Status of the Memory Industry 2019
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Simone is a Technology & Market analyst at Yole Développement (Yole) working with the Semiconductor & Software division. He is member of the Yole’s memory team and he contributes on a day-to-day basis to the analysis of memory markets and technologies, their related materials and fabrication processes. Previously, Simone carried out experimental research in the field of nanoscience and nanotechnology, focusing on emerging semiconducting materials and their device applications. He (co-) authored more than 15 papers in high-impact scientific journals and was awarded the prestigious Marie Curie Intra-European Fellowship. Simone obtained a PhD in physics in 2015 from École Polytechnique Fédérale de Lausanne (Switzerland), where he developed novel flash memory cells based on heterostructures of 2D materials and high-k dielectrics. Simone earned a double M. A. Sc. degree from Polytechnique de Montréal (Canada) and Politecnico di Milano (Italy), graduating cum laude.

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Walt Coon

Walt Coon joins Yole Développement’s memory team as VP of NAND and Memory Research, part of the Semiconductor & Software division. Walt is leading the day-to-day production of both market updates, Market Monitors and Pricing Monitors, with a focus on the NAND market and semiconductor industries. In addition, he is deeply involved in the business development of these activities. Walt has significant experience within the memory & semiconductor industry. He spent 16 years at Micron Technology, managing the team responsible for competitor benchmarking, and industry supply, demand, and cost modeling. His team also supported both corporate strategy and Mergers & Acquisitions analysis.

Previously, he spent time in Information Systems, developing engineering applications to support memory process and yield enhancement. Walt Coon earned a Master of Business Administration from Boise State University (Idaho, United-States) and a Bachelor of Science in Computer Science from the University of Utah (United-States).

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Mike Howard is member of the memory team at Yole Développement (Yole) as VP of DRAM and Memory Research. Mike’s mission at Yole is to deliver a comprehensive understanding of the entire memory and semiconductor landscape (with special emphasis on DRAM) via market updates, Market Monitors, and Pricing Monitors. Mike is also deeply involved in the business development of all memory activities. Mike has a deep understanding of the DRAM and memory markets with a valuable combination of industry and market research experience. For the decade prior to joining Yole, Mike was the Senior Director of DRAM and Memory Research at IHS. Before IHS, Mike worked at Micron Technology where he had roles in corporate development, marketing, and engineering. Mike earned a Master of Business Administration at The Ohio State University (United-States), a Bachelor of Science in Chemical Engineering and a Bachelor of Arts in Finance at the University of Washington (Washington, United-States).

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Santosh Kumar
Santosh Kumar is working as Principal Analyst and Director Packaging, Assembly & Substrates, Yole Korea, part of Yole Développement (Yole). Based in Seoul, Santosh is strongly involved in the market, technology and strategic analysis of the microelectronic assembly & packaging technologies and present his vision of the industry in numerous conferences as well as through papers and patents publication.
His main interest areas are advanced IC packaging technology including equipment & materials. He is the author of several reports on fan-out / fan-in WLP, flip chip, and 3D/2.5D packaging.
Santosh Kumar received the bachelor and master degree in engineering from the Indian Institute of Technology (IIT), Roorkee and University of Seoul respectively.
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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

**Preexisting information**

---

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

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

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

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**Semiconductor foundry activity**
- Capacity investments and equipment needs

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

**Secondary data**
- Press releases
- Industry organization reports
- Conferences

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SCOPE OF THE REPORT

Leveraging on a sound expertise in memory technologies and related markets, Yole decided to publish the new report “Status of the Memory Industry 2019”, providing a broad overview of the overall memory industry.

