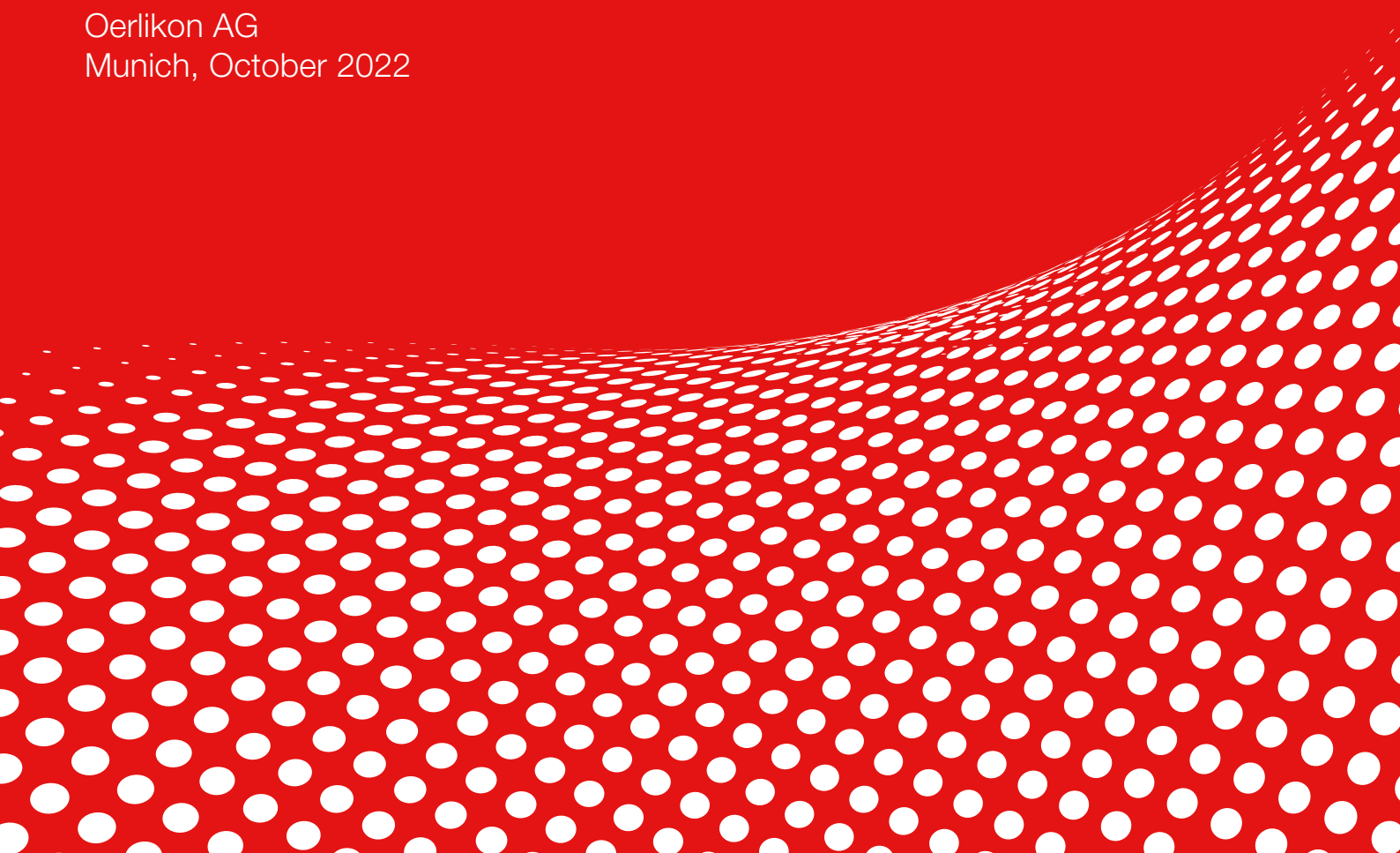


# CRAFT 5.0

## The Futures of Metal Additive Manufacturing 2030

**OC Oerlikon & PROFORE**  
**Author: Kai Gondlach**

Oerlikon AG  
Munich, October 2022



# EXECUTIVE SUMMARY

We all know about the benefits of metal AM and the most rewarding industries – automotive, space, defense, medical sector, and tooling. This report investigates on new, evolving industries that probably aren't on the radar of the AMTC partners by 2022, but could be worthwhile to prepare for the timespan through 2030. In accordance with the methods of scientific futurology, the explorative approach is oriented to known trends. Accordingly, on the one hand, these were formulated in advance as to which applications, process changes and effects of global and regional developments are likely. A compact desk research as well as discussions with international experts served to verify these theses. We describe the most

important drivers for widespread use in Trend Area 1. You can read more about the reasons for the expected rise of AM in the 2020s in detail in Trend Areas 2 and 3. There you will find in each case a description of the main drivers of development within the trend field ("what?") and then the implications for metal AM ("so what?") for every case.

**"Every industry is likely to scale"**

Prof. Dr.-Ing. Christian Seidel, University of Applied Sciences Munich, Fraunhofer IGCV, Germany

