

Printed electronics market- Is its growth potential becoming a threat to current suppliers?

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Abstract

3D printing in general and printed electronics in particular are attracting increasing interest. The markets for these technologies are growing faster than average. The aim of the present study is, on the one hand, to examine the growth potential for the next few years and, on the other hand, to analyze the suppliers of these technologies in relation to the competitive situation. The studies of existing market research institutes as well as databases for suppliers were used for the implementation. The results show that the expected annual market growth for 3D printing in general and printed electronics in particular is in the low positive double digits. The suppliers currently come mainly from North America and Europe. Furthermore, disproportionate growth is to be expected in the Asia-Pacific region in the future, which makes it likely that there will be more suppliers from this region. In this respect, the results of this study could be understood as early indicators that the positive growth expectations for 3D printing and printed electronics, increasing patent applications and the current global market distribution for the current suppliers could trigger negative effects in the near future, namely the emergence of various new suppliers and the fight for technological leadership - especially in the Asia-Pacific region - analogous to the photovoltaic market.

Keywords: Printed Electronics; 3D Printing; Market; Supplier; Technology; Growth

1. Introduction

The topic of 3D printing has become increasingly important in recent decades. To get an initial overview, a look according to Su and Al'Aref [1] into the past is helpful: "Since its invention 50 years ago, 3D printing technology has progressed at a rapid pace, with significant impact in both the industrial and commercial world. Stereolithography, selective laser sintering, and fused deposition modeling were among the first widely successful methods of 3D printing, initially used for industrial prototyping" [1]. The starting point for the development was the 1980s [2, 3]:

Table 1 Overview – Starting Point of Development 3D Printing [2,3]

1980	First patent by Japanese Dr Kodama Rapid prototyping
1984	Stereolithography by French engineers then abandoned
1986	Stereolithography taken up by Charles Hull
1988	First SLA-1 machine
1988	First SLS machine by DTM Inc then buy by 3D system

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The technology became relevant in public from the year 2000, when the first 3D printed objects appeared on the market [2]. The technology experienced a further boost with the availability of suitable materials for 3D printing from the 2020s [2]. In addition to the technological side, the economic side of 3D printing must of course also be considered. What can be said about the revolution in 3D printing compared to the digital revolution in general: “Yet, the 3D printing ‘revolution’ is likely to differ quite significantly from the previous digital revolutions. Indeed, while movies and music are nowadays predominantly transferred over the Internet to be 'manufactured' at home, it is unlikely that all manufacturing will follow this path, with every single object being fabricated at home on a personal 3D printer...” [4]. However, it turns out that 3D printing still plays a relevant economic role. This can be seen from the fact that this technology is now even available to the end user according to Raynaa and Striukova [4]. However, it is also true that the success of new technologies depends on the right business model [4, 5].

1.1. Overview - Technologies

The discussion about 3D printing is not always easy to understand in parts, since the terms are not clearly differentiated from each other. The terms 3D printing, additive manufacturing or printed or flexible electronics appear side by side according to Espera, Dizon and Chen [6]. Due to the large number of terms that do not overlap, a more technical definition should be chosen for 3D printing in the context of this study: "The main concept of 3D printing can be conveniently described as a replication of the 2D printing process, i.e., by stacking the 2D patterns as individual layers to produce a tangible three-dimensional output from a digital model created in a computer-aided design (CAD) software ..." [6]. A question that immediately arises in the context of 3D printing is how to define additive manufacturing. Are these two definitions describing the same thing? For this purpose, it is helpful to refer to the definition of large providers - such as General Electric [7] - of these technologies. According to this, the following applies: “Additive manufacturing uses data computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes” [7]. Comparing the above definitions, there is a large degree of agreement. Fortunately, General Electric also provides an approach to distinguish between the two terms: "Although the terms "3D printing" and "rapid prototyping" are casually used to discuss additive manufacturing, each process is actually a subset of additive manufacturing" [7]. According to this, additive manufacturing is the overarching concept and 3D printing is a subset [7]. This approach should be the basis for the present work.

After the terms “additive manufacturing” and “3D printing” have been defined, the third term “printed electronics” still needs to be defined. Here, too, it is worth resorting to well-known institutions in the field of "printed electronics", such as Lopec [8], the world's largest provider of trade fairs on the subject of printed electronics. The following definition was established by Lopec: “Printed electronics are conductive polymers and inks that can be printed onto foil, paper, glass, or fabrics, across large areas and at low cost” [8]. Connected to this type of production are very thin and also flexible electronics that can be used in a wide variety of areas [8]. The following table provides an overview of the areas of application [8]:

Table 2 Overview – Areas of Applications [8]

Organic electronics
Conductive synthetics/polymer electronics
Flexible electronics
Printable inorganic electronics
Large-area electronics
Thin-film electronics
Plastic electronics

Compared to traditionally manufactured electronics, this can differ in terms of the high flexibility in the choice of substrates, the design, the inks used and lower costs [6]. All in all, it can be said that 3D printing and printed electronics can be seen as sub-areas of additive manufacturing. However, there is no generally binding definition.