The objectives of the report are as follows:

• **Stand-alone memory market overview**
  • NAND and DRAM market trends
  • Other stand-alone memories:
    ▪ Stand-alone NOR Flash
    ▪ Emerging NVM (PCM, MRAM, RRAM)
    ▪ RAM: (nv)SRAM, FRAM, etc.
    ▪ EEPROM, EPROM, mask PROM/ROM
  • China memory market
  • Packaging of stand-alone memory devices

• **Technology trends and forecasts**
  • Revenue and bit demand-shipment forecasts
  • Future developments by technology
  • Memory packaging technology trends
  • Challenges and opportunities for emerging NVM
  • Scaling and functional roadmaps

• **Supply chain analysis**
  • Mapping of the supply chain from materials and equipment suppliers to module makers (SSD, DIMM)
  • Financial analysis of top 10 memory players involved in the NAND, DRAM and NOR businesses
  • Analysis of the China memory players
DEFINITIONS - STORAGE-CLASS MEMORY (SCM)

The main application for new stand-alone emerging NVM, such as 3D XPoint

- SCM is IBM's term for a new class of storage/memory devices in-between “working memory” and “data storage”

- Working memory: “short-term” memory (volatile)
- Data Storage: “long-term” memory (non-volatile)
- Storage-Class Memory: Novel memory technologies that fill the speed-cost-capacity gap between NAND and DRAM
• NAND and DRAM account for ≈XX% of the overall stand-alone memory market. NAND and DRAM markets are fueled by the growing need for memory in mobile devices (smartphone and tablet) and data centers (storage and memory).

• Combined NAND and DRAM revenue was ≈ $XXX billion in 2018, up XX% from 2017 - a new record for the industry.

• Due to price declines, revenues started to decline at the end of the year: Q4 2018 down XX% from Q3 2018.

**2018 Stand-Alone Memory Market Breakdown by Technology**

**Total Market in 2018 ≈ $165 billions**

**Combined NAND and DRAM revenues**

Yole Développement © March 2019
NAND MEMORY - LEADING PLAYERS BY MARKET SEGMENTS

- Samsung is the undisputed leader in the SSD and Mobile segments (largest markets) followed by the Toshiba-Western Digital alliance.
- Samsung does not focus on the Removable (e.g. MMC) & Consumer segment, which is dominated by Toshiba and Western Digital with a combined market share of ~XX%.

Total 2018 NAND market ~$XXB
Samsung is leading the largest market segments - Datacenter and Mobile - as well as Graphics and Consumer segments.

SK Hynix and Samsung are the top players for PC DRAM, whereas Micron leads the Automotive DRAM market.

Total 2018 DRAM market
~$ XXX B
NAND BIT GROWTH FORECAST - A SYSTEM POINT OF VIEW (1/2)

• Most of the NAND bits produced in the coming years will be used in enterprise SSDs for datacenter applications
• Automotive is the fastest growing segment for NAND-bit demand with a CAGR\textsubscript{18-24} = XX%
• Servers for datacentres and smartphones will be the major consumers of DRAM bits, reaching ~XX billion GB by 2024
• Automotive is the fastest growing segment for NAND-bit demand with a CAGR_{18-24} \approx XX

**DRAM demand from different systems (in GB)**

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<td>Servers</td>
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96L and 128L will be the dominant technology processes by 2021 (>XX% combined shares). Technology generations >128L will be dominant in 2024.
The average node is scaling by ca. X% each year from 2018 to 2024.

Lynm will become the dominant technology process by 2021 (>XX%).
3D XPOINT TECHNOLOGY FOR PERSISTENT MEMORY APPLICATIONS

The first emerging NVM technology to enter the non-volatile DIMM market

End of JV: Micron and Intel will develop 3D XPoint independently after the 2nd gen. development

- R&D on 3D XPoint
- Mass Production at Lehi, Utah

* Beginning of JV between Micron and Intel (IMFT)  First Optane SSD • First Optane DIMM


Initial prices from two US retailers (April 2019)

