Gas & Particle Sensors Report 2018
Biographies & contacts

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With almost 20 years of experience in MEMS, Sensors and Photonics applications, markets, and technology analyses, Dr. Eric Mounier provides deep industry insight into current and future trends. As a Principal Analyst, Technology & Market, MEMS & Photonics, in the Photonics, Sensing & Display division, he is a daily contributor to the development of MEMS and Photonics activities at Yole Développement (Yole), with a large collection of market and technology reports as well as multiple custom consulting projects: business strategy, identification of investments or acquisition targets, due diligences (buy/sell side), market and technology analysis, cost modelling, technology scouting, etc. Previously, Dr. Mounier held R&D and Marketing positions at CEA Leti (France).

He has spoken in numerous international conferences and has authored or co-authored more than 100 papers. Eric has a Semiconductor Engineering Degree and a Ph.-D in Optoelectronics from the National Polytechnic Institute of Grenoble (France).)

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Dr. Benjamin Roussel is Director, Life Sciences and Healthcare at Yole Développement (Yole), part of Yole Group of Companies. By supporting industrial companies and R&D institutes in their development, Benjamin and his team are creating the bridge between innovative microtechnologies and numerous diagnostic, pharmaceutical, life science and medical device applications. Benjamin Roussel is the author of a large collection of market & technology reports focusing on bioMEMS, microfluidics and solid state medical imaging, and performs multiple custom consulting projects. Thanks to his deep knowledge of these industries and related technologies, he has spoken in more than 20 industry conferences worldwide over the last 5 years.

Before joining Yole, Benjamin worked in an International Pharmaceutical company in the pharmacovigilance department. He holds a Pharmacy diploma from the University Claude Bernard Lyon (France), in addition to a master's degree in Technology & Innovation Management from EM Lyon Business School (France).

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GLOSSARY

- ASP: Average Selling Price
- CAGR: Compound Annual Growth Rate
- CNT: Carbon Nano Tubes
- E-nose: electronic nose
- FET: Field Effect Transistor
- FTIR: Fourier-Transform Infrared
- GC: Gas Chromatography
- HVAC: Heating, Ventilation, Air Conditioning
- IP: Intellectual Property
- MEMS: Micro Electro Mechanical Systems
- MOS: Metal Oxide Semiconductor
- NDIR: Non Dispersive Infrared
- PID: Photo Ionization Detection
- PM: Particle Matter
- ppb: part per billion
- ppm: part per million
- QCM: Quartz Micro Balance
- SAW: Surface Acoustic Wave
- UFP: Ultra Fine Particles
- VOC: Volatile Organic Compounds
WHAT IS INCLUDED/NOT INCLUDED

• Not included: smoke sensors & detectors
• The difference is in the concentration:
  • Particles: Particle sensors usually detect in the range of 1 particle/cm³. Reflection optical detection is used.
  • Smoke: high particles concentration (million particles/cm³). Scattering method is used

• Included:
  • Particles sensors for PM1 – PM10
  • Gas sensors
  • E noses
  • Environmental combos
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REPORT OBJECTIVES

Get a clear understanding of the applications and related technologies:

• **Identification and analysis of the applications:**
  • Determination of the range of applications
  • Market segmentation
  • Technical and economic requirements by segment
  • Chemical species to be measured
  • Key players at application and system levels
  • Sensor market size and market forecast 2017-2023 in $M and Munits

• **Analyze and describe the technologies involved:**
  • Existing and future gas & particles sensing technologies
  • Major actors and R&D organizations on a world basis
  • Technology roadmap for the different products and process
  • Who is developing what?
  • Competing technologies and organization per application
  • Sensor die market size and market forecast 2017-2023 in $M, Munits
  • Main challenges (sensitivity, selectivity, packaging...)

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WHO SHOULD BE INTERESTED IN THIS REPORT?