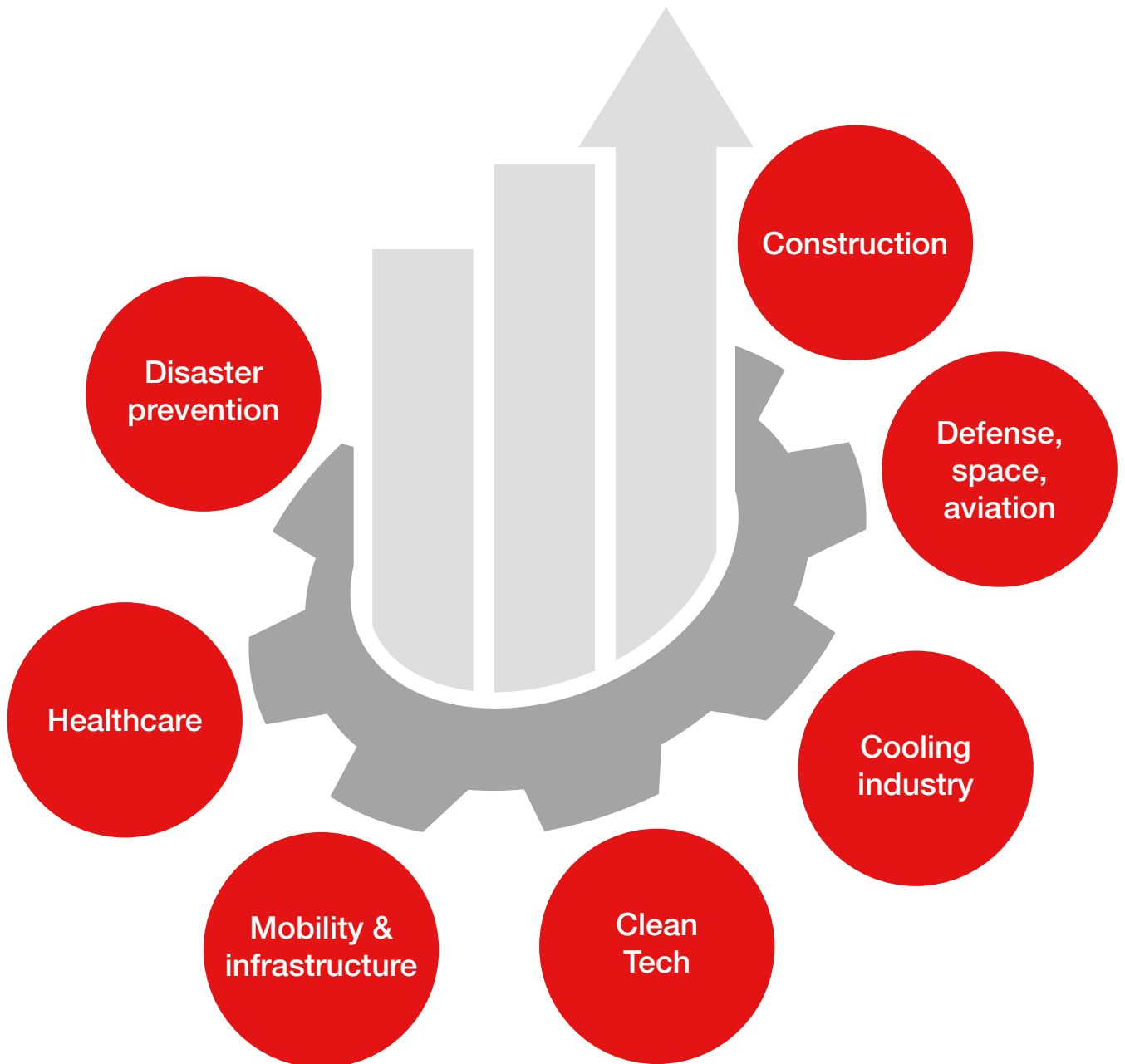
## The main findings are:

- Currently, AM accounts for an estimated 0.1% of industrial production, but the potential is 10 to 30 times that. The bottleneck in market penetration is expected to burst before the end of this decade.
- AM will massively benefit from the global shift towards sustainability and ageing societies and the related macrotrends, such as urbanization, longevity, and new mobility patterns.
- The speed of data transmission by digitalizing communication systems parallel to globalization led to an explosion of research papers in addition to bold company R&D efforts. Innovation cycles will become even shorter on the way to 2030.
- The demand for larger parts increases alongside the overall market expansion for metal AM.
- Also, the demand for small parts increases, especially in B2C-industries like sports and jewelry.
- The Global South is emerging as a byproduct of decentralization.
- Manufacturing times of metal AM might decrease up to 100 times until 2025.
- Meanwhile, certain parts run counter to the trends of acceleration and growth; especially printer and powder suppliers rather diversify regionally and collaborate with smaller providers to realize the full potential of their capacities.

## The main recommendations are:

- ☑ Re-think your business model and shift towards more decentralization, sustainability and collaboration. Getting from zero to one is the order of the day; like the role shift from a manufacturer to a renter, for instance.
- ☑ Engage in regulatory processes to accelerate change.
- ☑ Develop a sophisticated, customized foresight system to prepare for future shocks.
- ☑ Implement strategies and action plans for wildcards, such as the Covid19 pandemic. You probably won't need them, but it's better to have them just in case.

## Biggest growth is expected in the following industries:



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# PREFACE OERLIKON



**Prof. Dr. Michael Süß**  
Executive Chairman  
OC Oerlikon

Dear Readers,

It is in the nature of things that one always tackles challenges immediately, rarely thinking far ahead into the future. You deal with the immediate issues and then solve them one by one. In this way, AM technology moves forward step by step, becoming more and more future-proof. At the same time, companies in the AM industry are trying to find viable business models, develop markets, and come up with innovative ideas for new products and fields of application. At the AMTC we hear a lot about the progress made, about new products on established markets and it is always a benefit to exchange information about the latest developments and successes in the numerous discussions during the conference.

What we usually lack, however, is the ability to look beyond the end of our nose. We do see and recognize today's markets and current trends and derive strategies from them. But we usually only look further into the future when it comes to technological progress. For a production technology such as AM, whose application benefits depend crucially on market needs, this purely technical view of the future is not sufficient in my view. It therefore seems important to trace long-term

developments in order to anticipate new markets on the horizon.

With this trend study, we are deliberately breaking new ground. The focus here is not on everyday questions, but on looking beyond the horizon. It is not the classic market outlook, which, in relation to AM markets, rarely proves tenable anyway, that is to be reproduced here. Rather, this study is an attempt to discover future AM markets and their potential based on the observation of long-term trends, some of which are only just emerging. It seems only logical to foresee the market development of a technology whose unique selling point is to make previously seemingly impossible products possible, with an equally unconventional, visionary outlook on the future.

In this way I am with the great Italian filmmaker Federico Fellini, who once said: "The only true realist is the visionary". In this spirit, I wish you an inspiring read and many visionary ideas for the AM markets of the future.

# EDITORIAL



**Kai Gondlach**  
Founder & CEO  
PROFORE

This trend report is based on the methods of modern, interdisciplinary futures studies and is deliberately structured unconventionally. Instead of today's numbers and figures we rather discussed and anticipated likely and consistent future developments. We then discussed a selection of those theses with experts from Europe, the USA and Singapore. The goal of this procedure was to find blind spots and weak signals in neighboring fields of metal additive manufacturing (AM) in order to provide your strategy, business development and investment decisions a holistic foundation on the road to 2030.

Anticipating the most relevant mega and macro trends you'll find several back casts on the next pages. Our mental anchor in writing the report was a company that successfully reached the year 2030. We identified three trend areas that describe the crucial changes and shifts that have implications for AM. By that, we gauge our view from the outside to the inside and also from the futures to the past. Starting with mega trends, touching on macro and other trends to specific use cases, patents and other signals.

