### Glossaries

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<th>Abbreviation</th>
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<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
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<tr>
<td>ASIC</td>
<td>Application Specific Integrated Circuit</td>
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<tr>
<td>AR</td>
<td>Augmented Reality</td>
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<tr>
<td>BE</td>
<td>Back-End</td>
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<tr>
<td>BGA</td>
<td>Ball Grid Array</td>
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<tr>
<td>C2S</td>
<td>Chip to substrate</td>
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<td>C2W</td>
<td>Chip to wafer</td>
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<tr>
<td>CIS</td>
<td>CMOS Image Sensor</td>
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<td>CSP</td>
<td>Chip Scaled Package</td>
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<tr>
<td>CUF</td>
<td>Capillary Underfill</td>
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<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
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<tr>
<td>DA</td>
<td>Die Attach</td>
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<tr>
<td>DAF</td>
<td>Die Attach Film</td>
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<tr>
<td>ED</td>
<td>Embedded Die (in laminate substrate)</td>
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<tr>
<td>EMS</td>
<td>Electronics Manufacturing Services</td>
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<tr>
<td>FC</td>
<td>Flip Chip</td>
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<tr>
<td>FO</td>
<td>Fan-Out</td>
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<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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<tr>
<td>GPU</td>
<td>Graphics Processing Unit</td>
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<tr>
<td>HBM</td>
<td>High Bandwidth Memory</td>
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<tr>
<td>HDFO</td>
<td>High Density Fan-Out</td>
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<td>HPC</td>
<td>High Performance Computing</td>
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<tr>
<td>HVM</td>
<td>High Volume Manufacturing</td>
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<tr>
<td>I/O</td>
<td>Input/Output</td>
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<tr>
<td>IDM</td>
<td>Integrated Device Manufacturer</td>
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<tr>
<td>IC</td>
<td>Integrated Circuit</td>
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<tr>
<td>IIoT</td>
<td>Industrial Internet of Things</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
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<tr>
<td>L/S</td>
<td>Line/Space</td>
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<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
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<tr>
<td>M&amp;A</td>
<td>Merger &amp; Acquisition</td>
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<tr>
<td>MR</td>
<td>Mass Reflow</td>
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<tr>
<td>mSAP</td>
<td>modified Semi-Additive Process</td>
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<td>NCF</td>
<td>Non-conductive Film</td>
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<tr>
<td>NCP</td>
<td>Non-conductive Paste</td>
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<tr>
<td>OSAT</td>
<td>Outsourced Semiconductor Assembly and Test</td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<tr>
<td>PCBA</td>
<td>Printed Circuit Board Assembly</td>
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<td>PLP</td>
<td>Panel Level Packaging</td>
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<tr>
<td>PMIC</td>
<td>Power Management IC</td>
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<tr>
<td>PWB</td>
<td>Printed Wiring Board</td>
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<td>QFN</td>
<td>Quad Flat No-Leads</td>
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<tr>
<td>QFP</td>
<td>Quad Flat Package</td>
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<tr>
<td>RDL</td>
<td>Redistribution layer</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<tr>
<td>SAP</td>
<td>Semi-Additive Process</td>
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<td>SiM</td>
<td>System in Module</td>
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<tr>
<td>SiP</td>
<td>System in Package</td>
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<td>SMT</td>
<td>Surface Mount Technology</td>
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<td>STB</td>
<td>Set-Top Box</td>
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<td>TCB</td>
<td>Thermocompression Bonding</td>
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<tr>
<td>TSV</td>
<td>Through Si Via</td>
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<tr>
<td>TXVR</td>
<td>Transceiver</td>
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<tr>
<td>VR</td>
<td>Virtual Reality</td>
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<td>WB</td>
<td>Wirebond</td>
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<td>WE</td>
<td>Wearables</td>
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<tr>
<td>WiFi</td>
<td>Wireless Fidelity</td>
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<td>WLP</td>
<td>Wafer Level Package</td>
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Yole’s market forecast model is based on the matching of several sources:

**Comparison with existing data**
- Monitoring of corporate communication
- Using other market research data
- Yole analysis (consensus or not)

**Comparison with prior Yole reports**
- Recursive improvement of dataset
- Customer feedback

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**Top-to-bottom approach**
- Aggregate of market forecasts @ System level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of all players’ revenue @ System level

---

**Top-to-bottom approach**
- Aggregate of market forecast @ Semiconductor device level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of key players’ revenues @ Semiconductor device level

---

**Market**
- Volume (in Munits)
- ASP (in $)
- Revenue (in $M)

**Information Aggregation**

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**Primary data**
- Reverse costing
- Patent analysis
- Annual reports
- Direct interviews

**Secondary data**
- Press releases
- Industry organization reports
- Conferences
COMPANIES CITED IN THIS REPORT

> 100 companies cited in the report

(non-exhaustive list)

The “Die Attach Equipment Market 2019” is a new report dedicated to back-end packaging equipment. Die attach is a key process step in the semiconductor packaging covering all devices across various applications. The objectives of the report are as follows:

• Provide technology and business trends in the die attach equipment market
• Die attach equipment business investigated by various segmentation:
  • By various bonding technologies: mass reflow, TCB, eutectic, solder, sintering, epoxy, hybrid bonding etc.
  • By different device applications: logic, memory, RF, MEMS, cis, discrete, led, optoelectronics/photonics etc.
• Covers in depth analysis of the die bonder and flip-chip bonder market
• Comprehensive list of the die attach equipment suppliers with >70 companies identified.
• Technological roadmap and benchmarking of the equipment covering various devices and technologies
• Supply chain analysis: overview of the key equipment suppliers across various segments along with the installed base at customers
• Mergers and acquisitions trends in the die attach equipment business
• Competitive landscape of key tool suppliers
WHO SHOULD BE INTERESTED IN THIS REPORT