- **Gas & particles sensors companies:**
  - To have a broad overview of all gas sensors applications & markets
  - To identify new markets
  - To monitor and benchmark potential competitors

- **Financial & Strategic investors:**
  - To understand the potential for gas / Particle sensors
  - To get a list of gas / particles sensor players and their activities

- **R&D players:**
  - To understand new technical challenges in gas and particles sensing

- **Equipment & Material suppliers:**
  - To understand the technical evolution of gas and particles sensors
  - To identify business opportunities and prospects

- **OEMs & Integrators:**
  - To evaluate benefits of using gas and particles sensors in your systems
COMPANIES CITED IN THE REPORT (NOT EXHAUSTIVE LIST)

WHAT’S NEW SINCE 2016 YOLE GAS SENSORS REPORT

• New chapters on particles sensors: segmentation, market forecasts, players mapping and technologies benchmark.

• Updated gas sensors segmentation to take into account new applications.

• Brand new market forecast up to 2023 in value and units by application.

• Updated market shares and technologies breakdown.

• New part of gas and particle sensors in Asia (China, Taiwan, Japan).

• New part on gas and particle sensors IP.

• Updated analysis on combo and electronic noses.
GAS & PARTICLES MARKET QUANTIFICATION AND FORECASTS

By application, by player, by technology…
**GAS & PARTICLES MARKET SEGMENTATION**

What are the key requirements per end applications?

<table>
<thead>
<tr>
<th>Species</th>
<th>Particle Concentration</th>
<th>Particles</th>
<th>Gas</th>
<th>Environment</th>
<th>Sensitivity</th>
<th>Life Time (Year)</th>
<th>Size</th>
<th>Emerging market</th>
<th>Growing market</th>
<th>Mature market</th>
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<tr>
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<td>few 1000 particles per m³</td>
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<td>few B particles per m³</td>
<td>stoit level: 0 – 25 mg/m³</td>
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<td>0.3-10 PM</td>
<td>5-10 PM</td>
<td>0.1 PM</td>
<td>0.3-1 PM</td>
<td>0.1 PM</td>
<td></td>
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</table>

- **S1: INDOOR DEPOLUTION SYSTEMS**
- **S2: AIR CONFOR FOR TRANSPORTATION**
- **S3: ENVIRONMENT & INDUSTRIAL**
- **S4: ENVIRONMENT & INDUSTRIAL**
- **S5: POWERTRAIN MANAGEMENT**
- **S6: DEFENSE & INDUSTRIAL SAFETY**

<table>
<thead>
<tr>
<th>Species</th>
<th>Life Time (Year)</th>
<th>Size</th>
<th>Environment</th>
<th>Sensitivity</th>
<th>Gas</th>
<th>Life Time (Year)</th>
<th>Size</th>
<th>Environment</th>
<th>Sensitivity</th>
<th>Gas</th>
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<tr>
<td>2-5</td>
<td>5</td>
<td>1 cm³-1 dm³</td>
<td>Soft</td>
<td>ppm</td>
<td>10</td>
<td>&gt; 1 dm³</td>
<td></td>
<td>Harsh</td>
<td>Soft</td>
<td>ppm</td>
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GAS & PARTICLES TECHNOLOGY OVERVIEW

Reference technology vs. challengers
FOCUS ON ASIAN PLAYERS

Supply chain, technology mapping, Intellectual propety and company profiles
REVERSE ENGINEERING EXAMPLES

Devices Analyzed – Gas Sensor

- CCS801 (2015)
- SGP30 (2017)
- BME680 (2017)

Gas Sensor – MEMS Only

Not to scale

ASIC & Gas Sensor on the same die.

Environmental sensor

(MEMS: - Humidity, Temperature & Pressure
        - Gas
        + ASIC)

©2018 by System Plus Consulting | Gas Sensors Comparison 2018
Miniaturized Gas Sensor Comparison 2018
Structural, Process & Costing Report

By System Plus Consulting

Comparison of four gas sensors for consumer applications made by Bosch, ams and Sensirion.

Bundle offer possible for the Gas & Particle Sensors 2018 Report by Yole Développement, contact us.

