUROPE 14 – 16 NOVEMBER, BREMEN www.spacetechexpo-europe.com	**AMUG** 10-14 MARCH, 2024 CHICAGO, IL www.amug.com
INTERNATIONAL SYMPOSIUM ADDITIVE MANUFACTURING (ISAM) NOVEMBER 29 – DECEMBER 1 DRESDEN www.isam.network	**Rapid + TCT** 23-25 APRIL, 2024 ANAHEIM, CA www.rapid3devent.com
HANNOVER MESSE 22-26 APRIL 2024 HANNOVER www.hannover messe.de	**SPACE TECH EXPO US** 14-15 MAY, 2024 LONG BEACH, CA www.spacetechexpo.com

MORE EVENTS WILL BE ADDED LATER !