• Equipment and materials suppliers:
  • To understand the overall die attach equipment business and technology trends
  • To identify the high growth areas of the die attach equipment market
  • To identify business opportunities and prospects
  • To understand their tool positioning and market share among various tool suppliers
  • To monitor and benchmark potential competitors

• OSATs, IDMs, foundries:
  • To understand the technological trends in the die attach equipment across various devices
  • To understand the emerging technologies and its potential to disrupt the traditional die attach method
  • To know the key equipment suppliers and their tools competitiveness across different segmentations

• R&D players:
  • To gain insight into the latest developments in the die attach technologies
  • To understand the market potential of different emerging technologies

• Financial and strategic investors:
  • To know the key players involved in die attach equipment business
  • To understand which markets have the highest growth potential and how the tool suppliers involved in those segments will benefit
  • To explore the M&As opportunities

• OEMs and integrators:
  • To understand the technological trends in the die attach equipment across various devices
  • To understand the emerging technologies and its potential to disrupt the traditional die attach method
**Die Attach Equipment Market 2019 | Sample | www.yole.fr | ©2019**

**Die Attach Market Study**

**Technologies Classification**

**Die Attach Equipment**

- **Flip Chip Bonder**
  - **Die Face Down**
  - **Die Face Up or Face Down**

- **Die Bonder**
  - **Die Face Down**
  - **Die Face Up or Face Down**

**Pick and Place / Reflow Soldering**
- **Die is picked, fluxed and attached to substrate with minimal amount of force and mass-reflowed to form interconnection.**
- **Application:** logic, memory, CIS, Power, Photonics

**Thermocompression (TCB)**
- **Use force / heat / time**
- **Application:** logic, memory, MEMS, LED, Photonics

**Thermosonic Bonding**
- **Use force / heat / ultrasonic energy/time**
- **e.g. Au-Au interconnect (GGI) for display driver ICs**
- **Application:** logic, MEMS, LED, Photonics, RF, CIS

**Hybrid Bonding**
- **Use of no or small force and heat**
- **Application:** Logic/ASIC, Memory, CIS, MEMS/sensor, Photonics

**Epoxy / Adhesive (paste/film)**
- **Use of no or small force and heat**
- **Application:** Discrete, LED, MEMS/Sensor, Photonics

**Solder**
- **Use of force (small) and no heat**
- **Application:** Discrete, LED

**Sintering**
- **Use of force (large) and heat**
- **Application:** Discrete, LED

**Room temperature Cu-Cu bonding, low temperature annealing (around 300°C), no external pressure. Enables very low pitches < 1 μm. Applications:** CIS, Stacked memory, logic

Eutectic & Adhesive flip-chip bonding can be performed using TCB/TS process
Die attach market forecast by bonder type (M$)

- **Die attach tool include Flip chip bonder + Die bonder**
- **Total bonder market grow by 6% CAGR to reach from $XX in 2018 to ~ $XX in 2024**
- **FC bonder market grow by 12% CAGR to reach from $XXM in 2018 to ~$XXM in 2024**
- **Die bonder market grow by 5% CAGR to reach from $XXM in 2018 to ~$XX B in 2024**
- **Flip-chip bonder market constitutes 15% of total bonder market in 2018. It’ll increase to 21% by 2024**
Highest growth in stacked memory bonder market (24%) followed by optoelectronics (12%) & logic (8%).
Bonder market for stacked memory, which constitutes ~3% of total market in 2018 increase to 9% by 2024. In terms of revenue, it increase from $33M in 2018 to $121M in 2024.
Bonder market share for optoelectronics will increase from 11% in 2018 to 15% in 2024. Total market is expected to reach ~$213M by 2024.
LED bonder consists highest market share (28%) in 2018. However, the total market grow by only 2% CAGR to reach $310M by 2024 and market share will reduce to 22% by 2024.
• Epoxy bonding is the predominant technology of die bonding for the wire-bond packaging and die bonder constitutes ~XX% of the total bonder market in 2018. However, the share of epoxy reduce from XX% in 2018 to XX% by 2024.

• Hybrid bonding technology is still in its early stages on the C2W level and is expected to hit the market:
  • In 2021/2022 for stacked memories
  • In 2022/23 for logic devices (2.5D structure)

• TCB market will grow by XX% CAGR and its share of total bonder business increase from X% in 2018 to X% by 2024.

• Mass reflow bonder market is driven by the migration of wire-bond to flip-chip and increased adoption of Cu pillar. The bonder market will grow at 8% CAGR to reach ~XXM by 2024.