COMPLETE TEARDOWN WITH:

- Package views and dimensions
- Package cross-sections
- Precise measurements
- Die descriptions
- Technology descriptions
- Cost analyses
- Cost comparisons

More information on the report here.
Outdoor air pollution is one of the major challenges of the 21st century, and about 4 million deaths globally are attributed to it, according to a World Health Organization (WHO) estimate in 2014. Another estimate, from 2016, is that more than 90% of the world’s population lives in regions where air pollutant levels are higher than the WHO specified limits. Thus, there is a global drive to tackle this problem, specifically by developing and installing gas and particle sensors.

For a long time, the main gas and particle sensor market has been restricted to industrial applications. But nowadays, degradation of the air quality is impacting many different places, homes, offices, hotels, cars and urban areas. Air quality control is therefore becoming a selling argument to promote hotels or restaurants.

Historically, gas sensors were used to control air conditioning in buildings to save energy. Today, Yole Développement (Yole) analysts are observing a shift from comfort to safety as inhabitants want safe indoor air. This trend also extends to other environments, such as personal vehicles, public transportation, and homes.

As an example, the market for air purifier systems, which often embed gas and particle sensors, are expected to expand from $16B in 2017 to $33B in 2023 with a 12.5% Compound Annual Growth Rate (CAGR).

Commercial vehicles have increasingly adopted gas and particle sensors onboard to ensure high quality of air for their customers. Previously sensors were embedded in-cabin to activate the air conditioning system when CO₂ and volatile organic compound (VOC) concentrations become critical. Today, additional sensors can be found out of the cabin to sense the outside environment and close the ventilation system if pollution is detected. Metal Oxide Semiconductor (MOS) is the preferred technology because of its low cost, small size and improved sensitivity compared to previous generation. To support this increasing market demand, historical players involved in gas sensors, such as Paragon, and Amphenol, which has acquired SGX, are developing particle sensors. The big sensor leaders like Bosch and ams have identified the air quality market as a very promising one. They are therefore using their know-how to develop new technical solutions for both gas and particle sensing.

Although it had big promise, the consumer segment is taking more time than expected to be a real significant share of the gas sensors market. Therefore some players are currently de-emphasized their efforts to enter this segment (in the short term (example: ams).

In this report, Yole analyzes the impact of the global air quality in every market segment. The main impacted segments are Heating, Ventilation and Air Conditioning (HVAC), consumer products and air comfort for transportation. Technical requirements, gases to be measured, market forecasts, technologies, main suppliers and regulations are fully described for each segment. Yole forecasts that the gas sensor market will top $1B in 2022! A chapter is dedicated to environmental combos and electronic noses technology developments as they are considered as the next steps to improve air quality sensing in several applications (but there are still challenges ahead, such as having the right use-case and structuring an industrial food chain for e-noses).
GAS AND PARTICLE SENSORS 2018

MOS HAS FINALLY FOUND ITS MARKET, BUT INFRA-RED (IR) TECHNOLOGY IS THE REFERENCE FOR PARTICLE SENSING

MOS has been around for many years but its lack of sensitivity has prevented widespread adoption of this technology. Today, the use of MOS technology has been boosted thanks to two applications: indoor/outdoor automotive and air purifiers. MOS is the best trade-off technology in cost and size for VOC measurement.

MOS is the reference technology in automotive air quality sensing, but only for gases. In consumer applications, miniaturized Non-Dispersive Infra-Red (NDIR) sensors compete with MOS. NDIR is more expensive, but its form factor is today close to MOS and its sensitivity is better. The final choice will be application-dependent.

On the other hand, optical is the reference technology for particle sensing. Particle monitoring is becoming even more important than gas sensing. Ultra-fine particles, below 1µm in diameter (PM1) are increasingly being watched as they are the most dangerous species for health. So most players are investigating particle sensors for PM1 and below.

Yole estimates the particle sensor market to be worth about $150M in 2017, growing to more than $200M in 2023. The market is less fragmented than the market for gas sensors as four players today share more than 90% of the market. So there is room for newcomers!