1.2. Research Question and Hypothesis

In the current discussion about additive manufacturing, 3D printing and printed electronics, there are many publications on technological developments and the associated trends, e.g. Lu-Yu, Jianzhong and Yong [9] or Yap, Sing and Yeong [10] as well as Shahrubudina, Leea and Ramlana [11]. A look at the economic side shows that the number of

publications in this area is manageable according to Holzmann, Breitenecker and Schwarz [12]: "3D printing is a prominent topic in many research domains. However, research on business and economic aspects of the technology is still limited". The aim of this work is to examine the supply and demand for 3D printing in general and the market for printed electronics in particular. The aim is to examine in detail who the current providers or suppliers of this technology are and which competitors could enter the markets. The question of future market development and demand is also important. For this purpose, the following research question RQ was defined:

RQ: Is there significant demand or market potential for 3D printing in general and printed electronics in particular, and who are the current and future providers of these technologies?

Three hypotheses can be derived from this:

- H1: The technological and economic trends for 3D printing show that 3D printing has great future potential from both perspectives.
- H2: The analysis of the development of the market for printed electronics shows that this market is characterized by double-digit annual growth.
- H3: The analysis of the suppliers of printed electronics shows that the majority of the suppliers also come from the growth regions of this technology.

2. Material and methods

In the first step, the H1 hypothesis was examined on the basis of literature research and statistical databases. The aim was to record the market development in relation to 3D printing. The following sources were used, among others:

Table 3 Source for Hypothesis H1

Data Set	Source
No. 1	[13] https://scholar.google.de/
No. 2	[14] https://de.statista.com/

In the second step, the H2 hypothesis was carried out on the basis of internet research, which served to record the market for printed electronics - in the form of a meta-analysis. For this purpose, the results of the research of various institutes were analyzed and then summarized:

Table 4 Source for Hypothesis H2

Data Set	Source
No. 1	[15] https://www.grandviewresearch.com
No. 2	[16] https://www.imarcgroup.com
No. 3	[17] https://www.transparencymarketresearch.com
No. 4	[18] https://www.emergenresearch.com
No. 5	[19] https://www.globalmarketestimates.com
No. 6	[20] https://www.expertmarketresearch.com
No. 7	[21] https://www.marketstatsville.com
No. 8	[22] https://www.thebusinessresearchcompany.com
No. 9	[23] https://www.maximizemarketresearch.com
No. 10	[24] https://www.globenewswire.com
No. 11	[25] https://www.coherentmarketinsights.com

In the third and last step, a detailed analysis of the providers of printed electronics was carried out in order to check hypothesis H3. The following databases were used for this:

Table 5 Source for Hypothesis H3

Data Set	Source
No. 1.: Printed Electronics Now “Printed Electronics Now’s International Suppliers Guide offers comprehensive information on printed electronics systems, materials, equipment, services and more” [26]	[26] https://www.printedelectronicsnow.com/buyersguide/
No. 2.: IDTechEx “Since 1999 IDTechEx has provided independent market research, business intelligence and events on emerging technology to clients in over 80 countries” [27]	[27] https://www.idtechex.com/

3. Results

3.1. Market Analysis 3D Printing – Hypothesis 1

The 3D printing market shows – divided into selected sectors – a high growth potential up to 2030 compared to 2015 [27]:

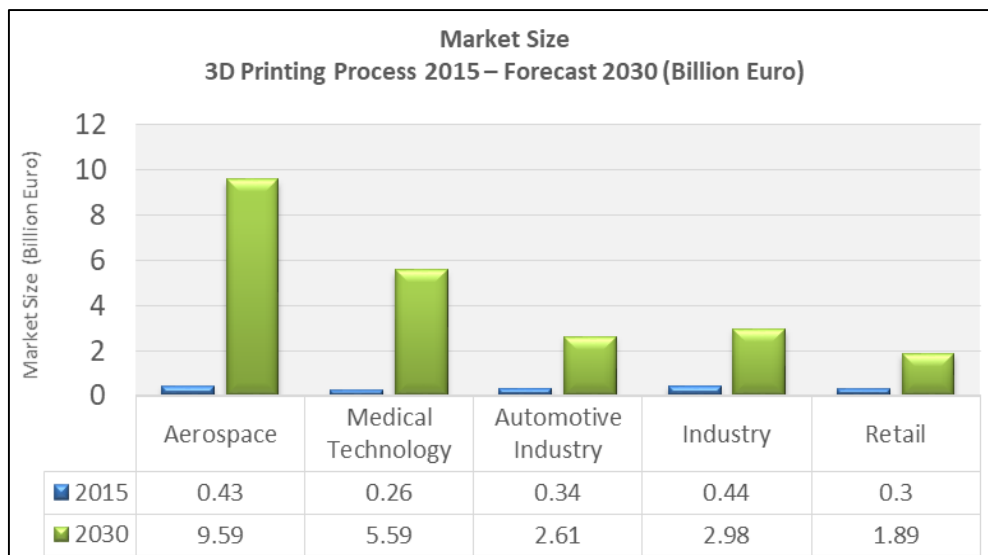


Figure 1 Market Size 3D Printing Process 2015 – Forecast 2030 in Billion Euro [27]