• Eutectic bonding growth is driven by the MEMS, high power LED and the optoelectronics application.
Die attach tool market is dominated by ASM & Besi, accounting for ~60% of the total business.
DIE ATTACH EQUIPMENT SUPPLIERS

Main players [Non-exhaustive list]
**Die Attach Equipment Suppliers**

By country & continent

- **Total 73 players identified**
- **12 players supply die attach for R&D/prototyping/LVM (manual/semiautomatic; table top size)**
- **China has highest number of companies (mostly due to their activities in LED/discrete) followed by Japan and Europe**
- **In Europe, many players are involved in manual/semi-automatic tool business. However, Besi is the key global player based in Austria**
- **Japanese companies are quite strong in terms of technology and have long experience of die attach tools development**
THERMO-COMPRESSION BONDING (TCB)

- TCB is using heat and pressure to bond a die to a substrate
- TCB is widely used for stacked memory and logic dies
- 5 different types of TCB exist and each is more or less dedicated to a certain type of applications

TCB

TC-NCF

TC-NCP

TC-CUF

TC-Mold

TC-ACF/ACP

Local / gang bonding

Application
- 3D TSV memory (HBM, 3DS)
- Logic
- Photonics
- Stacked CIS (CoW)
- Logic (APU/CPU)
- Logic (CPU)
- HD Fan-out die-first, face-up (APU, NPU, ASICs etc)
- FPD, LCD
- COG, COF, COP
HYBRID BONDING

Xperi DBI (hybrid bonding) technology at a glance (W2W)

• Hybrid bonding DBI technologie (Xperi proprietary technology):
  • Used for CMOS Image Sensors (CIS)
  • Room temperature Cu-Cu permanent bonding, low temperature annealing (around 300°C) & no external pressure bonding process (dielectric / metal).
  • Wafer or die bonding alignment for very fine 3D electrical interconnect (1.6µm pitch already proved by Xperi).
  • With or without TSV. Possible replacement of under-fill material in 3D stacked devices.
  • Minimal warpage or delamination problem.
  • Wafer & die surfaces planarization (CMP) required (0.1nm surface roughness required)

Electrical Interconnections without External Pressure
Minimizes Stress and Cost of Ownership

Cross-Section after Pick/Place (example)
Heating Closes Dishing Gap (~ 1 nm/µm/500°C)
Further Heating Compresses Metal w/out External Pressure

Spontaneous Chemical Reaction with Byproducts Diffusing Away from Bond Interface

Bond Interface 1.6 µm
1.6 µm DBI pitch, 300°C

Source: Xperi
Laser Assisted Bond (LAB) is the new interconnection technology using laser as a thermal energy for wetting between die bump and substrate pad and others.

Key is to emit homogenized & die sized laser beam and this laser power heat up the die only.

In the mass reflow, major challenge is the thermal stress during reflow for small nm-nodes with extra-low-k, which can be managed with LAB much better.

LAB will replace the “mass reflow” process step. All others process remain the same.
Today’s semiconductor megatrends include mobile devices, big data, artificial intelligence (AI), fifth generation (5G) wireless networking, high performance computing (HPC), the internet of things (IoT) including industrial IoT, smart automotive, industry 4.0, and data centres. These applications create demand for electronics hardware, which requires high computing power, high speed, more bandwidth, low latency, low power, more functionality, more memory, system level integration and a variety of sensors. Such trends create business opportunities across various electronic device packaging platforms. However, advanced packaging has one of the best opportunities, as it can fulfil various performance and complex heterogeneous integration requirements.

Die attach is a key process step in semiconductor packaging. It covers all devices across various applications and is a key contributor to assembly cost. The die attach equipment business benefits from assembly and packaging opportunities created by the above-mentioned trends. Die attach equipment can be classified into two categories: die bonders and flip-chip (FC) bonders. The total market was worth $979M in 2018 and is expected to grow at 6% CAGR from 2018-2024 to reach $1.3B. The FC bonder market will grow with a 12% CAGR to reach $290M in 2024 whereas the die bonder market will grow with a 5% CAGR to reach $1.09B in 2024.

By application, the highest growth is in stacked memory bonder market, with a 24% CAGR, followed by optoelectronics, with a 12% CAGR, and logic, with an 8% CAGR.

In terms of technology, epoxy bonding dominates die attach for wire-bond packaging, and related die bonders constituted around 85% of the total bonder market in 2018. However, epoxy bonding’s share will reduce to 53% by 2024. Eutectic bonding growth is driven by MEMS, high power light emitting diodes (LEDs) and optoelectronics applications. Chip-to-wafer (C2W) hybrid bonding is the emerging promising technology that can enable direct Cu-Cu bonding and has potential to replace TCB for the 3D stacked memory and high end logic application. However, C2W hybrid bonding is still in its early stages and is expected to hit the market in 2021 for stacked memory and in 2022/2023 for logic devices with 2.5D structures.

The Die Attach Equipment Market Report 2019 will cover the die attach equipment business in detail including market forecasts, player market shares by different technologies, and application segmentations. In this report, more than 70 equipment suppliers are identified across various geographical locations. The different applications covered are logic, memory, RF, MEMS, CIS, discrete, LED, optoelectronics etc. The various die attach technologies include mass reflow, TCB, eutectic, solder, sintering, epoxy and hybrid bonding.
Currently the main flip-chip bonding technology is mass reflow, followed by TCB. Different types of TCB exist, and each is more or less dedicated to a certain type of application: TC-NCF, TC-NCP, TC-CUF, TC-Mold, TC-ACF/ACP. Low unit-per-hour (UPH) rates are the key bottleneck for adoption of TCB in various applications. Equipment suppliers are using various methods, such as tool design and improved processes, to increase UPH rates.

To support the ultra-fine pitches below 20µm and high-density interconnect, new tools need to be developed. They must have high accuracy (<3µm at both global and local level), high speeds (>5,000 UPH), allow multi-mode operation to support different bonding processes, parallel pick up with more than four dies, with both flip and non-flip capabilities, have advanced inspection capabilities, a wider process window, able to handle large die sizes, large panel die bonding for areas above 600mm × 600mm etc.