The title of the report "Craft 5.0" refers to the next stage of industrialization but with a focus on metal AM. Craft manufacturing has been a backbone for technological and economic success for many economies as well as the foundation for establishing of further education and innovation in many regions. In this decade, we expect nothing less than a revolution of manufacturing through a digitization of customized craft by the spread of AM.

PROFORE's mission is to enable organizations to plan their possible and desirable futures on solid grounds. This report is designed to be your guide through this rapidly changing field of technology. We are excited to embark on this journey with you and wish you an insightful reading.

# BIG PICTURE



## Our World in 2030: Retrospect

On the one hand, the 2020s were undoubtedly off to a turbulent start. The most influential megatrends – globalization and digitalization – were gradually unfolding their potential, while the Covid19 pandemic at the beginning of the decade had sent the world into a state of global shock. Another ecological disaster was coming to a head: climate change. By 2030, we are feeling its effects in nearly every region of the world, whether through higher temperatures and risen sea levels accompanied by freshwater scarcity, loss of biodiversity, even more extreme weather events, or growing refugee movements from all parts of the world. Finally, what always happens in change processes happened: The polarization of political groups and geopolitical conflicts increased the already existing pressure on economic and financial cycles, which in turn put whole economies under pressure. Depending on how you read it, at the beginning of the decade humanity was facing annihilation either nuclear war or doomsday.

On the other hand, with the appropriate perspective, extensive opportunities arose from what was probably the greatest transformation phase of mankind. The global Green Deal was gradually gaining momentum. In addition to the transformation of the energy sector from fossil to renewable resources, all other industries and markets had to adapt to new framework conditions. The necessary investments and capital shifts were unprecedented in global scale and most comparable to the golden 1950s after World War II. Yet, it succeeded.

While the opportunities of this social transformation still seemed vague to many at the time, by 2030 a large part of industry has made the leap to Industry 4.0 and is even aiming for Industry 5.0; in many areas not focused on mass production, there is talk of Craft 5.0. Supply chains and markets have been reorganized, have become seemingly leaps and bounds more efficient, and now take at least secondary account of ecological and social criteria in addition to an economy that is still primarily profit oriented. In the meantime, this has meant nothing less than a consistent focus on closed raw material cycles for a genuine circular economy that places particular responsibility on manufacturers.

Without the occurrence of wildcards, the global average level of key development indicators rose again after further years of global tensions. More people worldwide are gaining access to personalized services and products and are better educated and more connected than ever. Universal education and access to food and medicine have again improved significantly in a post-Covid world, and global poverty declined. In addition, by 2030, average life expectancy had increased in nearly all countries. In the global Silver Society, the over-60s form a more active group that tends to consume less, but more consciously.

One of the most important, if not the most important, contributions to this has been made by industrial companies. »

They were able to massively reduce global greenhouse gas emissions with courageous decisions, it and used digitization where it sustainably increased efficiencies, it employed parts of the population that in turn became important and more prosperous components of a circular economy - and that in every region of the world that has openly dealt with the huge transformation.

**“By 2030, the number of devices connected to the internet will have reached 125 billion, up from 27 billion in 2017 ... 90% of the world population will be able to read; 75% will have mobile connectivity; 60% should have broadband access”<sup>1</sup>**

Let's not kid ourselves: Many companies have not survived this change. The elements of many supply chains were replaced, sometimes disruptively, when they failed to adapt. Skilled workers had long been in short supply in many sectors and regions, and when large segments of the working-age population then turned their backs on unsustainable employers, things moved comparatively quickly. First, years of full employment were followed by a wave of large scale unemployment, which was followed by a global training revolution that is still underway in

2030. Social systems in many countries underwent a tremendous test of endurance that was not always peaceful. However, large segments of the populations were mostly united behind the goal of saving the future of humanity together.

People's everyday lives have tended to slow down compared to the previous decade. Of course, digital assistance systems, virtual and augmented reality, the metaverse and cryptocurrencies still have their place in society. Contrary to common trend assumptions, however, their use - unlike the total number of networked devices inside the Internet of Things (IoT) - has not increased exponentially but has found its place in a more mature user group. Through global regulation with an increased focus on sustainability and increasingly decentralized production and distribution methods alongside an increase in the importance of consumers, more and more markets are transforming themselves around the sustainable satisfaction of the basic needs of their target customers at their core. Welcome to: Craft 5.0.



# TREND AREA 1: Global Threats = AM Opportunities



Facing multiple global threats and challenges, the whole world finds itself in an unprecedented transformation process in 2022. The covid pandemic still hasn't come to an end, especially in the Global South; many countries of the Global North ache in the light of demographic change; the war in Ukraine threatens the yearlong balance of world powers, energy and food safety.

Might the AM industry be one of the few profiteering industries of those threats?

**“In the long term, we expect the market to increase tenfold”**

Prof. Dr.-Ing. Christian Seidel, University of Applied Sciences  
Munich, Fraunhofer IGCV, Germany

## Market Outlook Metal AM

Growth rate expected between 2021 and 2026 averaging 25.5% per year. Growth distributed almost equally between part manufacturing supplier, material and system.

Source: AMPOWER Report 2022

# Climate Change & Sustainability

**„The best defence against future shocks is to transform systems now, to build resilience by addressing climate change and to reduce the vulnerability, exposure and inequality that drive disasters.”<sup>2</sup>**

## WHAT?

Presumably, the readers of this report are aware of topics related to climate change and sustainability. Some already speak of climate crisis rather than change and the increasing number of weather extremes worldwide in the past couple of years have shown, that humanity indeed is on the tipping point of a climate catastrophe. Bold action needs to be taken to decrease carbon equivalent emissions, protect wildlife as well as air and water quality – not to save the world, but essentially have a chance for our species to survive. The World Economic Forum (WEF) accordingly has been ranking climate-related threats as most of the top global risk factors for years, but still:

**“Respondents to the GRPS rank ‘climate action failure’ as the number one long-term threat to the world and the risk with potentially the most severe impacts over the next decade.”<sup>3</sup>**

This report suggests that AM can be a part of the solution puzzle to limit global warming to about 2°C, therefore the industry is expected to grow substantially – with all economic and political implications.