Globally available in 2H 2019

<table>
<thead>
<tr>
<th>Module</th>
<th>Price from CompSource.com</th>
<th>Price from ShopBLT.com</th>
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<tbody>
<tr>
<td>Optane DC Persistent Memory 128 GB</td>
<td>$893</td>
<td>$842</td>
</tr>
<tr>
<td></td>
<td>$6.97 per GB</td>
<td>$6.57 per GB</td>
</tr>
<tr>
<td>Optane DC Persistent Memory 256 GB</td>
<td>$2,850</td>
<td>$2,668</td>
</tr>
<tr>
<td></td>
<td>$11.13 per GB</td>
<td>$10.42 per GB</td>
</tr>
<tr>
<td>Optane DC Persistent Memory 512 GB</td>
<td>$7,816</td>
<td>N.A.</td>
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<tr>
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<td>$15.26 per GB</td>
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SK Hynix, Samsung and Intel are the major foreign chip manufacturers with significant memory production in China.

- **SK Hynix**’s 300mm China **DRAM** fab in Wuxi had an installed capacity of XXX WPM.
- **Samsung**’s **3D NAND** flash fab in X’ian had about USD XXX spent on it so far and has an installed capacity of XXXXXX wpm as Q4 2018. The total budget at the site is USD XXX.
- **Intel**’s 300mm fab in Dalian (Fab 68) switched to **3D NAND** manufacturing in 2015-2016 and had an installed capacity of XXXXX wafer starts per month in Q4 2018.

**Local Memory Players**

- **DRAM**
  - CXMT
  - 紫光集团
  - JHICC

- **NAND**
  - 紫光集团
  - UniIC
  - XMT
  - XMC

- **NOR**
  - GigaDevice
  - SMIC
  - ISSI

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ANALYSIS OF CHINA MEMORY LANDSCAPE

Key semiconductor manufacturing players in China (including foundries)

China has been investing for long in its domestic IC industry. It also has lured various multinational chipmakers to build memory and foundry fabs.

- Dalian (3D NAND)
- Wuxi (DRAM)
- Beijing (Foundry)
- Xiamen (Foundry)
- Xi'an (3D NAND)
- Xi'an (DRAM)
- Hefei (Fabless)
- Hefei (DRAM)
- Shanghai (Foundry)
- JiNan (DRAM and 3D NAND)
- WuXi (DRAM)
- H cheering (Foundry)
- Chengdu (3D NAND)
- Chengdu (22nm FD-SOI)
- Xi'an UniIC Semiconductors Co., Ltd.

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TSINGHUA UNIGROUP - MEMORY BUSINESS

A comprehensive group of companies to boost the Chinese memory business

**Notes**

1. Unigroup Guoxin plans to transfer its stake in Xi'an UniC Semiconductors (DRAM) to UNIC Memory Technology (UNIC). In this way, Tsinghua Unigroup can integrate resources and enhance its competitiveness in the memory business. Notably, Intel's Fable is sold to the consortium selling 3D NAND to UNIC.

2. UNIC's China's most advanced 3D NAND manufacturers, XMC, XMC's online marketing for its DDR business and the joint venture partner of UNIC for packaging NAND.

3. Thanks to UniFem Microelectronics, Unigroup can now provide back-end services for various memory products, including 3D/3D NAND, NOR, DRAM, and SRAM.

4. In 2018, Unigroup signed a logistics partnership with Massamba Longsys Electronics (SSD) and teamed with controller chip provider Phison Electronics for NAND controller chips to further expand the group's memory and storage ecosystem.
OTHER STAND-ALONE MEMORY TECHNOLOGIES

STAND-ALONE (nv)SRAM - MARKET EVOLUTION

The stand-alone (nv)SRAM market is been

- The stand-alone (nv)SRAM market in 2019 was US$1.6 B, up 12% year-on-year from 3 Q of 2018 (Apple, iPhone).  
- A similar trend was observed for ASPs are up significantly. 
- The average sales per unit have been significantly increased. 
- Cypress focus mainly on high-density NOR products (64Mb - 2Gb), which are more profitable than their low-density counterparts. Macronix and Winbond cover a broader range of capacities (512Kb - 2Gb).