Among other things, the technological importance is visible in the number of patents. A disproportionate increase has been recorded here since 2012 [27]. With regard to selected countries, the following picture emerges [27]:

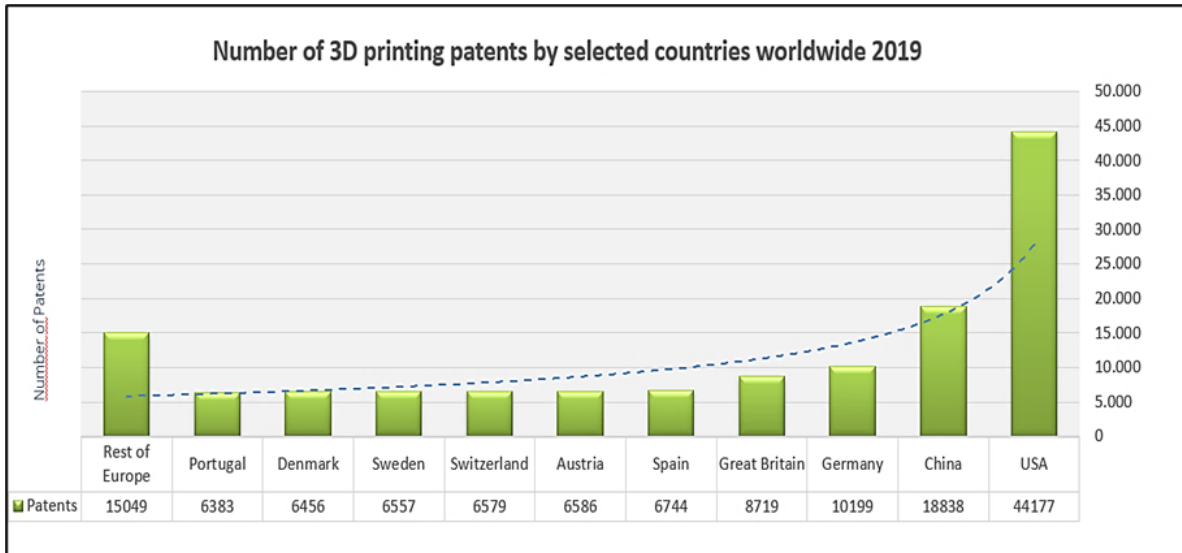


Figure 2 Number of 3D Printing patents by selected countries worldwide 2019 [27]

The figure shows that there are a disproportionately large number of patents in the USA in particular, with 44,177 patents in 2019 [27]. It is also noticeable that plastic continues to dominate as a material, but other materials are gaining in importance [27]. With regard to the companies as users, it is clear that the creation of complex geometries has the greatest benefit [27]:

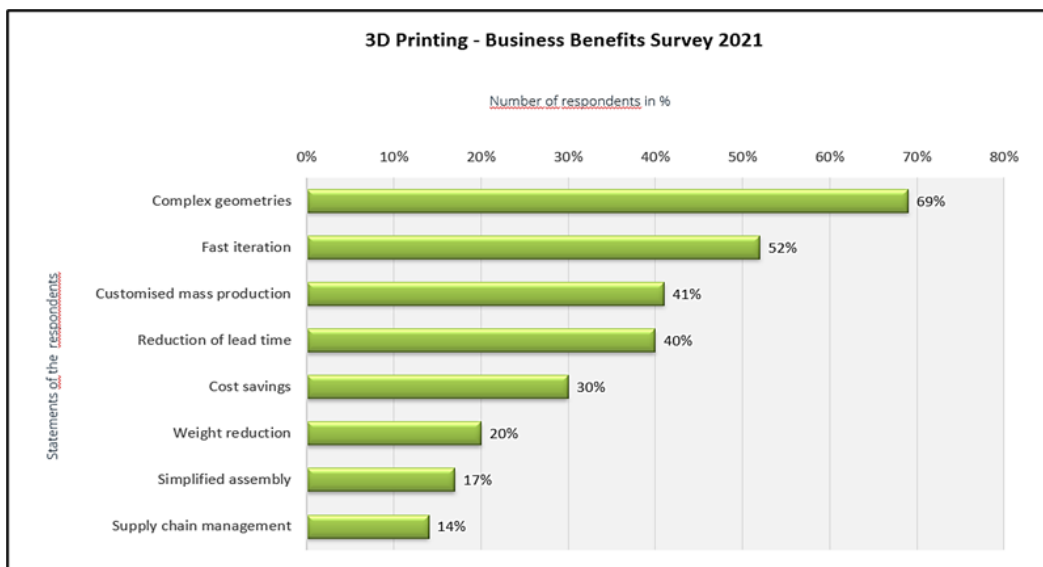


Figure 3 3D Printing – Business Benefits Survey 2021 [27]