THE ASIAN PLAYER ECOSYSTEM IS DEVELOPING FAST

Because Asia is very concerned by air quality, our report includes a special chapter on the ecosystem of Asian players. The air purifier market is expected to ship about 20 million units annually by 2020. The Chinese market currently accounts for more than 95% of the global air purifier market, with these products using both dust and VOC sensors.

As a consequence, Asian players are developing their own technological portfolio for the local market. They cover all sensing technologies, but with geographical differences. For example, Japan and Taiwan are focusing on MOS and NDIR only, but China has all gas and particle technologies available.

The strong interest in gas and particle sensors in Asia and the large diversity in technology and R&D work are reflected by the Intellectual Property (IP) activity. Our report includes a chapter on IP activity in Asia. Patenting activity in China has strongly increased since 2010. On the contrary, patenting activity in other countries is almost stable. 85% of patents in China have been filed as priority patents and only 15% have been filed via an extension of their priority patent. In fact, there is an increasing number of Chinese companies and R&D labs among newcomers in the patent landscape since 2014.
OBJECTIVES OF THE REPORT
Identification and analysis of the applications:
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• Competing technologies and organizations for each application
• Sensor die market size and market forecast 2017-2023 in $M, Munits
• Main challenges, including sensitivity, selectivity and packaging

COMPANIES CITED IN THE REPORT (non exhaustive list)
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The present document is valid 24 months after its publishing date: November 6, 2018

ABOUT YOLE DEVELOPPEMENT
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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Definitions: “Acceptance”: Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by signing the purchase order which mentions “I hereby accept Yole’s Conditions of Sale” or “I agree to the Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities, for its business needs) entering into the following general conditions to the exclusion of consumers acting in their personal, household or similar interests.

“Contracting Parties” or “Parties”: The Seller on the one hand and the Buyer on the other hand.

“Intellectual Property Rights” (“IPR”): means any right resulting from any patent, utility model, design, trademark, topography, mask works, computer programs, databases, original works of art, music, audiovisual creations, names, labels, et cetera.

1. SCOPE

1.1 The Contracting Parties undertake to observe the following general conditions as agreed by the Buyer and the Seller.

1.2 The Buyer is a company or trading names and any other intellectual property rights, commercial secrets and know-how, technical information, advice and acts it deduces thereof.

1.3 The Seller reserves the right to alter prices at any time without prior notice.

1.4 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products and for the use and interpretation he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

1.5 The Buyer shall have the right to use the Products solely for its business activities, shall be solely responsible for choosing the Products and for the use and interpretation he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

2. MAILING OF THE PRODUCTS

2.1 Products are sent by email to the Buyer:

2.2 Any Product returned to the Seller without prior notice to the Seller shall take reasonable steps to screen Products for defects, the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labor costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 3.2.2.

2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in article 3.

2.4 The mailing is operated through electronic means either by email or by download in PDF format. If the Product is electronically delivered, the Seller may debrief the Buyer that it is informed of the defective condition within 90 days from the date of the original download or receipt of the Product.

3. PRICE, INVOICING AND PAYMENT

3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are not free from any other tax. The prices may be reevaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.

3.2 Yole may offer a pre-rebate discount for the companies willing to acquire the report, the fact that the report may be released later than the anticipated release date. In exchange for this uncertainty, the company will get a discount that can vary from 15% to 10%.

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4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products and for the use and interpretation he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

4.2 The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary losses, caused by the Products or arising from a material breach of this agreement.

4.3 In no event shall the Seller be liable for:

a) damages of any kind, including without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or data stored in the Product or arising from a material breach of this agreement).

b) any negligence, malfeasance or omissions or other inaccuracies in the Product or interpretations thereof.

4.4 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

4.5 All the Products that the Seller sells may, upon prior notice to the Buyer from time to time be modified by or substituted with similar Products meeting the needs of the Buyer. This modification is done so that the best possible quality of the Seller provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

4.6 In the case where, after inspection, it is acknowledged that the Products delivered to the Buyer are not in conformity with the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labor costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 3.2.2.