## Ecological Implications of Climate Change in a Nutshell

Global warming is set to rise by approximately 1.5°C compared to pre-industrial times until 2030. Some countries, especially in Central Europe, already exceeded this. The Paris Agreement (2015) set the goal towards net zero CO<sup>2</sup> emissions until 2050 to prevent worst case scenarios in rising sea levels and decline of natural habitats for flora and fauna. Already, the required investments for disaster prevention have reached a magnitude

that some regions are about to move entire cities (see Jakarta, Indonesia). Also, the decrease of biodiversity is directly linked to an increasing likelihood of more pandemics like the Covid pandemic based on zoonoses (see [IPBES reports](#)). Weather extremes are expected to increase up to sevenfold annually until 2030 already (see [PIK report](#)).

## Economical & Political Implications of Climate Change

The political framework until the year 2030 is already mainly set by the Green New Deal and the 2-Degrees-Goal. Obviously, the dependence on fossil resources such as oil, gas and coal will be successively loosened and already regionally results in a transformation towards regenerative sources such as wind, solar or hydro. This development alone will probably lead to a disruption of global financial markets around the year 2030, since fossil assets will practically lose their values practically overnight and turn into stranded assets (see Jeremy Rifkin: The Green New Deal, 2017).

The very core of global economy is slowly shifting towards a circular economy. Subsidies for established industrial production, especially in oil & gas, might be abandoned in the coming years. Consumers already developed an ecological mindset in many regions worldwide and we expect the tipping-point of supply and demand to become sustainable and affordable around 2025, including tourism (see [Green Travel Index](#)). Severe ESG regulation (environmental & social governance) is likely to be rolled out almost globally until 2030, though countries in the Global South obviously demand

**“Although AM is not 100% green, it offers great amount of opportunities for sustainability and circular economy models”**

Prof. Dr.-Ing. Christian Seidel, University of Applied Sciences Munich, Fraunhofer IGCV, Germany

<sup>2</sup>United Nations Office for Disaster Risk Reduction (2022).

<sup>3</sup>World Economic Forum (2022), p. 8.

a higher CO2 budget for their economies. More national and translational legislations will push towards an ecological regulation that grants legal rights to ecological entities such as rivers or trees, like Ecuador, Bolivia, and New Zealand have done. Several countries around the globe are preparing appropriate legislations.

The debate around impacts of climate change has already started accelerating regional conflicts, many of which have the potential of becoming climate wars and definitely refugee crises. The New Cold War is already evident, as well as the New Space Race is in full operation.

**“Climate change is accelerating; we need to change and evolve quickly – especially in manufacturing! The world desperately needs more efficient parts, systems, and products with extended lifespans, while reducing consumption”**

Chaw-Sing HO, NAMIC

## SO WHAT?

As more and more decision-makers underline the narrative of Clean Tech, AM is almost sure to be part of a global solution and a circular economy. In addition to customization and time-to-market benefits, the crucial argument for AM will be the increased recyclability of resources, at least seen holistically. All experts we talked to agreed on this aspect.

The obvious downside to this development for companies in this field is the obligation to build working modes of recycling rather sooner rather than later.

## Economic Implications for AM

- Migration increases alongside political instabilities, up to 1.2 billion people might be fleeing from climate change implications – including wars and other conflicts – by 2050 (see [WEF 2021](#)). The likelihood of economic protectionism increases with the new distribution of geopolitical power between US, China, Russia and Europe. This opens opportunities for AM-companies to enter new markets and segments, replacing centralized structures.
- Governments and multinational corporations (MNC) cut down emissions in all industries, disrupting supply chains: “73 per cent of their [i. e. MNC] total emissions sitting in their supply chain ... 78 per cent say they will remove slow-to-transition suppliers by 2025 (including 15 per cent who have already started this process)”<sup>4</sup>. AM-companies should be prepared to reduce their carbon footprint sooner than later.
- Hotter temperatures will mean a drop in productivity by 2 %<sup>5</sup>: More automatization and decentralized production will be required, boosting both the demand and adoption of AM solutions.
- Demand for lighter and more efficient planes increases as well as sustainable tourism offers. Keeping in mind the massive benefits of AM components for aviation, there will be no space for heavy parts in aviation in the foreseeable future.
- Logistics and carrier industry to transform substantially from moving goods to moving components, e.g. powders and AM-equipment. Ports and marine traffic increase disproportionately to the decline of aerial logistics; shipping a ton of metal powder is way easier than shipping the according number of goods or products, plus their packaging. Railway transport will also grow, all depending on regions. The winner in this game will be material handling.

**“With AM, 1/3 fewer containers are required, which contributes to the goal to decrease carbon emissions. For that reason alone it will happen”**

Prof. Dr. Michael Süß, Executive Chairman OC Oerliko

<sup>4</sup>Standard Chartered Bank (2021), p. 3.

<sup>5</sup>Independent (2016).

# Fastest Growing AM-Industries due to Climate Change

## Healthcare:

Although parts of the turnarounds in healthcare already peaked in the first year of the pandemic, higher temperatures contribute to higher health threats, especially for elder people.

## Disaster prevention:

Fast and decentralized solutions are required to prevent and cure the impacts of natural disasters much more often.

## Cooling industry:

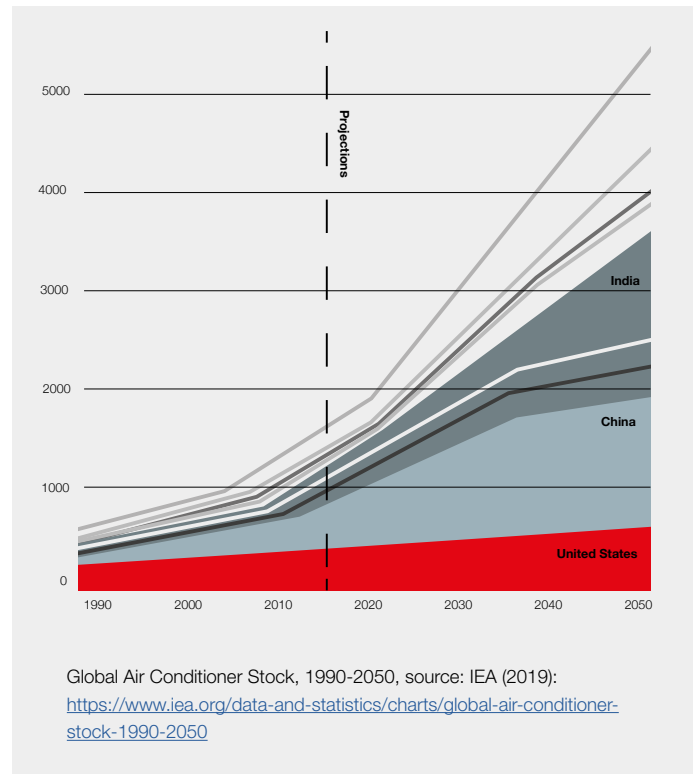
As temperatures rise, the demand for cooling devices in homes and business buildings rises, too. An [IEA study](#) states: “By 2050, around 2/3 of the world’s households could have an air conditioner. China, India and Indonesia will together account for half of the total number.”