As mentioned above, epoxy/adhesive bonding is the main die bonding method, with eutectic bonding growth driven by MEMS, high power LED and optoelectronics applications. Soldering is the main die-attach technology for power devices. Sintering is an emerging technology that will replace soldering in power devices in the future. To achieve high memory density, die stacking using wire-bonding is still the main technology for NAND flash packaging. It will remain the dominant technology in the coming years. Die Attach Film (DAF) is an ultra-thin film adhesive used to connect multiple dies in die-attach processes for flash memory. Ultra-thin die handling and cleanliness before die stacking are two main challenges for NAND flash packaging for die attach bonders. Flip-chip copper pillar adoption is increasing for DRAM for the PC and server applications.

Die-to-wafer hybrid bonding is an emerging technology that can replace TCB-NCF processed in 3D TSV memory. Existing tools that are compatible with such technology can be used to validate this approach. Next-generation hybrid bonding tool challenges also include surface cleanliness and die handling. Laser Assisted Bonding (LAB) is a new interconnect technology that could replace mass reflow processes for fine-pitch flip-chip bonding. It uses heat from a laser to wet out the areas between die bumps, substrate pads and other components. This report covers the technology trends, challenges, and requirements of die attach tools in different applications and packaging platforms in detail.

Although there are lot of companies involved in producing flip-chip and die attach bonders, just a few players dominate the various application segments. Two players, Besi and ASM, dominate the bonder business. They account for more than 50% of the market. This is because bonders are their main businesses, while bonders are a small part of for the other players’ businesses. Other key players are Shinkawa, Shibaura, Panasonic, and Hoson. Fastford is active in memory packaging, especially NAND flash. Hoson is the leader in LED packaging in the Chinese market. Four Tecnos, Ficontec and Palomar are mainly involved in the optoelectronics packaging tool business.

There is consolidation going on in the assembly equipment business. Players are diversifying their
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The present document is valid 24 months after its publishing date: October 3, 2019

ABOUT YOLE DÉVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services and well as IP and patent analysis. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and image sensors, Compound semiconductors, RF Electronics, Solid-state lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.
The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO, KnowMade and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

CONSULTING AND ANALYSIS
- Market data & research, marketing analysis
- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Patent analysis
- Design and characterization of innovative optical systems
- Financial services (due diligence, M&A with our partner)
More information on www.yole.fr

MEDIA & EVENTS
- i-Micronews.com website, application & related e-newsletter
- Communication & webcast services
- Events: TechDays, forums…
More information on www.i-micronews.com

REPORTS
- Market & technology reports
- Patent investigation and patent infringement risk analysis
- Structure, process and cost analysis and teardowns
- Cost simulation tool
More information on www.i-micronews.com/reports

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- Public Relations: Sandrine Leroy (leroy@yole.fr)
Yole Développement

From Technologies to Market
Photonics & Sensing
- Photonics
- Lighting
- Imaging
- Sensing & Actuating
- Display

Semiconductor & Software
- Semiconductor Packaging and Substrates
- Semiconductor Manufacturing
- Memory
- Computing and Software

Power & Wireless
- RF Devices & Technologies
- Compound Semiconductors & Emerging Materials
- Power Electronics
- Batteries & Energy Management
4 BUSINESS MODELS

- **Consulting and Analysis**
  - Market data & research, marketing analysis
  - Technology analysis
  - Strategy consulting
  - Reverse engineering & costing
  - Patent analysis
  - Design and characterization of innovative optical systems
  - Financial services (due diligence, M&A with our partner)
  
  [www.yole.fr](http://www.yole.fr)

- **Syndicated reports**
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  - Patent investigation and patent infringement risk analysis
  - Teardowns & reverse costing analysis
  - Cost simulation tool
  
  [www.i-Micronews.com/reports](http://www.i-Micronews.com/reports)

- **Monitors**
  - Monthly and quarterly update
  - Excel database covering supply, demand, and technology
  - Price, market, demand and production forecasts
  - Supplier market shares
  
  [www.i-Micronews.com/reports](http://www.i-Micronews.com/reports)

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6 COMPANIES TO SERVE YOUR BUSINESS

Yole Group of Companies

**Yole Développement**
Market, technology and strategy consulting
www.yole.fr

**SystemPlus Consulting**
Manufacturing costs analysis
Teardown and reverse engineering
Cost simulation tools
www.systemplus.fr

**KnowMade**
IP analysis
Patent assessment
www.knowmade.fr

**Piseo**
Design and characterization of innovative optical systems
www.piseo.fr

**Blumorpho**
Innovation and business maker
www.blmorpho.com

**Yole Finance**
Due diligence
www.yole.fr

About Yole Développement | www.yole.fr | ©2019
OUR GLOBAL ACTIVITY

40% of our business

30% of our business

30% of our business

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Frankfurt

Yole Korea
Seoul

Yole Japan
Tokyo

Greater China office
Hsinchu

Yole Inc.
Cornelius

Paris
Nantes
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Nice

SYSTE M P LUS

KnowMade

BLUMORPHO
SERVING THE ENTIRE SUPPLY CHAIN

Integrators, end-users and software developers

Device manufacturers

Suppliers: material, equipment, OSAT, foundries...