4.7 The deadlines that the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. The Seller does not warrant that it shall not lead to any damages or cancellation of the orders, except for non acceptable delays exceeding 6 months from the stated deadline, without information from the Seller. In such case only, the Buyer shall be entitled to ask for a reimbursement of the first down payment to the exclusion of any further damages.

5. FORCE MAJEURE

5.1 The Seller shall not be liable for any delay in delivery or errors committed due to force majeure such as acts of nature, fire, accident, riot, war, government intervention, embargoes, strikes, labor difficulties, equipment failure, late deliveries by suppliers or other circumstances which are beyond the control, and not the fault of the Seller.

6. PROTECTION OF THE SELLER’S IPR

6.1 All the IPR attached to the Products are and remain the property of the Seller.

6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish the Product, or any part of any non-breaching Party shall be entitled to terminate all the Contracting Parties after clear and non-equivocal consent of fact the investor of a company, the joint venture done with companies in which the Buyer have 100% shares. As a matter of fact, this is one of the main reasons why the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.

6.3 The Buyer shall therefore not use the Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmitters over any network (including and agents. Each of them is entitled to assert and enforce those rights.

6.4 Yole shall define within its company point of contact for the needs of the contract. This person will be the recipient of any new report in PDF format. This person shall also be responsible for receiving the report and sending it to the Buyer, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

6.5 In the context of annual subscriptions, the person of contact shall indicate to which address the report shall be sent, that the Buyer shall be entitled to make use of the Products or arising from a material breach of this agreement.

6.6 In the event of breach by one Party under these conditions the non-breaching Party shall be entitled to terminate all the Contracting Parties after clear and non-equivocal consent of fact the investor of a company, the joint venture done with companies in which the Buyer have 100% shares. As a matter of fact, this is one of the main reasons why the Buyer shall henceforward invoicing or payment, including and agents. Each of them is entitled to assert and enforce those rights.

6.7 In the event of breach by one Party under these conditions the non-breaching Party shall be entitled to terminate all the Contracting Parties after clear and non-equivocal consent of fact the investor of a company, the joint venture done with companies in which the Buyer have 100% shares. As a matter of fact, this is one of the main reasons why the Buyer shall henceforward invoicing or payment, including and agents. Each of them is entitled to assert and enforce those rights.

6.8 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to the Products. Although the Seller takes all necessary precaution in order to reduce the infection of viruses, worms, Trojan horses or other codes containing contagious or destructive properties before mailing the Products, the Buyer cannot guarantee that any Product will be free from infection.

7. TERMINATION

7.1 If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential damages resulting from the cancellation.

7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days, the Seller shall be considered to have defaulted. The non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

8. MISCELANEOUS

8.1 All the provisions of these Terms and Conditions are for the benefit of the Seller and its subsidiaries and agents. Each of them is entitled to assert and enforce those provisions against the Buyer. Any amendment to these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party. The Seller may, from time to time, update these Terms and Conditions and inform the Buyer by email to the Buyer, the latter shall be deemed to have accepted the latest version of these terms and conditions by the Buyer’s continued use of the Products and without any prior notice thereof.

9. GOVERNING LAW AND JURISDICTION

9.1 Any dispute arising out or linked to these Terms and Conditions or to the sale contract concluded on the basis of all the application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.

9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.
Yole Développement

From Technologies to Market
YOLE DEVELOPPEMENT – FIELDS OF EXPERTISE

**Life Sciences & Healthcare**
- Microfluidic
- BioMEMS
- Inkjet Printing
- Solid-State Medical Imaging & BioPhotonics
- Bio Technologies

**Power & Wireless**
- RF Devices & Technology
- Compound Semiconductors & Emerging Materials
- Power Electronics
- Batteries & Energy Management

**Semiconductor & Software**
- Package & Assembly & Substrates
- Semiconductor Manufacturing
- Memory
- Software & Computing

**Photonics, Sensing & Display**
- Solid-State Lighting & Display
- MEMS, Sensors & Actuators
- Imaging
- Photonics & Optoelectronics
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)