STAND-ALONE NOR FLASH MEMORY - MARKET EVOLUTION

NOR MEMORY - MAIN MARKET PLAYERS

- Players in Greater China (GigaDevice, Macronix and Winbond) hold more than XX of the total NOR market, followed by US players (Cypress and Micron) with more than XX of the market. 
- The NOR supply chain in Greater China is well developed (See Chapter on “China Memory Landscape”)
- Cypress and Micron focus mainly on high-density NOR products (64Mb - 2Gb), which are more profitable than their low-density counterparts. Macronix and Winbond cover a broader range of capacities (512Kb - 2Gb).

2018 NOR memory players market share, by revenue
FINANCIAL ANALYSIS

FINANCIAL ANALYSIS - ASP, OPERATING COST AND MARGIN

Focus on the DRAM business:

- Thanks to its diversified product portfolio, operating margins significantly improved.

FINANCIAL ANALYSIS - RESEARCH AND DEVELOPMENT

FINANCIAL ANALYSIS - TOP 10 PLAYERS BY REVENUE

Memory Revenues in Billion US$
MARKET FORECASTS

DRAM MARKET AVERAGE SELLING PRICE (ASP) - FORECAST

- Prices remain under pressure due to oversupply.
- The market will remain oversupplied through 2019 with prices falling ~36%.
- The DRAM market is forecasted to reach its peak revenue in 2022 (~$135 B).

NAND MARKET BIT SHIPMENTS - FORECAST

- NAND prices remained flat in 2018.
- Shipments to the consumer market will continue to grow.
- NAND market is forecasted to grow at a CAGR of 25%.

DRAM MARKET REVENUE - FORECAST

- Despite significant price pressure, DRAM revenue is expected to remain stable.
- DRAM revenue is forecasted to reach $38 B in 2019.

NAND MARKET CAPEX - FORECAST

- Differences in planar vs. 3D process flows shift capex focus from lithography to deposition and etch.
  - Substantial fab re-tooling is required to convert existing planar fabs to 3D.
- Processing time is significantly higher for 3D relative to planar NAND.
  - Major investments are required in new capacity to maintain flat wafer output during transitions.
MEMORY PLAYERS’ ANALYSIS

Micron is the only player focusing on all the four major stand-alone technologies.

WD acquired SanDisk in 2016

Alliance: Toshiba-WD

Micron acquired Inotera memory from Nanya in 2016

Intel-Micron JV - IMFT (from 2006 to 2019)

In 2018, SK Hynix and Cypress entered into a JV for NAND Flash business

Cypress and Spansion merged in 2014
SUPPLY CHAIN ANALYSIS - GENERAL SCHEME

IDM

DESIGN / FABLESS

FAB / FOUNDRY

ASSEMBLY / PACKAGING / TEST

MODULE MAKERS / INTEGRATORS

End Market

Materials, components and equipment suppliers

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(*) Although some foundries are active in the stand-alone memory business, most of them focus preferentially on embedded applications
SUPPLY CHAIN ANALYSIS – PLAYERS’ MAPPING

EMERGING NVM – MATERIALS AND EQUIPMENT SUPPLIERS

Materials/equipment players are critical for the development of emerging NVMs

- MATERION
- DOW
- MERCK
- VERSUM
- MII
- ON Semiconductor
- Applied Materials
- Canon
- TEL
- SINGULUS
- ...and more
- Lam
- Hitachi
- Applied Materials
- TEL
- Annealing (MRAM)
- TEL
- ...and more

TESTING EQUIPMENT:
- ADVANCE TEST
- HIOKI
- OHT
- CAPRES
- SHIMADZU

SEMICONDUCTOR PRODUCTION EQUIPMENT (SPE) SUPPLIERS

Key players
- Lithography
- Cleaning System
- CVD
- E-beam Deposition
- SEM
- Pattern
- Dry Etching
- Metal Deposition
- Wafer Inspection
- Photomask Inspection

STORAGE MODULE SUPPLIERS

Key players
- SSD
- Hynix
- Micron
- Intel
- Toshiba
- Samsung
A 360° analysis of the memory industry and its competitive landscape.