Financial investors, R&D centers
SERVING MULTIPLE INDUSTRIAL FIELDS

We work across multiple industries to understand the impact of More-than-Moore technologies from device to system.
Over the course of more than 20 years, Yole Développement has grown to become a group of companies. Together with System Plus Consulting and KnowMade, we now provide marketing, technology and strategy consulting, media and corporate finance services, reverse costing, structure, process and cost analysis services and well as intellectual property (IP) and patent analysis. Together, our group of companies is collaborating ever closer and therefore will offer, in 2019, a collection of over 125 reports, 10 new monitors and 120 teardowns. Combining respective expertise and methodologies from the three companies, they cover:

- MEMS & Sensors
- RF devices & technologies
- Medical technologies
- Semiconductor Manufacturing
- Advanced packaging
- Memory
- Batteries and energy management
- Power electronics
- Compound semiconductors
- Solid state lighting
- Displays
- Software
- Imaging
- Photonics

If you are looking for:

- An analysis of your product market and technology
- A review of how your competitors are evolving
- An understanding of your manufacturing and production costs
- An understanding of your industry's technology roadmap and related IPs
- A clear view supply chain evolution

Our reports and monitors are for you!

Our team of over 70 analysts, including PhD and MBA qualified industry veterans from Yole Développement, System Plus Consulting and KnowMade, collect information, identify trends, challenges, emerging markets, and competitive environments. They turn that information into results and give you a complete picture of your industry's landscape. In the past 20 years, we have worked on more than 2,000 projects, interacting with technology professionals and high-level opinion makers from the main players of their industries and realized more than 5,000 interviews per year.

WHAT TO EXPECT IN 2019?

In 2019 we will extend our offering with a new ‘monitor’ product which provides more updates on your industry during the year. The Yole Group of Companies is also building on and expanding its investigations of the memory industry. Moreover, in parallel, the Yole Group reaffirms its commitment to a new collection of reports mixing software and hardware and is increasing its involvement in displays, radio-frequency (RF) technology, advanced substrates, batteries and compound semiconductors. Last but not least, System Plus Consulting is developing its teardowns service providing 120+ offers related to phones, smart home, wearables and connected devices. Discover our 2019 program right now, and ensure you get a true vision of the industry. Stay tuned!
18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

**Market – Technology – Strategy – by Yole Développement**
Yole Développement (Yole) offers market reports including quantitative market forecasts, technology trends, company strategy evaluation and in-depth application analyses. Yole will publish more than 55 reports in 2019, with our partner PISEO contributing to some of the lighting reports.

The Reverse Costing® report developed by System Plus Consulting provides full teardowns, including detailed photos, precise measurements, material analyses, manufacturing process flows, supply chain evaluations, manufacturing cost analyses and selling price estimations. The reports listed below are comparisons of several analyzed components from System Plus Consulting. More reports are however available, and over 60 reports will be released in 2019. The complete list is available at www.systemplus.fr.

**Patent Reports – by KnowMade**
More than describing the status of the IP situation, these analyses provide a missing link between patented technologies and market, technological and business trends. They offer an understanding of the competitive landscape and technology developments from a patent perspective. They include key insights into key IP players, key patents and future technology trends. For 2019 KnowMade will release over 15 reports.

**The markets targeted are:**
- Mobile & Consumer
- Automotive & Transportation
- Medical
- Industrial
- Telecom & Infrastructure
- Defense & Aerospace

Linked reports are dealing with the same topic to provide a more detailed analysis.
OUR 2019 REPORTS COLLECTION (1/5)
18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

**MEMS & SENSORS**
- **MARKET AND TECHNOLOGY REPORT**
  - Status of the MEMS Industry 2019 - Update
  - Status of the Audio Industry 2019 - New
  - Uncooled Infrared Imagers and Detectors 2019 – Update
  - Consumer Biometrics: Technologies and Market Trends 2018
  - MEMS Pressure Sensor Market and Technologies 2018
  - Gas & Particle Sensors 2018
- **STRUCTURE, PROCESS & COST REPORT**
  - MEMS & Sensors Comparison 2019
  - MEMS Pressure Sensor Comparison 2018
  - Particle Sensors Comparison 2019
  - Miniaturized Gas Sensors Comparison 2018
- **PATENT REPORT**
  - MEMS Foundry Business Portfolio 2019 - New
  - Miniaturized Gas Sensors 2019 - New

**PHOTONIC AND OPTOELECTRONICS**
- **MARKET AND TECHNOLOGY REPORT**
  - Silicon Photonics and Photonic Integrated Circuits 2019
  - LiDARs for Automotive and Industrial Applications 2019 - Update
- **PATENT REPORT**
  - Silicon Photonics for Data Centers: Optical Transceiver 2019 - New
  - LiDAR for Automotive 2018

**RF DEVICES AND TECHNOLOGIES**
- **MARKET AND TECHNOLOGY REPORT**
  - 5G’s Impact on RF Front-End Module and Connectivity for Cell Phones 2019 – Update
    - 5G Impact on Telecom Infrastructure 2019 - New
    - Radar and Wireless for Automotive: Market and Technology Trends 2019 - Update
  - Passive & Active Antenna Systems for Telecom Infrastructure 2019 - New
  - RF Standards and Technologies for Connected Objects 2018
- **STRUCTURE, PROCESS & COST REPORT**
  - RF Front-End Module Comparison 2019 - Update
  - Automotive Radar RF Chipset Comparison 2018
- **PATENT REPORT**
  - Antenna for 5G Wireless Communications 2019 - New
  - RF Front End Modules for Cellphones 2018
  - RF Filter for 5G Wireless Communications: Materials and Technologies 2019
  - RF GaN 2019 – Patent Landscape Analysis