Obstacles regarding the application in the company are still seen in the high costs [27]. On the other hand, the following factors are beneficial for the application, based on a survey [27]:

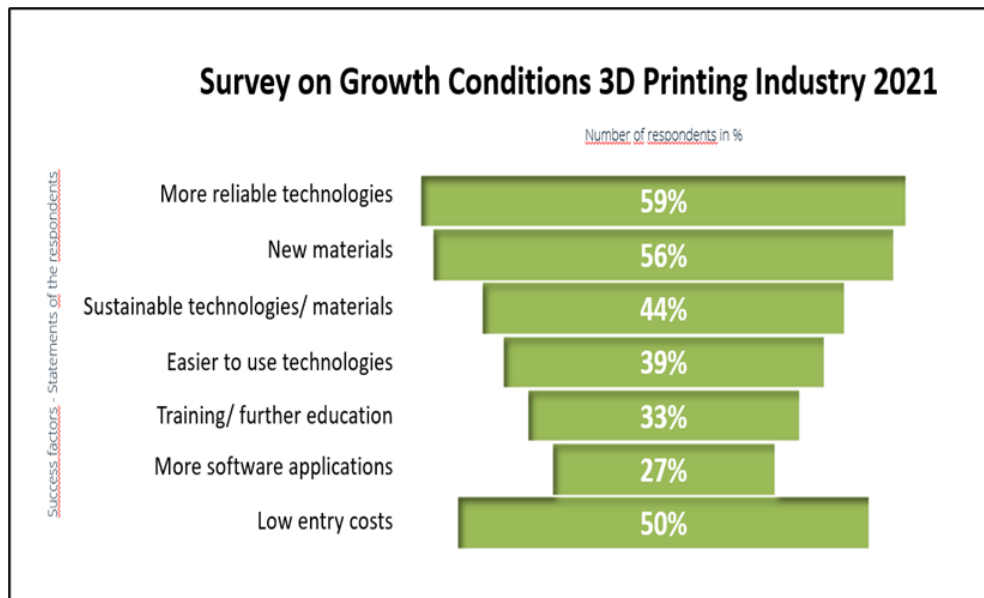


Figure 4 Survey on Growth Conditions 3D Printing Industry 2021 [27]

In summary, it can be stated that the potentials clearly outweigh the economic and technological ones.

3.2. Market Analysis Printed Electronics – Hypothesis 2

The results of the market analysis provide an insight into the various assessments of specialized market researchers in relation to the printed electronics market [15 - 25]:

Table 6 Overview - Market Research Institutes [15 – 25]

Data Set	Market Estimation
No. 1 Grand View Research [15]	<ul style="list-style-type: none"> Market size value in 2022: USD 10.47 billion Revenue forecast in 2030: USD 52.58 billion Growth rate: CAGR of 22.3% from 2022 to 2030
No. 2 Imarc Group [16]	<ul style="list-style-type: none"> Market size value in 2021: USD 53.5 billion * Revenue forecast in 2027: 130.8 billion * Growth rate (CAGR) of 16.56% from 2022 to 2027 *
No. 3 Transparency Market R. [17]	<ul style="list-style-type: none"> Market size in 2021: USD 9.23 billion Revenue forecast in 2031: USD 51.95 billion Growth rate (CAGR) of 19.6% from 2022 to 2031
No. 4 Emergen Research [18]	<ul style="list-style-type: none"> Market size in 2021: USD 8.66 billion Revenue forecast in 2031: USD 53.32 billion Growth rate (CAGR) of 22.3% from 2022 to 2030
No. 5 Global Market Estimates [19]	<ul style="list-style-type: none"> Market size in 2022: USD 10.1 billion Revenue forecast in 2027: USD 24.70 billion Growth rate (CAGR) of 18.5% from 2022 to 2027
No. 6 Expert Market Research [20]	<ul style="list-style-type: none"> Market size in 2020: USD 7.40 billion Revenue forecast in 2026: USD 21.40 billion Growth rate (CAGR) of 19.5% from 2022 to 2027
No. 7	<ul style="list-style-type: none"> Market size in 2020: USD 7.90 billion

Markets Statsville [21]	<ul style="list-style-type: none"> Revenue forecast in 2027: USD 22.70 billion Growth rate (CAGR) of 21.5% from 2021 to 2027
No. 8 Business R. Company [22]	<ul style="list-style-type: none"> Market size in 2021: USD 24.07 billion * Revenue forecast in 2027: USD 45.88 billion * Growth rate (CAGR) of 14.3% from 2021 to 2026 *
No. 9 Maximize Market R. [23]	<ul style="list-style-type: none"> Market size in 2021: USD 9.80 billion Revenue forecast in 2027: USD 25.53 billion Growth rate (CAGR) of 17.3% from 2021 to 2027
No. 10 Globe News Wire [24]	<ul style="list-style-type: none"> Market size in 2021: USD 10.02 billion Revenue forecast in 2029: USD 39.54 billion Growth rate (CAGR) of 19.1% from 2022 to 2029
No. 11 Coherent Market Insights [25]	<ul style="list-style-type: none"> Market size in 2021: USD 4.77 billion Revenue forecast in 2029: USD 55.56 billion Growth rate (CAGR) of 22.1% from 2022 to 2030