EXPLOSIVE MEMORY BIT DEMAND FROM DATA-CENTRIC SYSTEMS AND APPLICATIONS WILL DRIVE LONG-TERM MEMORY MARKET GROWTH

Despite some cyclical and seasonality, the stand-alone memory market has experienced extraordinary growth over the past decade. This has been driven by important megatrends, such as mobility, cloud computing, artificial intelligence (AI), and the Internet of Things (IoT). NAND and DRAM account together for around 97% of the overall stand-alone memory market. Their revenues hit a record high of around US$160 billion in 2018, registering an impressive compound annual growth rate (CAGR) of 32% between 2016 and 2018.

At the end of 2018, both NAND and DRAM markets started experiencing oversupply caused by unseasonably weak demand, including lower-than-expected smartphone sales and a slowdown in datacenter demand. DRAM prices are projected to decline by around 40% this year and likely will not increase again until 2020. For NAND, the outlook is more positive with potential for tight market conditions in the second half of 2019.

In the long-term, NAND and DRAM revenues are forecast to grow with CAGR 2018-2024 of 4% and 1% respectively. This is thanks to ever-growing bit demand fueled by novel AI/IoT applications and systems, such as smart cities, connected homes and intelligent factories, smartphones and Echo-like personal assistants, virtual and augmented reality and autonomous vehicles. All these rely on a massive amount of data and on the networks that connect them all. Thus, the coming rollout of fifth generation (5G) wireless technology will be critical for their future market expansion.

Yole Développement’s memory team carried out a systematic study of the evolution of memory requirements in various key systems, including servers, smartphones, PCs, enterprise/client solid state drives (SSDs), and vehicles. Servers and enterprise SSDs for datacenters are the most important bit-consuming systems for DRAM and NAND memory, respectively. On the other hand, autonomous vehicles is the fastest growing segment. The amount of bits in cars is expected to grow by orders of magnitude due to increasing penetration of advanced driver assistance systems (ADAS) for autonomous vehicles.

Notably, emerging non-volatile memory (eNVM) started making inroads into the storage-class memory (SCM) market with the introduction in 2017 of Intel’s Optane phase-change memory (PCM) products. As the new generations of Xeon server CPUs are conceived to be compatible with the new Optane persistent memory modules (NVDIMM), Intel might be able to gain significant business at the expense of Samsung and SK Hynix, who are now getting ready with their own PCM products.

The “Status of the Memory Industry” report provides a 360° overview of the stand-alone memory market and its competitive landscape, detailing the technology and market trends in the fields of NAND, DRAM, NOR, eNVM, and other stand-alone devices.

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**DRAM & NAND: average capacity & price evolution per system**

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<thead>
<tr>
<th>Capacity</th>
<th>Price</th>
<th>CAGR 2018-2024</th>
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<td>Server</td>
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<td>Vehicle</td>
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(Source: Yole Développement, May 2019)
COMPLEX TECHNOLOGY-SCALING CHALLENGES REQUIRE INCREASINGLY HIGHER CAPITAL EXPENDITURES TO ACHIEVE SIGNIFICANT BIT DENSITY GROWTH

Continuous advancements in semiconductor memory technologies are critical for the technical and economic viability of newly emerging data-centric applications. NAND and DRAM scalability was supposed to peak in 2020, but memory manufacturers and equipment players have found new solutions - just like in the past - to exceed this limit. New manufacturing techniques include self-aligned multiple patterning, extreme ultra-violet (EUV) lithography and metrology, as well as high aspect ratio (HAR) etching to produce contact holes in 3D NAND devices. Novel advanced packaging methods for heterogeneous integration include 2.5D silicon interposer and 3D stacking. Together, these technologies create new opportunities for the semiconductor industry to increase the bit density in next-generation memory devices, to improve their bandwidth and reduce their power consumption and cost-per-bit.