- **Syndicated reports**
  - Market & technology reports
  - 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/or Quarterly update
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  - Price, market, demand and production forecasts
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6 COMPANIES TO SERVE YOUR BUSINESS

Yole Group of Companies

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- Patent assessment
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**Yole Finance**
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- www.yole.fr
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HQ in Lyon

30% of our business

Greater China office
Hsinchu

30% of our business

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Phoenix

Yole Korea
Seoul

Yole Japan
Tokyo

Yole Inc.
Phoenix

Yole Korea
Seoul

Yole Japan
Tokyo

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

Integrators, end-users and software developers

Device manufacturers

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

Financial investors, R&D centers
We work across multiple industries to understand the impact of More-than-Moore technologies from device to system.
o Yole Développement, System Plus Consulting, KnowMade and PISEO, all part of Yole Group of Companies, keep on increasing their collaboration to offer, in 2018, a collection of 150+ reports. Combining respective expertise and methodologies from the 4 companies, the reports aim to provide market & technology analysis, patent investigation and patent infringement risk analysis, teardowns & reverse costing analysis. They cover:

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

o You are looking for:
  - An analysis of your product market
  - A review of your competitors evolution
  - An understanding of your manufacturing and production costs
  - An understanding of your industry technology roadmap and related IPs
  - A clear view on the evolution of the supply chain…

Our reports are for you!

The combined team of 60+ experts (PhDs, MBAs, industry veterans…) from Yole Développement, System Plus Consulting, KnowMade and PISEO, collect information, identify the trends, the challenges, the emerging markets, the competitive environments and turn it into results to give you a complete picture of your industry landscape.

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o In 2018, Yole Group of Companies plan to publish +150 reports. Gain full benefit from our Bundled Offer and receive at least a 36% discount.
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  - Inkjet Functional and Additive Manufacturing for Electronics 2018
  - Fingerprint Sensor Applications and Technologies – Consumer Market Focus 2017
  - Sensors and Sensing Modules for Smart Homes and Buildings 2017
  - Acoustic MEMS and Audio Solutions 2017
  - MEMS & Sensors for Automotive Market & Technology Trends 2017
  - High End Inertial Sensors 2017
  - Magnetic Sensor 2017
- **REVERSE COSTING® – STRUCTURE, PROCESS & COST REPORT** – by System Plus Consulting
  - Piezo MEMS 2018 *
- **PATENT ANALYSES** – by KnowMade
  - MEMS Microphone – Patent Landscape Analysis
  - Knowles MEMS Microphones in Apple iPhone 7 Plus – Patent-to-Product Mapping 2017
- **LINKED REPORTS** – by Yole Développement, System Plus Consulting and KnowMade
  - MEMS Pressure Sensor 2018 – Market & Technology Report
  - Gas & Particles 2018 – Market & Technology Report
  - LiDARs for Automotive and Industrial Applications 2018 – Market & Technology Report
  - LiDAR for Automotive 2018 – Patent Landscape Analysis
  - MEMS Packaging 2017 – Market & Technology Report

RF DEVICES AND TECHNOLOGIES
- **MARKET AND TECHNOLOGY REPORT** – by Yole Développement
  - Wireless technologies (Radar, V2X) for Automotive 2018
  - RF Standards and Technologies for Connected Objects 2018
  - RF & Photonic Components & Technologies for 5G Infrastructure 2018
- **REVERSE COSTING® – STRUCTURE, PROCESS & COST REPORT** – by System Plus Consulting
  - Automotive Radar Comparison 2018
- **PATENT ANALYSES** – by KnowMade
  - RF Acoustic Wave Filters 2017 – Patent Landscape Analysis
- **LINKED REPORTS** – by Yole Développement, System Plus Consulting and KnowMade
  - 5G impact on RF Front End Modules and Connectivity for Cellphones 2018 – Market & Technology Report – Update
  - RF Front End Modules for Cellphones 2018 – Patent Landscape Analysis
  - RF GaN 2018 – Patent Landscape Analysis