Note: * Excluded sources due to the fact, that the definition of “Printed Electronics” differs from those of the other institutions

Looking at the above results, a trend can be seen for the market size of printed electronics. Due to the different years that the eleven market research institutes used as a basis, a standardization to the year 2021 was necessary. This was possible due to the available "growth rate (CAGR)" in the form of a forward or backward calculation. It should also be noted that data set no. 2 - Imarc Group [16] and no. 8 - Business R. Company [22] had to be excluded as outliers, since these institutes had defined “printed electronics” more broadly than the other institutes considered. The results, based on market research [15] up to [25] can be presented as follows:

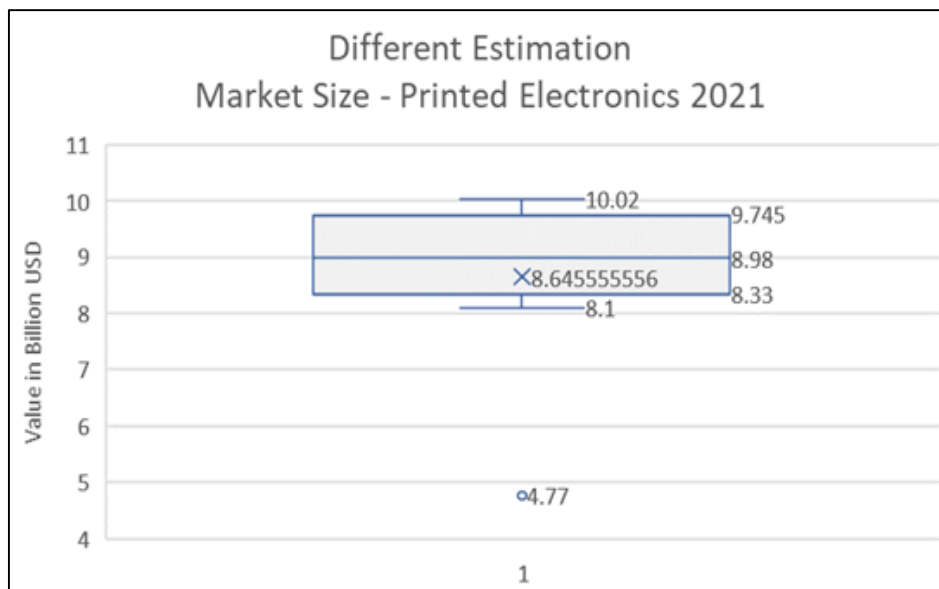


Figure 5 Different Estimation – Market Size Printed Electronics 2021 [15 – 25]

According to the boxplot, the median is USD 8.98 billion (= mean value at USD 8.65 billion) and the minimum and maximum values are USD 8.1 billion and USD 10.02 billion [15 – 25], respectively, for 2021. With regard to the revenue forecast for the year 2027 - normalized and to include data sets no. 2 and no. 8 adjusted – the results were as follows:

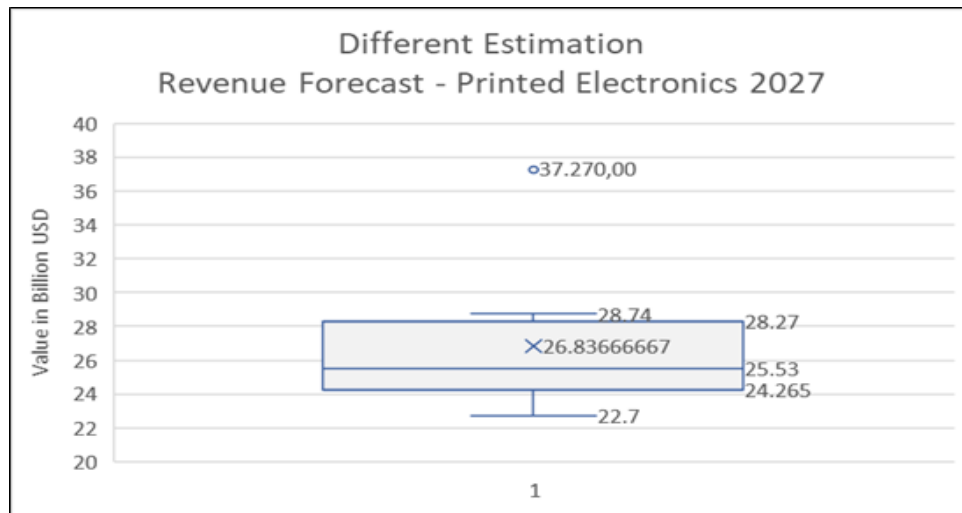


Figure 6 Different Estimation – Revenue Forecast Printed Electronics 2027 [15 – 25]