Update: 2018 version still available
OUR 2019 REPORTS COLLECTION (2/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

IMAGING

- MARKET AND TECHNOLOGY REPORT
  - Status of the CIS Industry 2019: Technology and Foundry Business - Update
  - Imaging for Automotive 2019 - Update
  - Neuromorphic Technologies for Sensing 2019 - Update
  - Status of the CCM and WLO Industry 2019 – Update
  - 3D Imaging & Sensing 2018
  - Machine Vision for Industry and Automation 2018
  - Sensors for Robotic Vehicles 2018

- STRUCTURE, PROCESS & COST REPORT
  - Compact Camera Modules Comparison 2019
  - CMOS Image Sensors Comparison 2019

- PATENT REPORT
  - Facial & Gesture Recognition Technologies in Mobile Devices 2019 - New
  - Apple iPhone X Proximity Sensor & Flood Illuminator 2018

MEDICAL IMAGING AND BIOPHOTONICS

- MARKET AND TECHNOLOGY REPORT
  - X-Ray Detectors for Medical, Industrial and Security Applications 2019 - New
  - Microscopy Life Science Cameras: Market and Technology Analysis 2019
  - Ultrasound technologies for Medical, Industrial and Consumer Applications 2018

- PATENT REPORT
  - Optical Coherence Tomography Medical Imaging 2018

MICROFLUIDICS

- MARKET AND TECHNOLOGY REPORT
  - Status of the Microfluidics Industry 2019 - Update
  - Organ-on-a-Chip Market & Technology Landscape 2019 - New
  - Point-of-Need Testing Application of Microfluidic Technologies 2018
  - Liquid Biopsy: from Isolation to Downstream Applications 2018
  - Chinese Microfluidics Industry 2018

- PATENT REPORT
  - Microfluidic Manufacturing Technologies 2019 – New
  - Nanopore Sequencing 2019 - New

INKJET AND ACCURATE DISPENSING

- MARKET AND TECHNOLOGY REPORT
  - Inkjet Printheads - Dispensing Technologies & Market Landscape 2019 - Update
  - Emerging Printing Technologies for Microsystems Manufacturing 2019 - New
  - Piezoelectric Devices from Bulk to Thin Film 2019 - New
  - Inkjet Functional and Additive Manufacturing for Electronics 2018

- STRUCTURE, PROCESS & COST REPORT
  - Piezoelectric Materials from Bulk to Thin Film Comparison 2019
OUR 2019 REPORTS COLLECTION (3/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

BIOMEMS & MEDICAL Microsystems

MARKET AND TECHNOLOGY REPORT
- Medical Wearables: Market & Technology Analysis 2019 - New
- Neurotechnologies and Brain Computer Interface 2018
- BioMEMS & Non-Invasive Sensors: Microsystems for Life Sciences & Healthcare 2018

PATENT REPORT
- 3D Cell Printing 2019 - New
- Circulating Tumor Cells Isolation 2019 - New

SOFTWARE AND COMPUTING

MARKET AND TECHNOLOGY REPORT
- Artificial Intelligence Computing For Automotive 2019 - New
- Hardware and Software for Artificial Intelligence (AI) in Consumer Applications 2019 - Update
- Image Signal Processor and Vision Processor Market and Technology Trends 2019
- xPU (Processing Units) for Cryptocurrency, Blockchain, HPC and Gaming 2019 – New
- Artificial Intelligence for Medical Imaging 2019 - New

PATENT REPORT
- Artificial Intelligence for Medical Diagnostics - New

MEMORY

MARKET AND TECHNOLOGY REPORT
- Status of the Memory Industry 2019 - New
- MRAM Technology and Business 2019 - New
- Emerging Non Volatile Memory 2018

STRUCTURE, PROCESS & COST REPORT
- Memory Comparison 2019

PATENT REPORT
- Magnetoresistive Random-Access Memory (MRAM) 2019 - New
- 3D Non-Volatile Memory 2018

ADVANCED PACKAGING

MARKET AND TECHNOLOGY REPORT
- Fan Out Packaging Technologies and Market Trends 2019 - Update
- 3D TSV Integration and Monolithic Business Update 2019 - Update
- Advanced RF SiP for Cellphones 2019 - Update
- Status of the Advanced Packaging Industry 2019 - Update
- Status of the Advanced Substrates 2019 - Update
- Panel Level Packaging Trends 2019 - Update
- Automotive Packaging Market & Technology Trends 2019 - New
- Trends in Automotive Packaging 2018
- Thin-Film Integrated Passive Devices 2018

STRUCTURE, PROCESS & COST REPORT
- Advanced RF SiP for Cellphones Comparison 2019

Update: 2018 version still available
OUR 2019 REPORTS COLLECTION (4/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

SEMICONDUCTOR MANUFACTURING

- **MARKET AND TECHNOLOGY REPORT**
  - Nano-Imprint Technology Trends for Semiconductor Applications 2019 - New
  - Equipment and Materials for Fan Out Packaging 2019 - Update
  - Equipment for More than Moore: Thin Film Deposition & Etching 2019 - New
  - Wafer Starts for More Than Moore Applications 2018
  - Polymeric Materials at Wafer-Level for Advanced Packaging 2018
  - Bonding and Lithography Equipment Market for More than Moore Devices 2018