SOFTWARE
- **MARKET AND TECHNOLOGY REPORT** – by Yole Développement
  - Consumer Biometrics: Sensors & Software 2018 – Update
  - Processing Hardware and Software for AI 2018 - Vol. 1 & 2
  - From Image Processing to Deep Learning, Introduction to Hardware and Software

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  - Machine Vision for Industry and Automation 2018
  - Imagers and Detectors for Security and Smart Buildings 2018
  - Uncooled Infrared Imagers 2017
- **PATENT ANALYSES** – by KnowMade
  - iPhone X Dot Projector – Patent-to-Product Mapping
- **LINKED REPORTS** – by Yole Développement, System Plus Consulting and KnowMade
  - Status of the CMOS Image Sensor Industry 2018 – Market & Technology Report - Update
  - CMOS Image Sensors Monitor 2018** – Quarterly Update**
  - Camera Module 2017 – Market & Technology Report
  - LiDARs for Automotive and Industrial Applications 2018 – Market & Technology Report
  - LiDAR for Automotive 2018 – Patent Landscape Analysis

ADVANCED PACKAGING
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  - Status of Advanced Packaging Industry 2018 – Update
  - Status of Advanced Substrates 2018: Embedded Die and Interconnects, Substrate Like PCB Trends
  - 3D TSV and Monolithic Business Update 2018 – Update
  - Power Modules Packaging 2018 – Update
  - Discrete Power Packaging 2018 – Update*
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  - Trends in Automotive Packaging 2018
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  - Thin-Film Integrated Passive Devices 2018
  - Memory Packaging Market and Technology Report 2018 – Update*
- **PATENT ANALYSES** – by KnowMade
  - Hybrid Bonding for 3D Stack – Patent Landscape Analysis
- **LINKED REPORTS** – by Yole Développement and System Plus Consulting
  - Advanced RF System-in-Package for Cellphones 2018 – Market & Technology Report - Update*
  - Fan-Out Packaging 2018 – Market & Technology Report – Update*

MANUFACTURING
- **MARKET AND TECHNOLOGY REPORT** – by Yole Développement
  - Wafer Starts for More Than Moore Applications 2018
  - Equipment for More than Moore: Technology & Market Trends for Lithography & Bonding/Debonding 2018
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  - Laser Technologies for Semiconductor Manufacturing 2017
  - Glass Substrate Manufacturing in the Semiconductor Field 2017
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  - Equipment and Materials for 3D TSV Applications 2017
- **LINKED REPORTS** – by Yole Développement and System Plus Consulting

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- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Emerging Non Volatile Memory 2018 – Update
  - Memory Packaging Market and Technology Report 2018 – Update*
- QUARTERLY UPDATE – by Yole Développement**
  - Memory Market Monitor 2018 (NAND & DRAM)
- MONTHLY UPDATE – by Yole Développement**
  - Memory Pricing Monitor 2018 (NAND & DRAM)
- REVERSE ENGINEERING & COSTING REVIEW – by System Plus Consulting
  - DRAM Technology & Cost Review 2018
  - NAND Memory Technology & Cost Review 2018
- PATENT ANALYSES – by KnowMade
  - 3D Non-Volatile Memories – Patent Landscape

COMPOUND SEMICONDUCTORS
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Status of Compound Semiconductor Industry 2018*
  - GaAs Materials, Devices and Applications 2018
  - InP Materials, Devices and Applications 2018
  - Bulk GaN Substrate Market 2017
- LINKED REPORTS – by Yole Développement, System Plus Consulting and KnowMade
  - SiC Transistor Comparison 2018 – Structure, Process & Cost Report
  - Power SiC 2018 – Patent Landscape Analysis
  - GaN-on-Silicon Transistor Comparison 2018 – Structure, Process & Cost Report