Here, too, it can be seen that the market research institutes came to comparable results overall. The median was USD 25.53 billion (= mean at USD 26.84 billion) and the minimum and maximum values were USD 22.7 billion and USD 28.74 billion, respectively [15 - 25]. The growth rate (CAGR) was considered as the last relevant variable. Even though the periods of time considered were different and the comparison is therefore only conditionally permissible, a trend could be derived from the determined annual growth rates of between a minimum of 14.3% and a maximum of 22.3%. [15 – 25]. According to this, annual market growth in the lower double-digit range is to be expected. Finally, it is also necessary to take a look at the global regions, i.e. where is future growth expected. The Asia-Pacific region (APAC) is obviously of particular importance here: "APAC will be the leading region with 50% of the market's growth during the forecast period. South Korea (Republic of Korea), Japan, and China are the key markets for printed electronics in APAC. Market growth in APAC will be faster than the growth of the market in other regions. The availability of low-cost products due to the high concentration of display and electronic device manufacturers in the region such as E-ink Holdings and AU Optronics will facilitate the printed electronics market growth in APAC over the forecast period" [28]. In summary, global growth in the low double-digit range with a focus on APAC is expected in the next few years.

3.3. Supplier Analysis Printed Electronics – Hypothesis 3

The subject of this section is the question of the suppliers or providers of printed electronics, i.e. their global distribution. The IDTechEx [27] database, which has extensive databases of suppliers, served as the data source. In the first step, according to the IDTechEx [27] database, 10 countries - sorted by the number of suppliers - were considered. The results can be summarized as follows:

Table 7 Overview – Top 10 Supplier according to IDTechEx [27]

Sr.No.	Country	IDTechEx [27]
1.	United States	280
2.	Germany	136
3.	United Kingdom	86
4.	Japan	83
5.	Korea	49
6.	France	38
7.	Netherlands	21
8.	Italy	19
9.	Sweden	19
10.	Switzerland	18
11.	SUMME	749

A strong dominance of suppliers from the USA can be seen [27]. A direct comparison of the results with those of the Printed Electronics Now [26] database shows significant deviations in the Asian suppliers area. Their number was significantly lower than at IDTechEx [27]. In other words, there are inconsistencies regarding the number of suppliers in Asia. If you don't just look at the TOP 10 countries, then the IDTechEx dataset includes 1018 companies [27]. These are divided among the global regions as follows [27]:

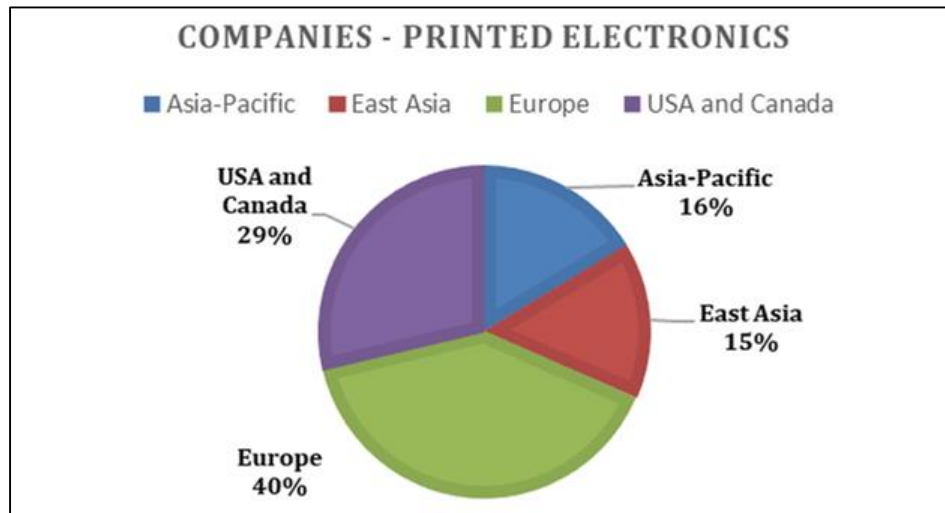


Figure 7 Supplier – Data Set of n = 1018 Companies [27]

It can thus be stated that, according to IDTechEx [27], the majority of the suppliers come from America and the USA.

4. Discussion

4.1. Hypothesis Testing

The results of the study show that the technological and economic trends show that the 3D printing market still has great potential that has not yet been fully exploited. Hypothesis 1 is thus confirmed.

As part of Hypothesis 2, the market situation and the demand side of printed electronics should be examined. Based on various market studies, low double-digit annual growth is emerging for this sub-market. Asia-Pacific (APAC) has been identified as a future growth region in several studies. Overall, Hypothesis 2 can therefore also be confirmed.