## Clean Tech:

Green New Deal implementation shifts the energy sector from fossil primary resources towards 32 % from renewables in EU alone (2030). There’s a huge potential for customized solar panels, wind turbines on- and off-shore, etc. is skyrocketing worldwide. “Researchers at MIT have previously used 3D printing to reduce the production costs of solar panels by an incredible 50%. For the optimized constructions, the team made use of a material called perovskite, which is known to be a relatively cheap photovoltaic material when compared to glass, polysilicon, and indium” (see [What Next Global](#))

## Defense, space, aviation:

On the one hand, the war in Ukraine symbolically depicts the end of a relatively peaceful era, at least in Europe. The roots of this historic event are diverse, but one thing is new: It’s not only about raw resources, but also access to and control over food. The next stage of warfare might be fueled by the lack of drinking water. On the other hand, the combination of the pandemic and the war accelerated an unprecedented transformation of value chains in global markets. Traditional niche markets of AM are therefore expected to increase.



## Construction:

Architectural customizing on the one hand, decentralized construction on the other hand, is moving forward globally. After several investment rounds and also established corporates moving into the sector, the professionalization of metal AM in construction is happening rather sooner rather than later. “Global 3D printing construction market is estimated at roughly \$19 million and is expected to reach almost \$5 billion by 2030” (see [3D Printing Media](#)) ... “Hence, we are seeing more and more signs that 3DCP technology will indeed disrupt the industry” (see [3D Printing Media](#)).

# Demographics & Silver Societies

## WHAT?

Most countries in the global north are ageing – and keep moving into urban areas. Many countries in the global south are quite the opposite. The modes of living and moving show a massive transformation in the light of this and neighboring trends worldwide. The global population grows from 7.8 billion in 2022 to 8.6 billion in 2030, while some regions (like Europe) are shrinking. The global population is expected to peak around 2060 due to decreasing birth rates and increasing average household income.

Demographic change is truly no new or modern trend, but the 2020s or at latest the 2030s are about to change the balance in many countries' social systems and labor markets, but also generate several opportunities for certain industries.

### Urbanization

- By 2030 two-thirds of those will live in cities. There will be around 43 megacities with over five million inhabitants, the majority of big cities will have one to five million inhabitants (see [UN population outlook & EU Commission 2016](#)).
- A growing population in urban areas increases the challenges for city-planners in the light of climate change (see above) accordingly. In addition, higher population density in certain areas might lead to higher standards in security and safety both for products and federal bodies.

### Ageing Societies in Industrialized Countries

- As healthcare, hygiene and medical conditions almost everywhere have drastically improved over the past decades, the average population is getting older. Also, the peak lifespan is lived more actively. The global population ages in average: 12% of the world population will be over 65 years in 2030, up from about 8% today. One main reason for this is the long peaceful period in many regions since the second World War combined with a high birth rate afterwards and the rise of accessibility of birth prevention devices and drugs.
- The workforce shrinks by 2 % in Europe alone until 2030. This directly requires more automatization in almost every manufacturing branch.
- Terms like “social cohesion erosion”, “livelihood crises” and “mental health deterioration” are already common in mass media, therefore more people need professional medication and or physical therapy.

## SO WHAT?

### Longevity Increases Demand

We do expect a mass extinction of middle-sized companies in many regions due to the complex challenges, especially the labor shortage due to a high percentage of workforce entering pension age soon.

Countries with pension schemes fear this development, many discuss a rationalization or generalization of social transfer systems such as the general basic income. Healthcare industry and insurances are shifting their budgets from curing to prevention.

**„Humans are getting older and expected to stay healthier longer. The personalization of medical devices will become a bold trend for healthcare and biomedical“**

Chaw-Sing HO, NAMIC

Demand for orthoses, prostheses, medical models, inert implants, surgical instruments, dental prostheses, hip endoprosthesis, hospital equipment & other medical devices (walking aids and other body augmentations) will increase in wealthy nations.<sup>6</sup>

**“The trend towards customization in automotive might end sooner than later, when mobility-as-a-service becomes the dominating mode of individual mobility”**

Eng Yian, Economic Development Board Singapore

### Urbanization and New Mobility Patterns

1. On the one hand, the construction industry might shift from building to redevelopment of buildings and infrastructure due to regional ground sealing standards. On the other hand, some regions already left the path of urbanization, especially in pandemic times.
2. AM is touching every industry sector. From aviation to medical to energy and beyond. In particular, construction industry has been experiencing a significant amount of attention across the world. Lack of standards and codes for Additive Manufacturing in construction continues to be a major barrier for adoption. While still some new technologies are under development, we believe the impact of AM in this sector will be a major one.” (Dr. Mohsen Seifi, ASTM International)
3. Regardless of the type of residential area, the automotive industry slowly shifts from selling cars to individuals to selling them to ride sharing providers. Mobility as a service (MaaS) will certainly become a disruption for the way many people perceive mobility – at least in Europe and Northern America, parts of Asia, while China is projected to have an increase of 50 % in car ownership until 2030. Customization in automotive is likely to end sooner rather than later.
3. Although the specific systems differ extremely on a global level, the rise of public transport seems to be inevitable as well for many of them. This adds to the shifted mobility needs of consumers, and the manufacturing demands coherently.
4. Finally there’s an undeniable transformation towards vehicles without combustion engines, battery electric cars or hydrogen electric cars. Both require a substantially transformed infrastructure, for example charging stations or integrated induction rolls. Printing lithium-based batteries<sup>7</sup> could be an interesting niche in some sectors.

<sup>6</sup>E.R. Ghomi et al. (2020), p. 5.

<sup>7</sup>Shuang Zhou et al. (2021), p. 141-156.

## TREND AREA 2: Industries' & Regions' Maturity



Little strokes fell big oaks. In trend area 1 we observed that fundamental threats to the environment, the economy and ultimately humankind could accelerate AM implementations in certain industries. Now let's take a closer look which industries, which regions and which procedures or paradigms are expected to shift through 2030?

AM has reached adolescence, but what does it take for AM companies to survive and thrive and what should they focus on?

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**“Innovation culture is one of the biggest hurdles of AM implementation in many organizations. Focus on R&D and educating the workforce to develop talent pool to keep abreast with the latest advancements in AM is vital to break the barriers in adopting AM in many organizations”**

Dr. Mohsen Seifi, ASTM International

# Steady Evolution leads to Disruption

## WHAT?

Disruption never falls from the sky. Just like the iPhone-moment or the success of the Apollo mission to bring mankind to the moon, incredible amount of R&D, strategies and investments were required ex-ante. The same applies to AM. Most of the companies addressed with this report have been using AM techniques for years or decades. Many of them are best-in-class with their standards, machines, powders, software, and ultimately their other products and services. What our research revealed might be familiar to some readers, in that case they're still ahead of the development curve.

In general, we found numerous signals that underpin the expectations of optimistic market reports like the AM-POWER Report or the Wohler's Reports (ASTM International).

## Innovation-Immunity vs. Adoption

It's no secret that many innovations are being impeded by middle management in many organizations, since they fear the devaluation of their knowledge and experience. We assume that this has been the case for AM in the past decades as well. In this decade, many more modern or lateral thinkers enter decision-making positions all over the world (see above), advancing the craft 5.0 movement.

We observe that the so-called early adopter stage is finally finished, especially the middle class is starting to embrace AM.

**“Many are afraid of losing their jobs. But the worker will not be replaced, but further developed. This means a huge opportunity for the education market on the one hand. On the other hand, AM could also be exciting for (pre-)retirees because there is less physical work involved”**

Prof. Dr. Michael Süß, Executive Chairman OC Oerlikon

## Multi-material AM

We found numerous signals for multi-material AM including metal AM components. One 2020 article claims that hybrid 3D printing “could lead to increased production of fully functional 3D-printed electronics” (Prof. Dr. Shinjiro Umezo, Waseda University)<sup>8</sup>. Another interesting procedure called Computed Axial Lithography aims to “encase an already existing object with new materials— for example, adding a handle to a metal screwdriver shaft—which current printers struggle to do”<sup>9</sup>. The procedure is especially interesting for medical replacement parts, from “prosthetics to eyeglass lenses”.

**“Multi-material applications hold high potential for innovations in various industries”**

Prof. Dr.-Ing. Christian Seidel, University of Applied Sciences  
Munich, Fraunhofer IGCV, Germany

## SO WHAT?

### Larger Parts (B2B) and More Small Parts (B2C)

Adding all numbers and evaluating the statements of our experts, we expect two distinct developments for metal AM:

- Bigger machines to produce larger parts will very likely become a thing in this decade, especially in the construction industry, but also automotive or energy.
- B2C-markets also start gaining momentum, especially in luxury, jewelry and sports (see [HP's Golf Putter](#), sterling silver and 18K yellow gold by [Desktop metal](#), computer titanium mount by Silca (bike industry will grow substantially!), dive helmets by [Kirby Morgan](#) or printed biathlon stocks by [Athletics 3D](#), for example).

<sup>8</sup>Jing Zhan et al. (2020).

<sup>9</sup>Brett E. Kelly et al. (2019).



## Large and Very Large metal AM Machines on the Rise

Between 2021 and 2026, the sales share of small and medium-sized printer-Systems (<350 mm) will drop from 74% to around 58%. The share of sales of large and very large printer-systems (350-600 mm and >600 mm) increases from 26% to approx. 42%

Source: AMPOWER Report 2022

### Global South is Emerging

- After decades of slow adoption of metal AM, many advanced companies in industrialized countries naturally implemented the related technologies. Due to that, the technological gap to less industrialized parts of the world (i.e. the Global South) might grow even bigger – or, and we've spotted several weak signals for this thesis, the process of leapfrogging could be initiated.
- The biggest hurdle for the progress in AM evolution, i.e. skilled labor shortage, hits the Global South harder than other regions. But seemingly some countries, like Brazil, nonetheless proceed in adopting metal AM friendly policies and economic conditions.
- Monitoring the progress of UN's sustainable development goals (SDG), many regions obviously suffer(ed) from the pandemic, crises and wars. But the global community committed to supporting the emerging countries and their economies substantially to combat global challenges.
- The tendency towards a high technology-openness and growing tech-investments into countries of the Global South offers great potential for early-stage movers and could fulfil numerous goals arising from trend area 1 – from solving climate crisis-related issues (especially medical, aviation, and tooling) over decentralizing the supply chain to attracting skilled labor due to a more humane purpose (= employer branding).
- Companies are well-advised to set up an ongoing scouting system to continuously monitor the attractive regions for their own business model; the sweet spot for market entry might be closer than many might currently think – especially in times of crises.

**“AM is growing globally. However, the level of adoption across different countries vary. While some of them are already at the tipping point of AM industrialization, few of them are emerging, and the rest are still on the process of developing a strategy for AM adoption”**

Dr. Mohsen Seifi, ASTM International

## Software Companies Scale Up

One crucial question to leverage AM turnarounds is: Who is going to become the driving force of the next phase of implementation? All players from design, process monitoring, post-processing, material and device manufacturers have been waiting for the tipping point. The research for this report

indicates that software companies might play this role in the upcoming years for one simple reason: Scaling a software company obviously is more risk-resilient than a production of physical means, (re-)allocating investments in different global regions even more so.

## Metal AM market – Regionally different growth

Average growth rate from 2021 to 2026 per year:

- Americas: 25.9% (from 0.88 billion EUR in 2021 to 2.79 billion EUR in 2026)
- Asia Pacific: 24.9% (from EUR 0.69 billion in 2021 to EUR 2.09 billion in 2026)
- Europe, Middle East and Africa: 25.7% (from 0.93 billion EUR in 2021 to 2.93 billion EUR in 2026)

Source: AMPOWER Report 2022



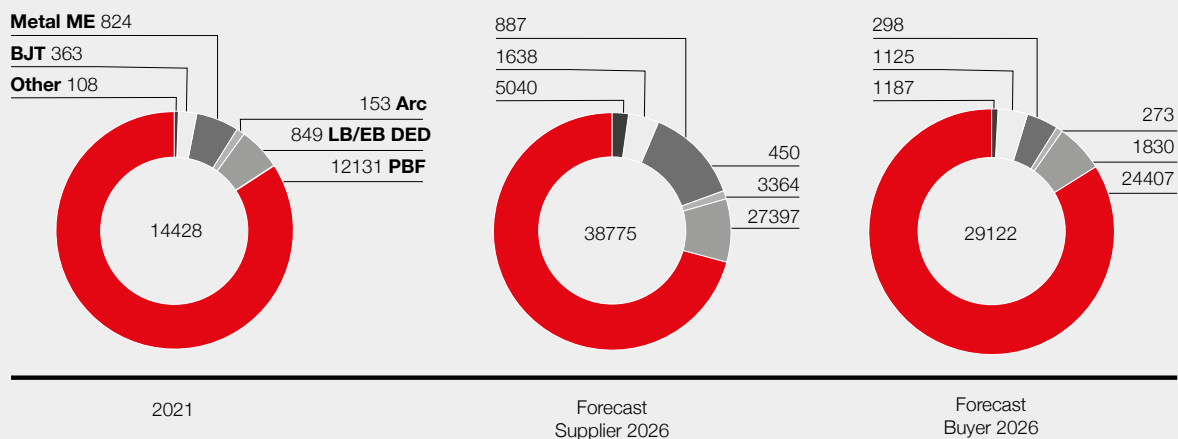
## TREND AREA 3: Acceleration of Everything



The world is accelerating – like it was based on natural laws, some refer to this phenomenon as a human gigatrend. The first two trend areas of this report are rather symptoms of change. This third trend area digs deeper into one of the most influential driving trends of the previous decades: digitization. Advanced Manufacturing offers numerous advantages of a digitally connected manufacturing industry and can be realized in a decentral procedure – this again accelerates transformation of industry 4.0 and even towards industry 5.0 – from a manufacturing company’s point of view, cost, and time to market are being reduced dramatically.

This chapter therefore unravels some phenomena in the tension field between different speeds of adoption both in terms of global competition and business modelling.

Ultimately, how can you prepare for future shocks like pandemics, wars, and other crises?



Installed Metal AM Machines 2021 and Forecast of Suppliers and Buyers 2026, source: AMPOWER 2022.

# Digitalization vs. Analogization

## WHAT?

The digital (r)evolution is advancing across different speeds in different regions and economies. While the global population increased eightfold over the past 220 years, the amount of digitally connected devices exceeded this development in less than 40 years. Digitization even contributes to the spread of education, democracy, free science, and other humanist goals as an intervening variable. Even in times of global crises the growth of digitally available information accelerates.

Three general recommendations arise from this situation: engage in the regulatory processes, rethink business models, and develop a sophisticated, customized system to prepare for future shocks.

## Digitalization and the Analogization of Digital Goods (IoT / IoE)

On the one hand, digitization and digitalization of processes are continuing. The merging metaverses and other virtual or augmented reality applications are expected to create a new wave of parallel economies.

On the other hand, a certain degree of saturation of consumers regarding their willingness to spend even more time in digital-only surroundings can be observed. Therefore, the according countertrend to digitization, analogization, is about to unfold in this decade. Consumers have now reached a level of maturity inside the internet of things (IoT) or internet of everything (IoE). What started with simple home printing devices will likely evolve into hyperconnected households with more smart devices and virtual layers between persons and surfaces. And, of course, an increased understanding of additively manufactured goods and home 3D printers – including those for metal AM.

The main hindering obstacle for the rise of AM still is standardization on the one hand and conformity assessment on the other hand. Although it's part of normal business to successively increase investment in R&D and

shift from collaboration to competition, the AM industry seemingly is urged to complete several steps shorter than other industries. That's why new business models are required rather sooner than later, see "so what?".

**“Without the active participation of innovative companies, standardization will take too long - by 2030, however, a large part of the application-specific standards required can be available”**

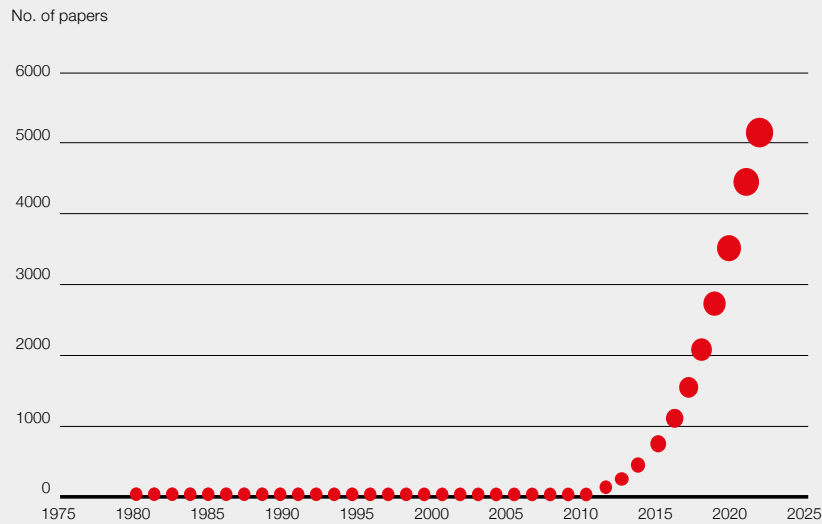
Prof. Dr.-Ing. Christian Seidel, University of Applied Sciences  
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## More Competition = More Research = Shorter Innovation Cycles

The formula for success can be easy: More investment into research and development will lead to innovation breakthroughs sooner or later. Alas, in complex systems we are often confronted with fuzzy or chaotic logic and only understand the patterns afterwards. That's why after decades of development and applications the market distribution of AM is still heavily driven by the big player and multinational companies.

Meanwhile, the internet happened. The past few years – especially before the pandemic – showed a steady and almost sudden appearance of numerous smaller companies and startups. In addition, the number of scientific papers literally exploded.

Accordingly, it can be reasonably assumed that the triumphal march of AM will continue in the coming years and reach a new level of market penetration in numerous global markets.



Research papers on “Additive Manufacturing” 1980-2022, Source: Springer, <https://link.springer.com> (open search)

## Accelerated AM Procedures

We’ve found several signals that the speed of AM and hybrid 3D printing is about to increase substantially in the not-so-distant future.

- Prof. Shinjiro Umezo from Waseda University said about hybrid 3D printing tech, it “could lead to increased production of fully functional 3D-printed electronics” by using two nozzles instead of one (see [NewAtlas](#)).
- Computed Axial Lithography: „Researchers at UC Berkeley have developed a method – Computed Axial Lithography (CAL) -that can synthesize arbitrary geometries volumetrically through photopolymerization. In brief, it uses light to transform gooey liquids into complex solid objects in only a matter of minutes” (see [Green Car Congress](#)).
- Area Printing: “According to Seurat’s website, the technique is already 10 times faster than other laser-based PBF technologies and 50% cheaper. By 2025, the startup anticipates it being 100 times faster ... The company has developed a technique called Area Printing that splits a single, powerful laser beam into more than two million “pixels.” The laser can then be programmed to melt (or not) the metal powder being hit by each pixel in its beam at one time, allowing it to cover a much larger area more quickly” (see [Freethink](#)).

## SO WHAT?

### Getting from Zero to One

- One of the biggest hurdles in the evolution of almost any more or less disruptive technology is the necessary rethinking and reorientation in business. In the case of AM, this means viewing data and information technology as an asset rather than an internal management entity.
- Just as Prof. Süß said at the beginning, a paradigm shift is taking place through AM, in which material is becoming a design factor. This circumstance requires manufacturing companies to make massive efforts in their internal recruitment and training policies.
- Since specialized professionals are scarce, it will be essential to develop in-house personnel in the new areas and to collaborate with other companies. The coming years up to 2030 are likely to be characterized above all by an unusually high degree of collaboration - both regional and sectional.
- For executives at the first decision-making level, this means: Getting from zero to one – instead of incrementally tweaking processes and ROI.

# Degrowth & Deceleration

## WHAT?

The digital (r)evolution is advancing in different ways. The Covid19 pandemic and more recent wars and crises have heralded at least a partial end to globalization. Of course, this does not apply to communication, science, and tourism. But it does apply to those parts of manufacturing that can be produced closer to where they are needed to reduce the negative impacts in trend field 1 while strengthening regional autonomy. Accordingly, there is also more room for the counter-trends of the major megatrends: degrowth and deceleration.

For many industries, this process of decentralization and degrowth will end disastrously. The first signs of mass insolvency in many economies are already emerging in the early fall of 2022. Looking back from 2030, the decade will go down in history as the largest mass death of companies. As described in trend field 1, however, AM is likely to be less affected by this and may even emerge as a winner.

## Printer & Powder Suppliers Diversify Regionally

One of the biggest advantages of AM is the fundamental ability to manufacture anywhere, once the key conditions for running a printer are in place. After decades of development, the next step in economization is therefore obvious: larger suppliers must prepare themselves to accept a deeper fragmentation of supply right through to the manufacturing process. Established powder suppliers are well advised to diversify regionally soon. Like a grassroots movement, smaller providers are likely to conversely provide the necessary means for production in many areas.

**“Manufacturing is too centralized. The trend towards circular value chains will accelerate the demand for AM and more micro factories worldwide”**

Chaw-Sing HO

**“The new Cold War could lead to more conservative decisions in business“**

Prof. Dr. Michael Süß, Executive Chairman OC Oerlikon

## Wildcards

Wildcards are low-probability, but high-impact events that influence several societal sectors. Contrary to what is assumed in the Big Picture, the inclined readers of this report will want – and need – to prepare themselves and their strategy for wildcards. At least since the Covid19 pandemic, we have all learned that it would have been better to have prepared a plan that you don't need - and if you do need it, to have thought about the impact of a pandemic on supply chains and other complex systems.

That's why, in addition to the AM area, we also conducted a risk assessment for wildcards up to 2030 and asked the experts about it. This is the list of the most common mentions and hits in desk research that can be considered consistent after combining with other influencing factors (in order of likelihood and expected time of occurrence):

1. Another pandemic (not MPXV) is very likely to occur before 2030.
2. Tipping points of climate change could be reached sooner than expected, e.g., the decline of the Gulf Stream, acidic tilting of oceans, or extensive melting of the permafrost and consequent release of gigantic amounts of methane.
3. Civil war in the US and a resulting separation of states.
4. Nuclear war.
5. Collapse of global financial markets, also causing political instabilities first in OPEC countries, spreading to almost all countries.
6. Volcanic eruption and consequent starting point of another ice age.

## SO WHAT?

### **Bold Transformation & Foresight**

Based on the researched developments in the AM sector and in connection with the permanent horizon scanning, we conclude:

This decade, the 2020s, will be characterized by probably the largest transformation process in the history of mankind. No industry, no region in the world is not facing fundamental change. The central question will be how the transformation of resilient value chains can take place in harmony with people and nature without overstressing the capabilities of the individual players. In the spirit of the 17th SDG of the United Nations, partnerships within the sectors as well as of a transnational nature are essential.

The motto “be prepared” used by the Scouts directly translates to “foresight” for companies. Being prepared for unlikely developments is one of the most valuable strategic advantages, especially in times of crisis. The concluding recommendation of this compact trend report closes the circle to the foreword: Strategic foresight is more than a nice-to-have. It is essential for survival in uncertain times and complex systems.

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# Appendix: Reflected Megatrends & Macrotrends for Metal AM

The following trends were identified as particularly relevant and accordingly form the primary basis for the report. Megatrends are trends that have an effect on a global scale and consist of several macrotrends, which, on their end, can be observed only in parts of societies or regions. This report has also considered more levels of trends, more sectors than STEEP (society, technology, economy, ecology, politics) and also (weak) signals. However, for a general overview and a deeper understanding of the argumentation, the higher levels are sufficient.

Feel free to get in touch if you want to learn more [www.profore-future.de](http://www.profore-future.de)

## Primary megatrends

- Society: Individualization & Silver Society
- Technology: Digitization & Automation, New Space Race
- Economy: Decentralization of Supply Chains while Industrialization of Emerging Countries
- Ecology: Sustainability / Climate Change
- Politics: Polarization / Neo Cold War

## Primary macrotrends

- Society: Trans-/Posthumanism
- Technology: Internet of Everything (IoT and IoE)
- Economy: Circular Economy, Glocalization
- Ecology: Zero Waste, Zero Emissions, Renewable Energies, Peak Everything, Consumer Minimalism
- Politics: Polarization

## Secondary megatrends

- Society: Pluralization (shift from Patriarchy and White Hegemony), Urbanization
- Technology: Global Connectivity & ongoing demand for Electronic Devices (B2B&B2C)
- Economy: Global GDP per capita growth, Mobility as a Service (MaaS), Degrowth / Common Good Economy
- Ecology: Sustainable Consumption & GreenTech
- Politics: Deglobalization / Rearrangement of Power

## Secondary macrotrends

- Society: Metaverse & Great Resignation
- Technology: Cybersecurity & Post-Quantum Encryption
- Economy: Agile Management, Coopetition, Digital Business Models, Consumer DIY, Redefinition of Intellectual Property, Individualization
- Ecology: Biodiversity Loss, Rising Sea Levels, Rising Temperatures
- Politics: Transparency and Regulation

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