However, with each technology generation bit growth is also becoming significantly more expensive. For instance, multi-patterning requirements are increasing with each node migration, resulting in additional processing steps and therefore more cleanroom space per wafer produced. Huge annual capital expenditure (CAPEX) and R&D investments, reaching several billion US dollars, are still being made in existing DRAM and NAND technologies. However, due to the degradation of the pricing environment initiated in late 2018, CAPEX investments are now being reduced in order to quickly achieve a balanced market condition. In the long-term, the CAPEX required per 1% of bit growth is expected to continue rising, as illustrated in the figure for the case of DRAM.

THE ENTRANCE OF CHINESE PLAYERS MIGHT TRIGGER A NEW PHASE OF CONSOLIDATION OF THE MEMORY MARKET

Market concentration has accelerated dramatically in the last decade and is now very high, with three dominant NAND and DRAM players, namely Samsung, Micron, and SK Hynix, and two pure NAND players, namely Toshiba and SanDisk/Western Digital, holding a combined 95% market share. Nowadays, it is unlikely that the memory market could consolidate further. No significant mergers or acquisitions were recorded in 2018 in the DRAM industry. The major event in the NAND business was the sale of Toshiba’s memory unit to an investment group led by Bain Capital and including Apple, SK Hynix, Dell, Kingston and Seagate.

Meanwhile, Chinese players could become a threat and might trigger a new phase of market consolidation in the long term. In China, central and local governments, in partnership with a number of private players, are investing billions of dollars to develop a local semiconductor memory ecosystem. The objectives are (i) to bridge the gap between domestic production and consumption, (ii) reduce dependency on the supply of global memory companies, and (iii) fulfill huge memory-chip demand in strong growth segments like mobile/wireless, consumer, servers, AI, IoT, and automotive.

In the NAND business, Yangtze Memory Technologies Co. (YMTC) is the most likely to succeed out of all the publicly-known Chinese memory players, thanks to significant financial backing from government investment funds and a head start on R&D and manufacturing. The company’s volume production of 64-layer 3D NAND devices based on the newly-developed Xtacking™ technology is expected to take off in the second half of 2019.

On the other hand, DRAM in China is still in the technology-development phase. DRAM manufacturing is incredibly difficult and it will likely take a while longer for China to achieve competitive parity with the rest of the industry.

We expect that significant output from Chinese vendors could reach the market in 2020 for NAND, likely later for DRAM. Meanwhile, stand-alone NOR will remain the most solid memory business in China thanks to a well-developed local supply-chain system. In coming years, a possible relaxation of the China-US trade tension might open up new opportunities for China to acquire key companies across the memory supply chain, which could reinforce China’s position in the semiconductor memory industry.

The “Status of the Memory Industry” report offers a critical overview of all key market players’ activities, highlighting challenges and opportunities to consolidate their business in the competitive memory landscape.
REPORT OBJECTIVES

• Present an overview of the stand-alone memory market:
  > NAND, DRAM, NOR, (NV)SRAM, 3D XPoint, and more
  > Current technological status and roadmap for the coming years
  > Competitive landscape, activities and strategies of key market players
• Provide an understanding of stand-alone memory technologies and applications:
  > Roadmaps with technology nodes, product development status, chip-density evolution, scaling challenges and potential solutions
  > Main memory end-markets: datacenter, mobile, automotive, PC and consumer electronics
  > Memory content evolution in key systems: servers, smartphones, personal computers, vehicles, client and enterprise SSDs
• Deliver market forecasts for the stand-alone memory businesses:
  > Market forecast for 2018-2024 for established and emerging stand-alone memory technologies
  > Detailed NAND and DRAM market forecasts for 2018-2024: revenues and CAPEX by players, price per bit, market shares, bit demand, bit shipments, wafer production, and more
• Detail and analyze the competitive landscape:
  > Financial analysis: revenues, CAPEX, R&D, operating costs and margins of key memory companies
  > Recent acquisitions and funding
  > Latest company news

COMPANIES CITED IN THE REPORT (non exhaustive list)


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ABOUT YOLE DÉVELOPPEMENT
Founded in 1998, Yole Développement 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 80 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-State Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Nanomaterials, Power Electronics and Batteries & Energy Management.
The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and KnowMade, support industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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Our analysts provide market analysis, technology evaluation, and business plans along the entire supply chain.