POWER ELECTRONICS
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Status of Power Electronics Industry 2018 – Update
  - Discrete Power Packaging 2018 – Update*
  - Power Electronics for Electric Vehicles 2018 – Update
  - Integrated Passive Devices (IPD) 2018
  - Wireless Charging Market Expectations and Technology Trends 2018
  - Thermal Management Technology and Market Perspectives in Power
  - Electronics and LEDs 2017
  - Gate Driver 2017
  - Power MOSFET 2017
  - IGBT 2017
  - Market Opportunities for Thermal Management Components in Smartphones 2017
- LINKED REPORTS – by Yole Développement, System Plus Consulting and KnowMade
  - Power Modules Packaging 2018 – Market & Technology Report – Update
  - Power ICs Market Monitor 2018 – Quarterly Update**

BATTERY AND ENERGY MANAGEMENT
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Li-ion Battery Packs for Automotive and Stationary Storage Applications 2018 – Update
- PATENT ANALYSES – by KnowMade
- LINKED REPORTS – by Yole Développement and KnowMade
  - Solid State Electrolyte Battery 2018 – Market & Technology Report
  - Solid-State Batteries 2018 – Patent Landscape Analysis
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SOLID STATE LIGHTING
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - LiFi: Technology, Industry and Market Trends
  - LED Lighting Module Technology, Industry and Market Trends 2017
  - CSP LED Lighting Modules
  - Phosphors & Quantum Dots 2017 - LED Downconverters for Lighting & Displays
  - Horticultural Lighting 2017
- LINKED REPORTS – by Yole Développement and System Plus Consulting
  - VCSELs Comparison 2018 – Structure, Process & Cost Report

DISPLAYS
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Quantum Dots and Wide Color Gamut Display Technologies 2018 – Update
  - Displays and Optical Vision Systems for VR/AR/MR 2018
- PATENT ANALYSES – by KnowMade
  - MicroLED Display – Patent Landscape Analysis

MEDTECH
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - BioMEMS & Non Invasive Emerging Biosensors: Microsystems for Medical
  - Applications 2018 – Update
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  - CRISPR-Cas9 Technology: From Lab to Industries 2018
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  - Inkjet Functional and Additive Manufacturing for Electronics 2018
  - Liquid Biopsy: from Isolation to Downstream Applications 2018
  - Chinese Microfluidics Industry 2018
  - Scientific Cameras for the Life Sciences & Analytical Instrumentation Laboratory Markets 2018*
  - Artificial Organ Technology and Market 2017
  - Connected Medical Devices Market and Business Models 2017
  - Status of the Microfluidics Industry 2017
  - Organs-On-Chips 2017
  - Solid-State Medical Imaging 2017
  - Medical Robotics Market & Technology Analysis 2017
- PATENT ANALYSES – by KnowMade
  - Microfluidic IC Cooling – Patent Landscape
  - Circulating Tumor Cell Isolation – Patent Landscape
  - OCT Medical Imaging – Patent Landscape
  - Pumps for Microfluidic Devices – Patent Landscape 2017
  - Microfluidic Technologies for Diagnostic Applications – Patent Landscape 2017
  - FLUIDIGM – Patent Portfolio Analysis 2017
- LINKED REPORTS – by Yole Développement, System Plus Consulting and KnowMade
  - Organs-On-Chips 2017 – Market & Technology Report
  - Organ-on-a-Chip – Patent Landscape Analysis

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- RF Acoustic Wave Filters Patent Landscape Analysis
- NMC Lithium-Ion Batteries Patent Landscape Analysis
- Pumps for Microfluidic Devices Patent Landscape
- III-N Patent Watch
- FLUIDIGM Patent Portfolio Analysis
- Knowles MEMS Microphones in Apple iPhone 7 Plus Patent-to-Product Mapping 2017
- Consumer Physics SCiO Molecular Sensor Patent-to-Product Mapping
- Patent Licensing Companies in the Semiconductor Market - Patent Litigation Risk and Potential Targets
- Microfluidic Technologies for Diagnostic Applications Patent Landscape

TEARDOWN & REVERSE COSTING – by System Plus Consulting
More than 60 teardowns and reverse costing analysis and cost simulation tools published in 2017

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ONSITE
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Contact: Camille Veyrier (veyrier@yole.fr), Marketing & Communication Project Manager

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