Hypothesis 3 dealt with the supply side, i.e. the providers of this technology. The results showed that the majority of suppliers of printed electronics come from the USA and Europe and thus - contrary to the hypothesis - do not come from the current or future growth region APAC. In this respect, the hypothesis based on the data from IDTechEX [27] could not be confirmed.

Limitations

The analysis of the market growth for printed electronics, based on the assessments of 11 market research institutes, can be seen as a limitation. The difficulty lay in the partly different definition of the term "printed electronics". Different definitions inevitably lead to different growth forecasts and market volumes. For this reason, two institutes had to be excluded from the present study, which illustrates the problem. For future investigations it is recommended to carry out your own survey.

A further limitation was the recording of the global distribution of suppliers of printed electronics. Although the two databases considered, Printed Electronics Now [26] and IDTechEx [27], delivered similar results in terms of results for Europe and North America, they differed significantly for the Asian market. It is therefore advisable to carry out your own survey or to use other databases in order to check the results.

5. Conclusion

The market for 3D printing in general and printed electronics in particular will continue to be very attractive for European and North American suppliers in the future, but due to the high growth potential in the Asia-Pacific region (APAC), it may be expected that there in the future not only does the demand continue to increase, but also the number of suppliers and technological developments (see patents) in the region itself will increase and they will supply the market with their own offer and then in the next step appear as competitors in the European and North American markets. The development of the solar industry shows that there are comparable experiences, as the Fraunhofer Institute for Solar Energy Systems ISE states in 2021: "Photovoltaics is the mainstay of the energy transition, together with wind energy. While Germany and Europe are still leaders in research and development for solar cells and modules, production has shifted to Asia in the last ten years. Technology sovereignty and independence threatened to be lost in Europe".

The above statement can also be confirmed by numbers from ISE Fraunhofer: "Photovoltaics is a fast-growing market: The Compound Annual Growth Rate (CAGR) of cumulative PV installations including off-grid was 34% between year 2010 to 2020. In 2020 producers from Asia count for 95% of total c-Si PV module production. China (mainland) holds the lead with a share of 67%. Europe contributed with a share of 3%; USA/CAN with 2%".

Despite good market growth forecasts, the current suppliers of printed electronics could face greater challenges in the future, on the one hand on the supply side in the form of new, strong competitors and on the other hand with regard to technological leadership.

Compliance with ethical standards

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References

- [1] Su A, Al'Aref S J. 12 Chapter 1 - History of 3D Printing, 3D Printing Applications in Cardiovascular Medicine. 2018; 1 – 10: DOI: <https://www.sciencedirect.com/science/article/pii/B9780128039175000018>
- [2] Sculpteo.com. The History of 3D Printing: 3D Printing Technologies from the 80s to Today3D Learning Hub [Internet].; BASF Germany: 2022 [cited 2022 Sep 9]. Available from <https://www.sculpteo.com/en/3d-learning-hub/basics-of-3d-printing/the-history-of-3d-printing/>
- [3] Savvides, L. A History of 3D Printing: Three Waves of Development. 3D Printing Cultures, Politics and Hackerspaces. In: Digital Activism and Society: Politics, Economy and Culture In Network Communication. Emerald Publishing Limited, Bingley, 29-51: <https://doi.org/10.1108/978-1-80071-665-020211005>
- [4] Raynaa T, Striukova L. From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. Technological Forecasting and Social Change. 2016; 102: 214-224. DOI: <https://doi.org/10.1016/j.techfore.2015.07.023>
- [5] Rayna T, Striukova L. The Impact of 3D Printing Technologies on Business Model Innovation. In: Benghozi, P., Krob, D., Lonjon, A., Panetto, H. (eds) Digital Enterprise Design & Management. Advances in Intelligent Systems and Computing. 2014; 261: DOI: https://doi.org/10.1007/978-3-319-04313-5_11
- [6] Espera A H, Dizon J C R, Chen Q. 3D-printing and advanced manufacturing for electronics. Prog Addit Manuf, 2019; 4:245–267. DOI: <https://doi.org/10.1007/s40964-019-00077-7>
- [7] ge.com. What is additive manufacturing? [Internet]. USA: General Electric Additive Company; 2022 [cited 2022 Sep 9]. Available from <https://www.ge.com/additive/additive-manufacturing>