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Mobile phone and consumer electronics

From A to Z…
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 indepth 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.
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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
  - Photonic Integrated Circuit 2019 - New
  - LiDARs for Automotive and Industrial Applications 2019 - Update
  - Silicon Photonics 2018

- 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 Wireless Infrastructure 2019
  - Radar and Wireless for Automotive: Market and Technology Trends 2019 - Update
  - Advanced RF Antenna Market & Technology 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 : Materials, Devices and Modules 2018

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**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 - Update
  - 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

**INKJET AND ACCURATE DISPENSING**
- **MARKET AND TECHNOLOGY REPORT**
  - Inkjet Printheads - Dispensing Technologies & Market Landscape 2019 - Update
  - Emerging Printing Technologies for Microsystem Manufacturing 2019 - New
  - Piezoelectric Materials 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

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

BIOTECHNOLOGIES
- MARKET AND TECHNOLOGY REPORT
  - CRISPR-Cas9 Technology: From Lab to Industries 2018
- PATENT REPORT
  - Personalized Medicine 2019 – New

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
  - Nanopore Sequencing 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
  - From Image Processing to Deep Learning 2019 - Update
  - xPU (Processing Units) for Cryptocurrency, Blockchain, HPC and Gaming 2019 – New

MEMORY
- MARKET AND TECHNOLOGY REPORT
  - Status of the Memory Business 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 Advanced Packaging 2019 - Update
  - Status of Advanced Substrates 2019 - Update
  - Panel Level Packaging Trends 2019 - Update
  - System in Package (SiP) Technology and Market 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

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**SEMICONDUCTOR MANUFACTURING**
- **MARKET AND TECHNOLOGY REPORT**
  - Nano Imprint Lithography 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
- **STRUCTURE, PROCESS & COST REPORT**
  - Bonding and Lithography Equipment Market for More than Moore Devices 2018
- **PATENT REPORT**
  - Hybrid Bonding for 3D Stack 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
- **STRUCTURE, PROCESS & COST REPORT**
  - VCSELs - Technology, Industry and Market Trends 2019 - Update
- **PATENT REPORT**
  - VCSELs 2018

**DISPLAY**
- **MARKET AND TECHNOLOGY REPORT**
  - Next Generation 3D Display 2019 - New
  - Next Generation Human Machine Interaction (HMI) in Displays 2019 - New
  - Micro-and Mini-LED Displays 2019 - Update
- **PATENT REPORT**
  - MicroLED Displays : Intellectual Property Landscape 2018

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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 Compound Semiconductor 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
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OUR 2019 MONITORS COLLECTION (1/2)

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.
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 epitwafers, 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 epitwafers, 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 (LiNiM02), 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
  - 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.

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<td>Targeted audience involvement equals clear, concise perception of your company’s message.</td>
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<td>FreeFullPDF.com</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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<tr>
<td><strong>Unique, cost-effective ways to reach global audiences.</strong></td>
<td><strong>#15,800+ monthly unique visitors on i-Micronews.com</strong></td>
<td><strong>#380 registrants per webcast on average to gain new leads for your business</strong></td>
</tr>
<tr>
<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><strong>#10,900+ weekly readers of i-Micronews e-newsletter</strong></td>
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<tr>
<td><strong>#10,900+ weekly readers of i-Micronews e-newsletter</strong></td>
<td><strong>#110 attendees on average</strong></td>
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<td><strong>#110 attendees on average</strong></td>
<td><strong>#7+ key events planned for 2019 on different topics</strong></td>
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