- **STRUCTURE, PROCESS & COST REPORT**
  - Wafer Bonding Comparison 2018

- **PATENT REPORT**
  - Hybrid Bonding for 3D Stack 2019 – New

BIOTECHNOLOGIES

- **MARKET AND TECHNOLOGY REPORT**
  - CRISPR-Cas9 Technology: From Lab to Industries 2018

- **PATENT REPORT**
  - Personalized Medicine 2019 – New

SOLID STATE LIGHTING

- **MARKET AND TECHNOLOGY REPORT**
  - Status of the Solid State Light Source Industry 2019 - New
  - Edge Emitting Lasers (EELS) 2019 - New
  - Light Shaping Technologies 2019 - New
  - Automotive Advanced Front Lighting Systems 2019 - New
  - VCSELs – Market and Technology Trends 2019 - Update
  - IR LEDs and Laser Diodes – Technology, Applications, and Industry Trends 2018
  - UV LEDs - Technology, Manufacturing and Application Trends 2018
  - LiFi: Technology, Industry and Market Trends 2018

- **STRUCTURE, PROCESS & COST REPORT**
  - VCSEL Comparison 2019

- **PATENT REPORT**
  - VCSELs 2018

DISPLAY

- **MARKET AND TECHNOLOGY REPORT**
  - Next Generation 3D Displays 2019 - New
  - Next Generation Human Machine Interaction (HMI) in Displays 2019 - New
  - Micro- and Mini-LED Displays 2019 - Update
  - Displays & Optical Vision Systems for VR, AR & MR 2018

- **PATENT REPORT**
  - MicroLED Displays: Intellectual Property Landscape 2018
**POWER ELECTRONICS**

- **MARKET AND TECHNOLOGY REPORT**
  - Power SiC: Materials, Devices and Applications 2019 - Update
  - Power Electronics for EV/HEV and e-mobility: Market, Innovations and Trends 2019 - Update
  - Status of the Power Electronics Industry 2019 - Update
  - Discrete Power Packaging: Material Market and Technology Trends 2019 - New
  - Status of the Power ICs Industry 2019 - Update
  - Status of the Passive Components for the Power Electronics Industry 2019 - Update
  - Status of the Inverter Industry 2019 - Update
  - Status of the Power Module Packaging Industry 2019 - Update
  - Wireless Charging Market Expectations and Technology Trends 2018
  - Power GaN 2018: Epitaxy, Devices, Applications and Technology Trends

- **STRUCTURE, PROCESS & COST REPORT**
  - Automotive Power Module Packaging Comparison 2018
  - GaN-on-Silicon Transistor Comparison 2019
  - SiC Transistor Comparison 2019

- **PATENT REPORT**
  - Power SiC: Materials, Devices and Modules 2019 - New
  - Power GaN: Materials, Devices and Modules 2019 – Update

**BATTERY & ENERGY MANAGEMENT**

- **MARKET AND TECHNOLOGY REPORT**
  - Status of the Rechargeable Li-ion Battery Industry 2019 - New
  - Li-ion Battery Packs for Automotive and Stationary Storage Applications 2019 - Update

- **PATENT REPORT**
  - Battery Energy Density Increase: Materials and Emerging Technologies 2019 - New
  - Solid-State Batteries 2019 - New
  - Status of the Battery Patents 2018

**COMPOUND SEMI.**

- **MARKET AND TECHNOLOGY REPORT**
  - Emerging Semiconductor Substrates: Market & Technology Trends 2019 - New
  - Status of the Compound Semiconductor Industry 2019 - New
  - InP Materials, Devices and Applications 2019 - New
  - GaAs Wafer and Epiwafer Market: RF, Photonics, LED and PV Applications 2018

- **PATENT REPORT**
  - GaN-on-Silicon Substrate: Materials, Devices and Applications 2019 - Update

Update: 2018 version still available
Get the most updated overview of your market to monitor your strategy

Yole Développement, System Plus Consulting and KnowMade, all part of the Yole Group of Companies, are launching a collection of 10 monitors in 2019. The monitors aim to provide updated market, technology and patent data as well dedicated quarterly analyses of the evolution in your industry over the previous 12 months. Furthermore, you can benefit from direct access to the analyst for an on-demand Q&A and discussion session regarding trend analyses, forecasts and breaking news.

Topics covered will be compact camera modules (CCMs), advanced packaging, compound semiconductors, microfluidics, batteries, RF and memory.

**MARKET MONITOR** by Yole Développement

**A FULL PACKAGE:**
The monitors will provide the evolution of the market in units, wafer area and revenues. They will also offer insights into what is driving the business and a close look at what is happening will also be covered in it.

The following deliverables will be included in the monitors:
- An Excel database with all historical and forecast data
- A PDF slide deck with graphs and comments/analyses covering the expected evolutions

**ADVANCED PACKAGING – NEW**
This monitor will provide the evolution of the advanced packaging platforms. It will cover Fan-Out Wafer Level Packaging (WLP), Fan-Out Panel Level Packaging (PLP), Wafer-Level Chip Scale Packaging (WLCSP), Flip Chip packaging platforms, and 2.5D and 3D Through Silicon Via (TSV) integration. **Frequency: Quarterly, starting from Q3 2019**

**COMPOUND SEMI. – NEW**
This monitor will describe how the compound semiconductor industry is evolving. It will offer a close look at GaAs, InP, SiC, GaN and other compounds of interest providing wafer volumes, revenues, application breakdowns and momentum. **Frequency: Quarterly, starting from Q3 2019**

**CAMERA MODULE – NEW**
This monitor will provide the evolution of the imaging industry, with a close look at image sensor, camera module, lens and VCM. Volumes, revenues and momentum of companies like Sony, Samsung, Omnivision and OnSemi will thus be analysed. **Frequency: Quarterly, starting from Q3 2019**

**MEMORY – UPDATE**
For the memory industry you can have access to a quarterly monitor, as well as an additional service, a monthly pricing. Both services can be bought separately:
- **DRAM Service:** Including a quarterly monitor and monthly pricing.
- **NAND Service:** Including a quarterly monitor and monthly pricing.

**REVERSE TECHNOLOGY MONITOR** by System Plus Consulting

**SMARTPHONES – NEW**
To stay updated on the latest components, packaging and silicon chip choices of the smartphone makers, System Plus Consulting has created its first Smartphone Reverse Technology monitor. This year, get access to the packaging and silicon content database of at least 20 different flagship smartphones – more than five per quarter. Starting at the beginning of 2019, the monitor will include an Excel database report for each phone and a quarterly comparison.
OUR 2019 MONITORS COLLECTION (2/2)

Get the most updated overview of your market to monitor your strategy

PATENT MONITOR by KnowMade

A FULL PACKAGE:
Starting at the beginning of the year, the KnowMade monitors include the following deliverables:

- An Excel file including the monthly IP database of:
  - New patent applications
  - Newly granted patents
  - Expired or abandoned patents
  - Transfer of IP rights through re-assignment and licensing
  - Patent litigation and opposition
- Quarterly report including a PDF slide deck with the key facts & figures of the quarter: IP trends over the three last months, with a close look to key IP players and key patented technologies.

- GaN for Power & RF Electronics
  Wafers and epiwafers, GaN-on-SiC, silicon, sapphire or diamond; semiconductor devices such as transistors, and diodes, devices and applications including converters, rectifiers, switches, amplifiers, filters, and Monolithic Microwave Integrated Circuits (MMICs), packaging, modules and systems.

- GaN for Optoelectronics & Photonics
  Wafers and epiwafers, GaN-on-sapphire, SiC or silicon; semiconductor devices such as LEDs and lasers; and applications including lighting, display, visible communication, photonics, packaging, modules and systems.

- Li-ion Batteries
  Anodes made of lithium metal, silicon, and lithium titanate (LTO); cathodes made of Lithium Iron Phosphate (LFP), Nickel-Manganese-Cobalt (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Nickel Metal Dioxide (LiNiMO2), Lithium Metal Phosphate (LiMPO4), and Lithium Metal Tetroxide (LiMO4); electrolytes including liquid, polymer/gel, and solid inorganics; ceramic and other separators; battery cells including thin film/microbattery, flexible, cylindrical and prismatic; and battery packs and systems.

- Post Li-ion Batteries
  Battery technologies including redox-flow batteries, sodium-ion, lithiumsulfur, lithium-air, and magnesium-ion, and their supply chains, including electrodes, electrolytes, battery cells and battery packs/systems.

- Solid-State Batteries
  Supply chain including electrodes, battery cells, battery packs/systems and electrolytes, including polymer, inorganic and inorganic/polymer, inorganic materials, including argyrodites, Lithium Super Ionic CONductor, (LISICONs), Thio-LISICONs, sulfide glasses, oxide glasses, perovskites, anti-perovskites and garnets.

- RF Acoustic Wave Filters
  Including Surface Acoustic Wave (SAW), Temperature Compensated (TC)- SAW, Bulk Acoustic Wave- Free-standing Bulk Acoustic Resonator (BAWFBAR), BAW-Solidly-Mounted Resonator (BAW-SMR), and Packaging.

- RF Power Amplifiers
  Including Low Noise Amplifiers, Doherty Amplifiers, Packaging, and Millimeter-Wave technology.

- RF Front-End Modules

- Microfluidics
  From components to chips and systems, including all applications.
To meet the growing demand for market, technological and business information, i-Micronews Media integrates several tools able to reach each individual contact within its network.

We will ensure your company benefits from this

<table>
<thead>
<tr>
<th>ONLINE</th>
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<tr>
<td>i-Micronews e-newsletter</td>
<td>Events</td>
<td>Webcasts</td>
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<td>i-Micronews.com</td>
<td>Brand visibility, networking opportunities</td>
<td>Targeted audience involvement equals clear, concise perception of your company’s message.</td>
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<tr>
<td>FreeFullPDF.com</td>
<td>Online display advertising campaigns are great strategies for improving your product/brand visibility. They are also an efficient way to adapt with the demands of the times and to evolve an effective marketing plan and strategy.</td>
<td>Today’s technology makes it easy for us to communicate regularly, quickly, and inexpensively – but when understanding each other is critical, there is no substitute for meeting in-person. Events are the best way to exchange ideas with your customers, partners, prospects while increasing your brand/product visibility.</td>
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Online display advertising campaigns are great strategies for improving your product/brand visibility. They are also an efficient way to adapt with the demands of the times and to evolve an effective marketing plan and strategy.

Unique, cost-effective ways to reach global audiences. Online display advertising campaigns are great strategies for improving your product/brand visibility. They are also an efficient way to adapt with the demands of the times and to evolve an effective marketing plan and strategy.

| #15,800+ monthly unique visitors on i-Micronews.com | #110 attendees on average | #380 registrants per webcast on average to gain new leads for your business |
| #10,900+ weekly readers of i-Micronews e-newsletter | #7+ key events planned for 2019 on different topics | #7+ key events planned for 2019 on different topics |

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