- [8] Lopec.com. Printed electronics: Innovation with a Bright Future [Internet]. Germany: Large-area, Organic & Printed Electronics Convention (LOPEC) Exhibition Company; 2022 [cited 2022 Sep 9]. Available from <https://lopec.com/en/trade-fair/information/printed-electronics/>
- [9] Lu-Yu Z, Jianzhong F, Yong H. A Review of 3D Printing Technologies for Soft Polymer Materials. *Advanced Functional Materials*. 2020; 30 (28): DOI: <https://doi.org/10.1002/adfm.202000187>
- [10] Yap J L, Sing S L, Yeong W Y. A review of 3D printing processes and materials for soft robotics, *Rapid Prototyping Journal*. 2020; 26 (8): 1345-1361. DOI: <https://doi.org/10.1108/RPJ-11-2019-0302>
- [11] Shahrubudina N, Leea T C, Ramlana R. An Overview on 3D Printing Technology: Technological, Materials, and Applications. *Procedia Manufacturing*. 2019; 35: 1286-1296. DOI: <https://www.sciencedirect.com/science/article/pii/S2351978919308169>
- [12] Holzmann P, Breiteneker R J, Schwarz E J. Business model patterns for 3D printer manufacturers. *Journal of Manufacturing Technology Management*. 2020; 31 (6): 1281-1300. DOI: <https://doi.org/10.1108/JMTM-09-2018-0313>
- [13] Google Scholar. Publications [Internet]. USA: Search Engine Provider Google LLC; 2022 [cited 2022 Sep 9]. Available from <https://scholar.google.de/>
- [14] Statista.com. 3D Printing Survey [Internet].; Germany: Statista GmbH Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.statista.com/statistics/315386/global-market-for-3d-printers/>
- [15] Grand View Research. Printed Electronics Market Size, Share & Trends Analysis Report By Material (Substrate, Ink), By Technology (Inkjet, Screen), By Device (Displays, RFID), By Region (Asia Pacific, Europe), And Segment Forecasts 2022 - 2030 [Internet]. USA: Grand View Research Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.grandviewresearch.com>
- [16] Imarc Group. Printed Electronics Market Size, Share and Forecast 2022-2027 [Internet]. India: Imarc Group Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.imarcgroup.com>
- [17] Transparency Market Research. Printed Electronics Market Demand, Research Insights by 2031 [Internet]. USA: Transparency Market Research Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.transparencymarketresearch.com>
- [18] Emergen Research. Printed Electronics Market, By Material (Ink, Substrate), By Technology (Inkjet Printing, Gravure, Flexographic, Offset, Screen), By Devices (Displays, Photovoltaic Lighting, RFID, Others), and By Region Forecast to 2030 [Internet]. India: Emergen Research Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.emergenresearch.com>
- [19] Global Market Estimates. Global Printed Electronics Market Size, Trends & Analysis - Forecasts to 2027 [Internet]. USA: Global Market Estimates Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.globalmarketestimates.com>
- [20] Expert Market Research. Global Printed Electronics Market to Grow at a CAGR of 19.5% During 2022-2027, Aided by the Thriving Military and Defence Sector [Internet]. USA: Expert Market Research Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.expertmarketresearch.com>
- [21] Markets Stats Ville. Printed Electronics Market 2021: Industry Size, Regions, Emerging Trends, Growth Insights, Development Scenario, Opportunities, and Forecast By 2027 [Internet]. India: Markets Stats Ville Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.marketstatsville.com>
- [22] The Business Research Company. Flexible Electronics Global Market Report 2022 [Internet]. Europe: The Business Research Company Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.thebusinessresearchcompany.com>
- [23] Maximize Market Research. Printed Electronics: Global Overview and Forecast 2022-2027 [Internet]. India: Maximize Market Research Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.maximizemarketresearch.com>
- [24] Globe News Wire. The Global Printed Electronics Market size is expected to reach \$31.6 billion by 2028, rising at a market growth of 20.1% CAGR during the forecast period [Internet]. USA: Globe News Wire Market Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.globenewswire.com>

- [25] Coherent Market Insights. Printed Electronics Market to Reach US\$ 55,566.5 Mn by 2030 [Internet]. USA: Global market intelligence and consulting organization; 2022 [cited 2022 Sep 9]. Available from <https://www.coherentmarketinsights.com>
- [26] Printed Electronics Now. Buyersguide [Internet]. USA: Printed Electronics Now Magazine; 2022 [cited 2022 Sep 9]. Available from <https://www.printedelectronicsnow.com/buyersguide/>
- [27] IDTechEx.com. Supplier Database [Internet].; USA: Independent market research, business intelligence and events on emerging technology institute; 2022 [cited 2022 Sep 9]. Available from <https://www.idtechex.com/>
- [28] PR News Wire. Market Research [Internet].; USA: Cision PR News Wire Research Institute; 2022 [cited 2022 Sep 9]. Available from <https://www.prnewswire.com/news-releases/printed-electronics-market-size-to-grow-by-usd-20-10-billion--growing-demand-for-flexible-display-to-boost-market-growth--17-000-technavio-research-reports-301473948.html>
- [29] ISE Fraunhofer. Europäische Photovoltaik Industrie im Aufwind [Internet]. Germany: Fraunhofer Institute for Solar Energy Systems; 2021 [cited 2022 Sep 9]. Available from <https://www.ise.fraunhofer.de/de/presse-undmedien/presseinformationen/2021/europaeische-photovoltaik-industrie-im-aufwind-fraunhofer-ise-begleitet-5-gigawatt-projekt-in-andalusien.html>
- [30] ISE Fraunhofer. Photovoltaik Report [Internet]. Germany: Fraunhofer Institute for Solar Energy Systems; 2022 [cited 2022 Sep 9]. Available from <https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf>