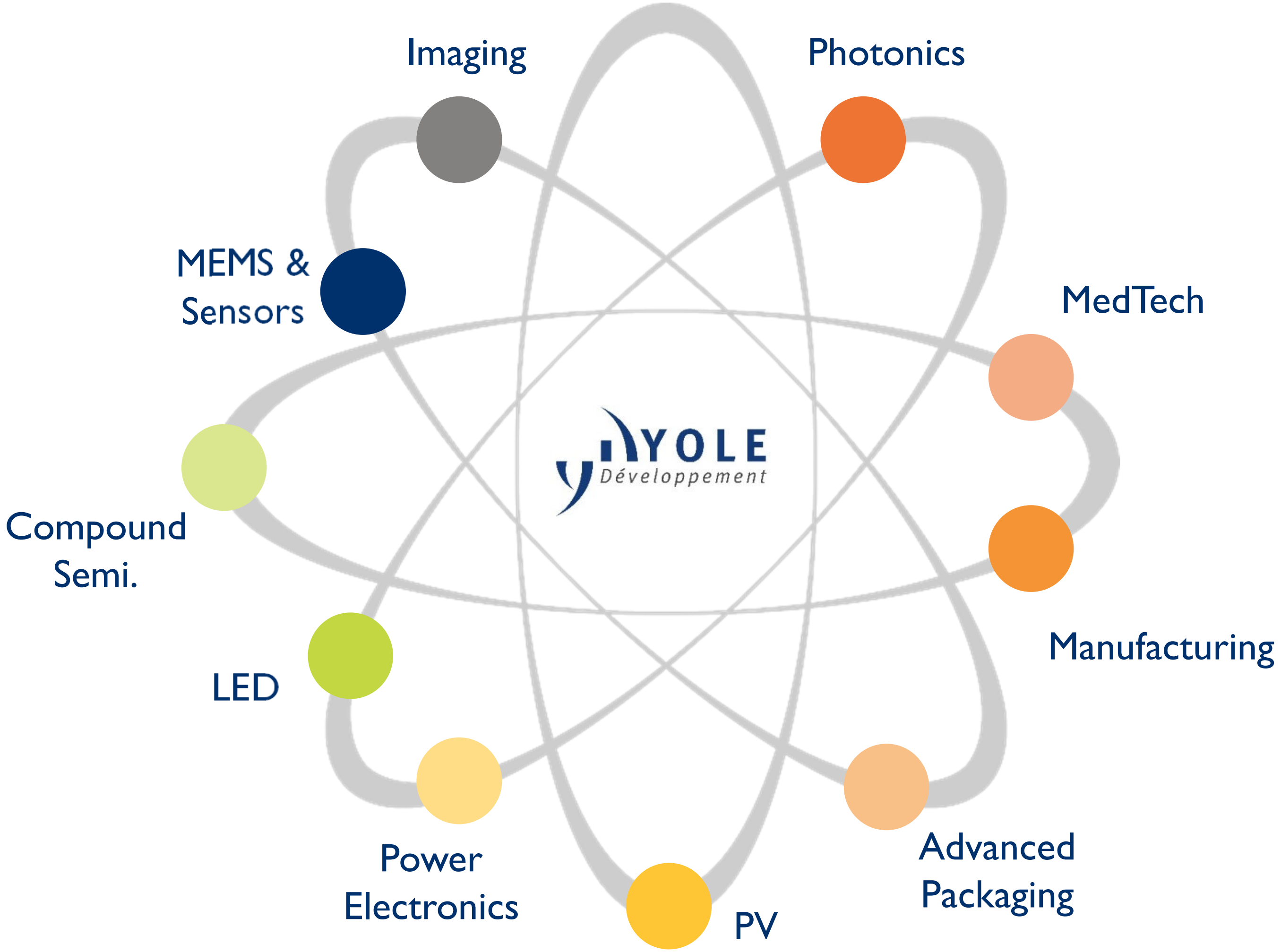
YOLE reports abstract for EPIC

TABLE OF CONTENT

FIELDS OF EXPERTISE

Yole Développement's 30 analysts operate in the following areas



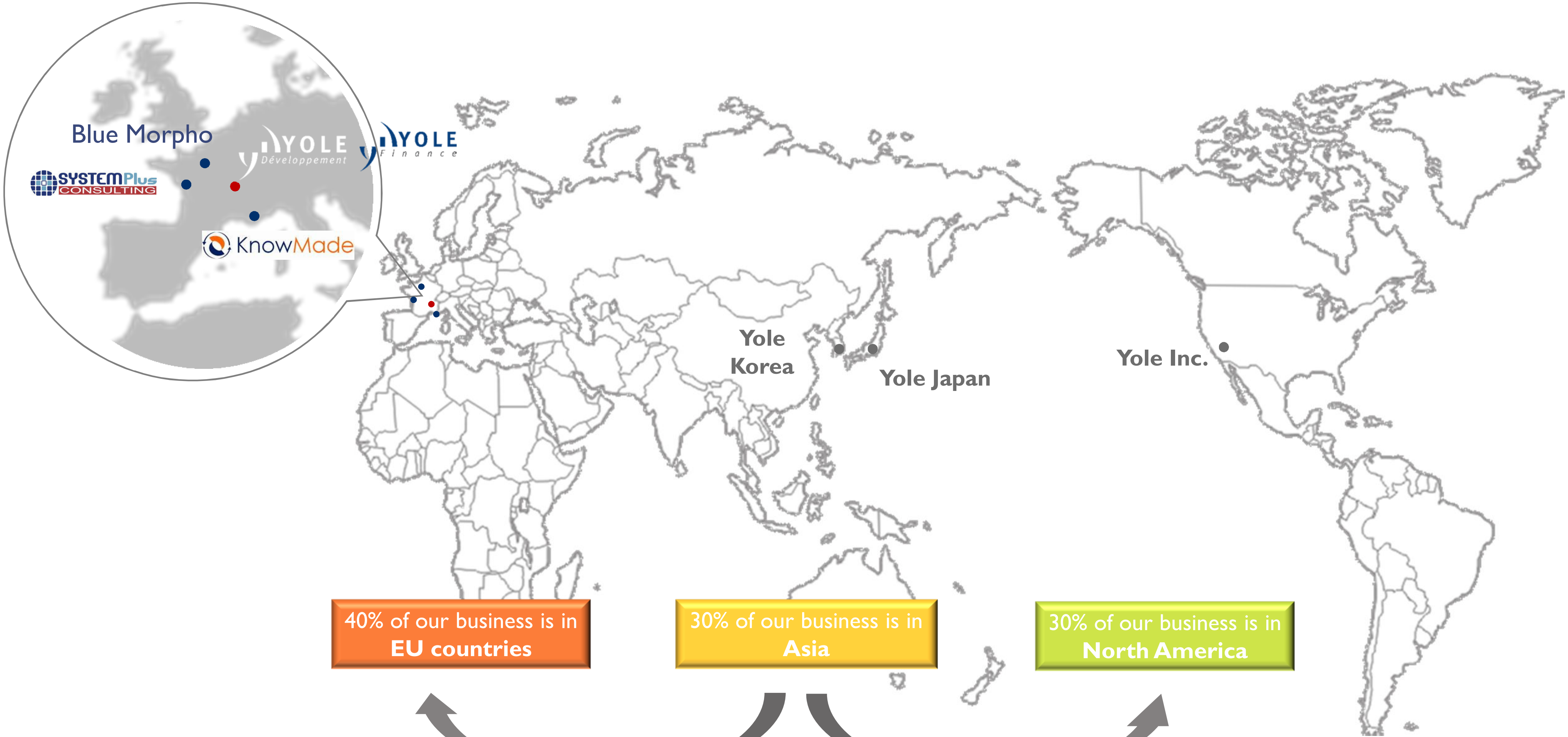
A GROUP OF COMPANIES

Market, technology and strategy consulting

www.yole.fr

Yole Finance	M&A operations Due diligences www.yolefinance.com
BLUMORPHO	Fundraising Maturation of companies IP portfolio management & optimization www.bmorpho.com
SYSTEMPlus CONSULTING	Manufacturing costs analysis Teardown and reverse engineering Cost simulation tools www.systemplus.fr
KnowMade	IP analysis Patent assessment www.knowmade.fr

OUR GLOBAL ACTIVITY



40% of our business is in **EU countries**

30% of our business is in **Asia**

30% of our business is in **North America**

SERVING THE ENTIRE SUPPLY CHAIN

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

Integrators and end-users

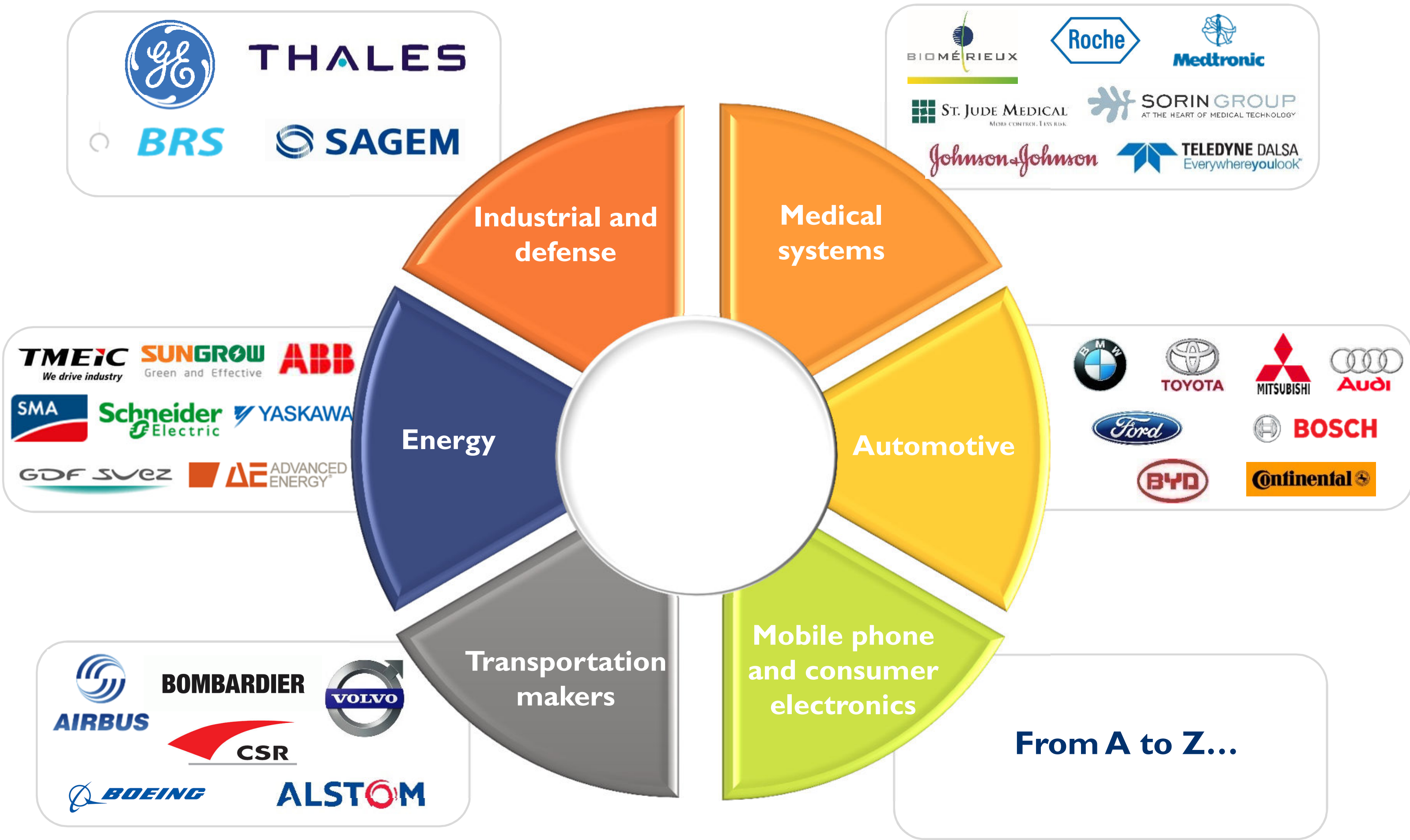
Device makers

Suppliers: material, equipment, OSAT, foundries…

Financial investors, R&D centers

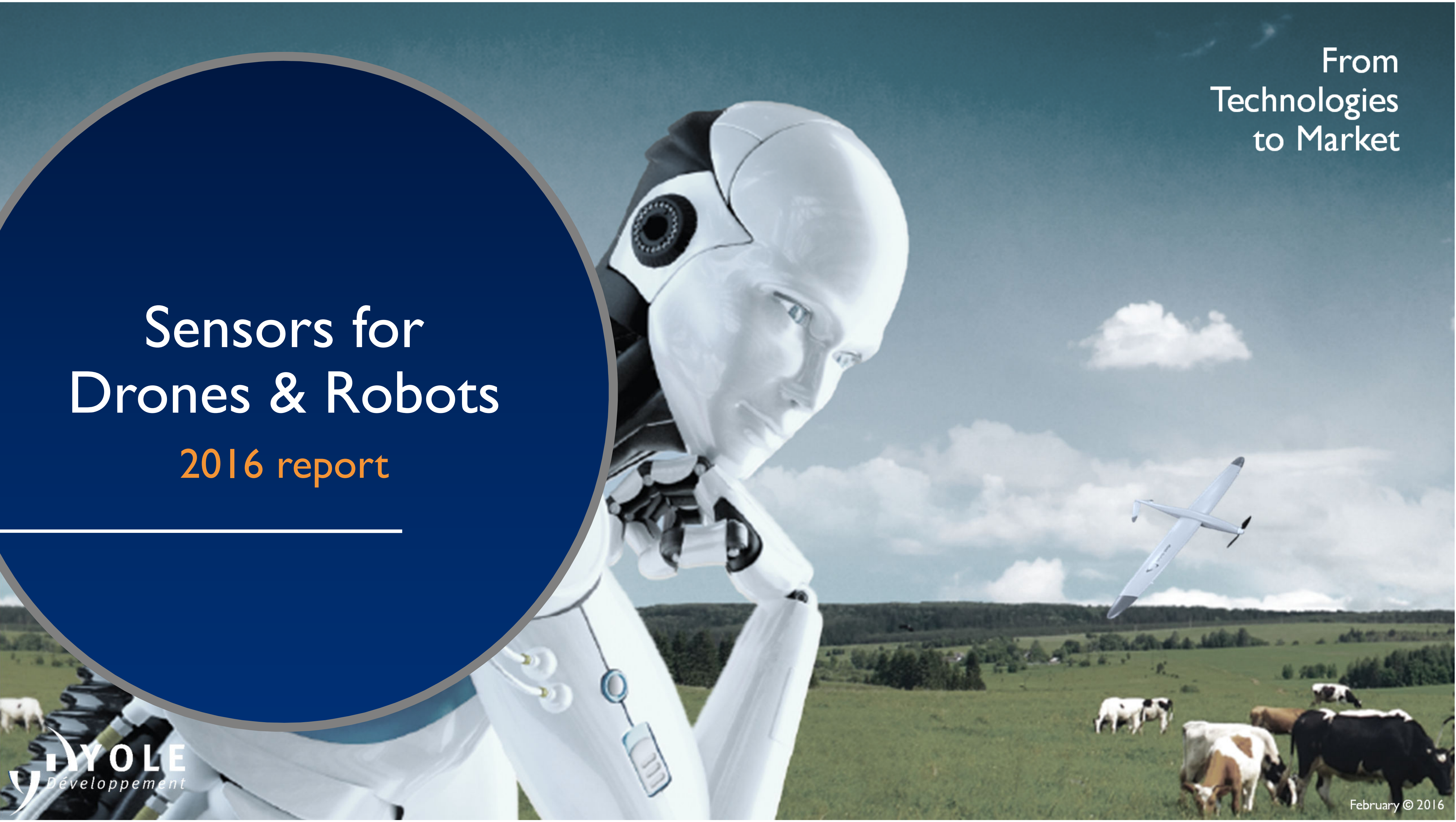
SERVING MULTIPLE INDUSTRIAL FIELDS

We are working accross multiples industries to understand the impact of More-than-Moore technologies from device to system



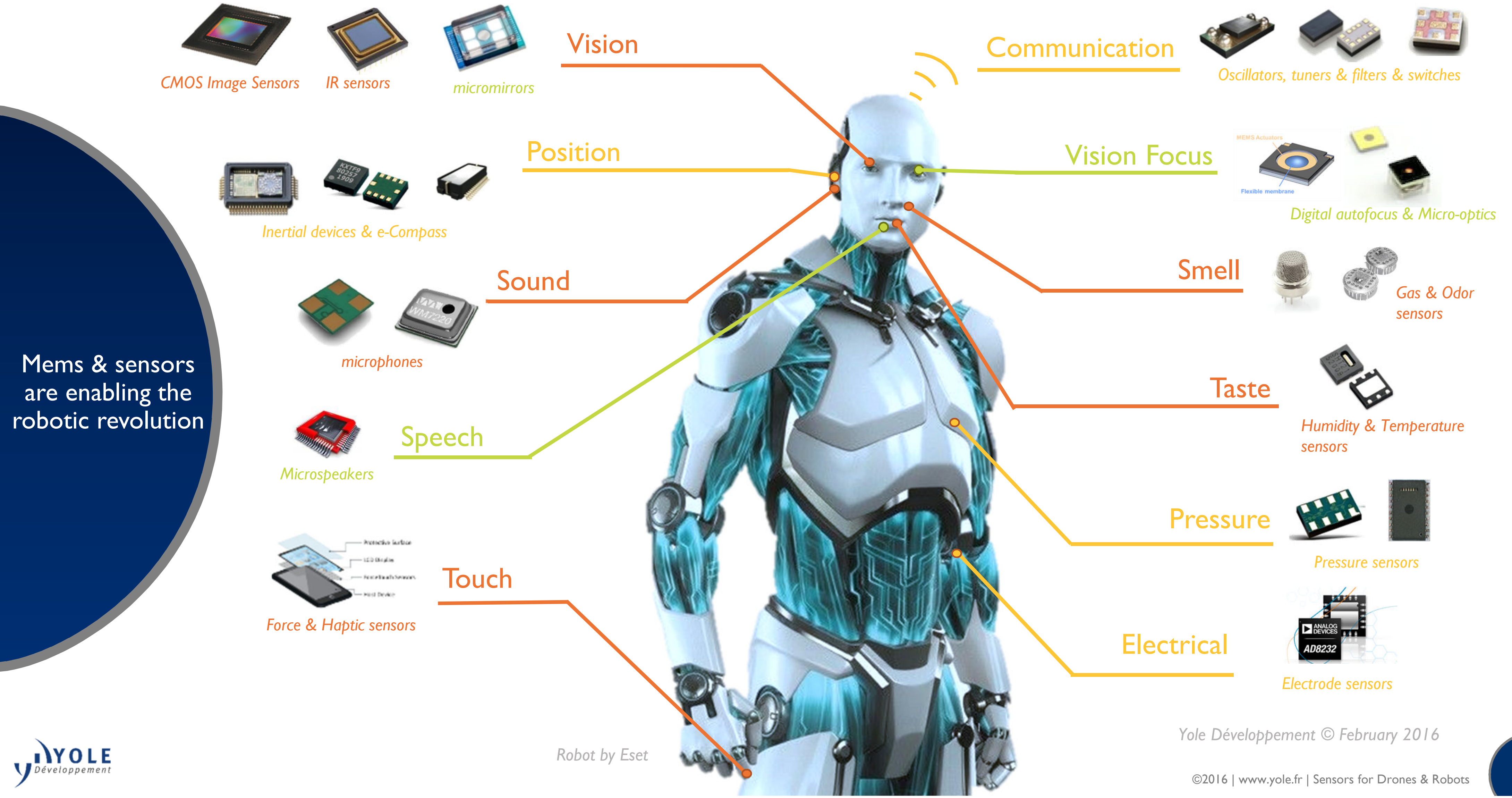
Sensors for Drones & Robots

2016 report



YOLE Développement

MEMS & SENSORS : BEYOND THE HUMAN SENSES…



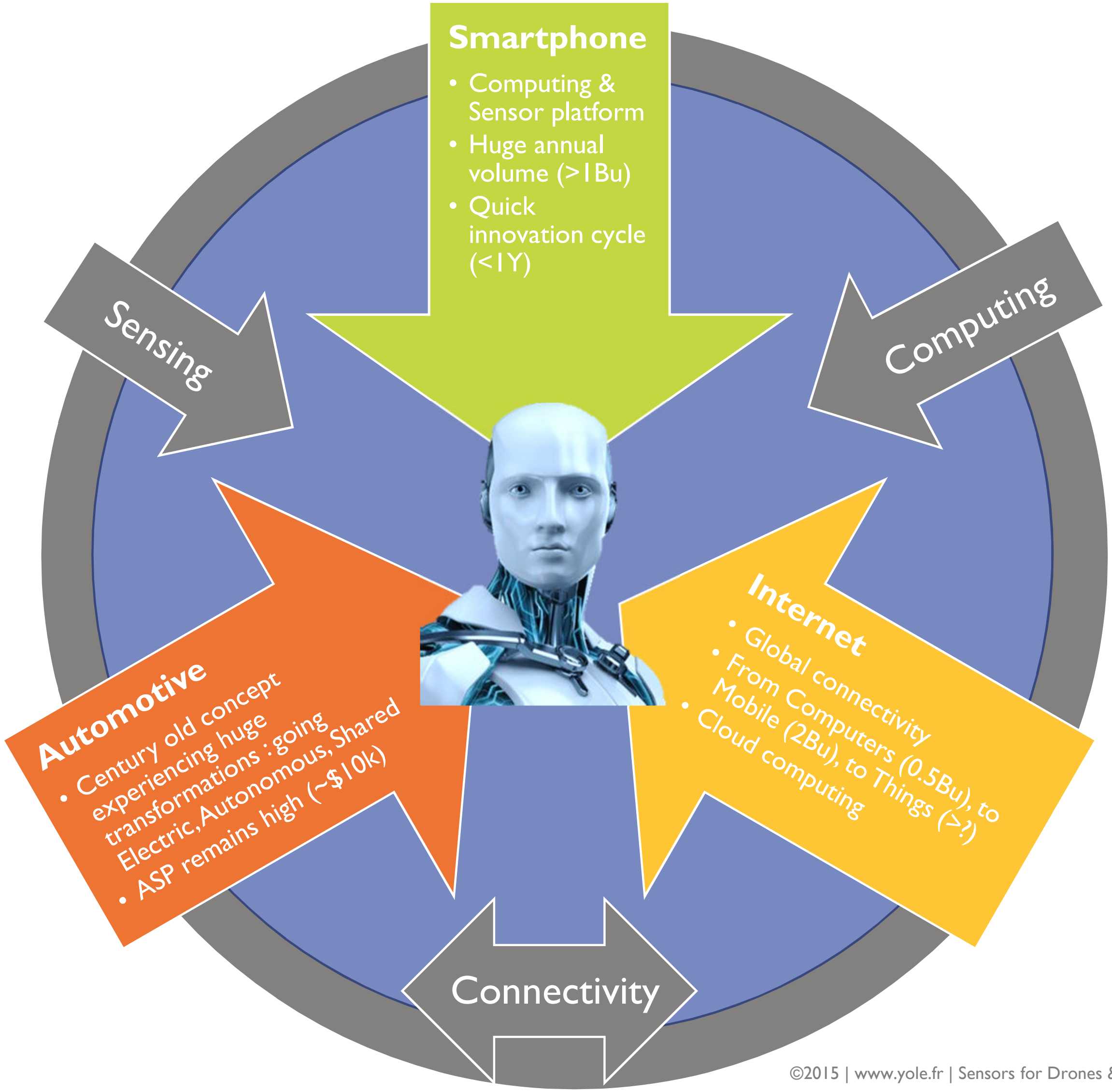
Yole Développement © February 2016

CONVERGENCES LEADING TO THE ROBOTIC REVOLUTION

3 Industries converging for the robotic revolution

Why now?

- Smartphones helped develop advanced microelectronic technologies at low cost
- Internet is providing communication / cloud computing infrastructure coupled with high demand for connected devices
- Autonomous vehicles R&D allow for high priced technology testbeds fueled by car brand search for differentiation

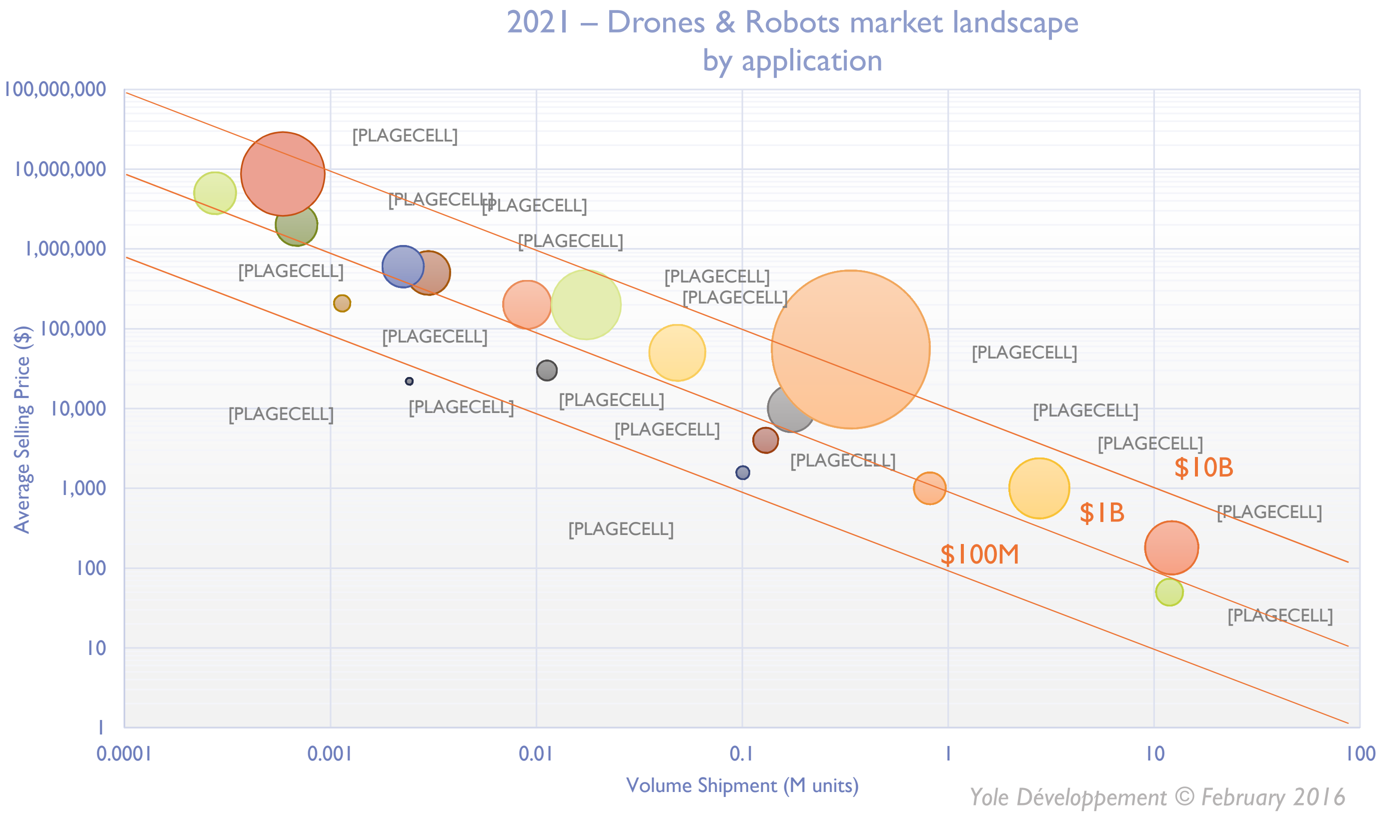


DRONES & ROBOTS MARKET LANDSCAPE

Rise in diversity of drones & robots applications

Within 5 years

- Defense and Industry will no more standout as the only robotic markets
- 10 new drones & robots applications will cross the $1B threshold



SENSORS FOR DRONES & ROBOTS REVENUE FORECAST 2010-2021

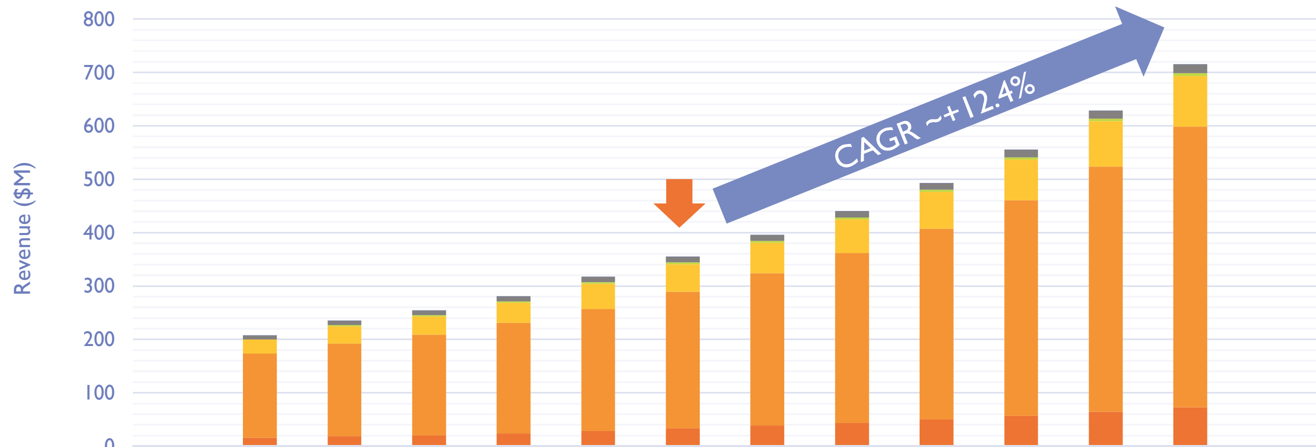
by sensor type (*in $M*)

74% of revenues will be captured by optical sensors

The growth in revenue of +12.4% CAGR will be essentially captured by optical sensors

Position and acoustic sensors have also a significant market share of sensors for drones and robots market

2010-2021 Sensors for Drones & Robots revenue forecast (in $M)
by sensor type



	Implementation	2010	2011	2012	2013	2014	2015e	2016e	2017e	2018e	2019e	2020e	2021e	CAGR 2015-2021
Environment		0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	28%
Microwave		8	8	8	9	10	10	11	12	12	13	15	16	8%
Touch		0	2	2	3	3	3	3	4	4	5	5	6	9%
Position		26	32	34	38	47	52	57	63	69	76	85	95	11%
Optical		157	173	189	207	229	256	286	318	357	404	459	526	13%
Acoustic		16	19	20	24	28	33	38	44	50	57	64	73	14%

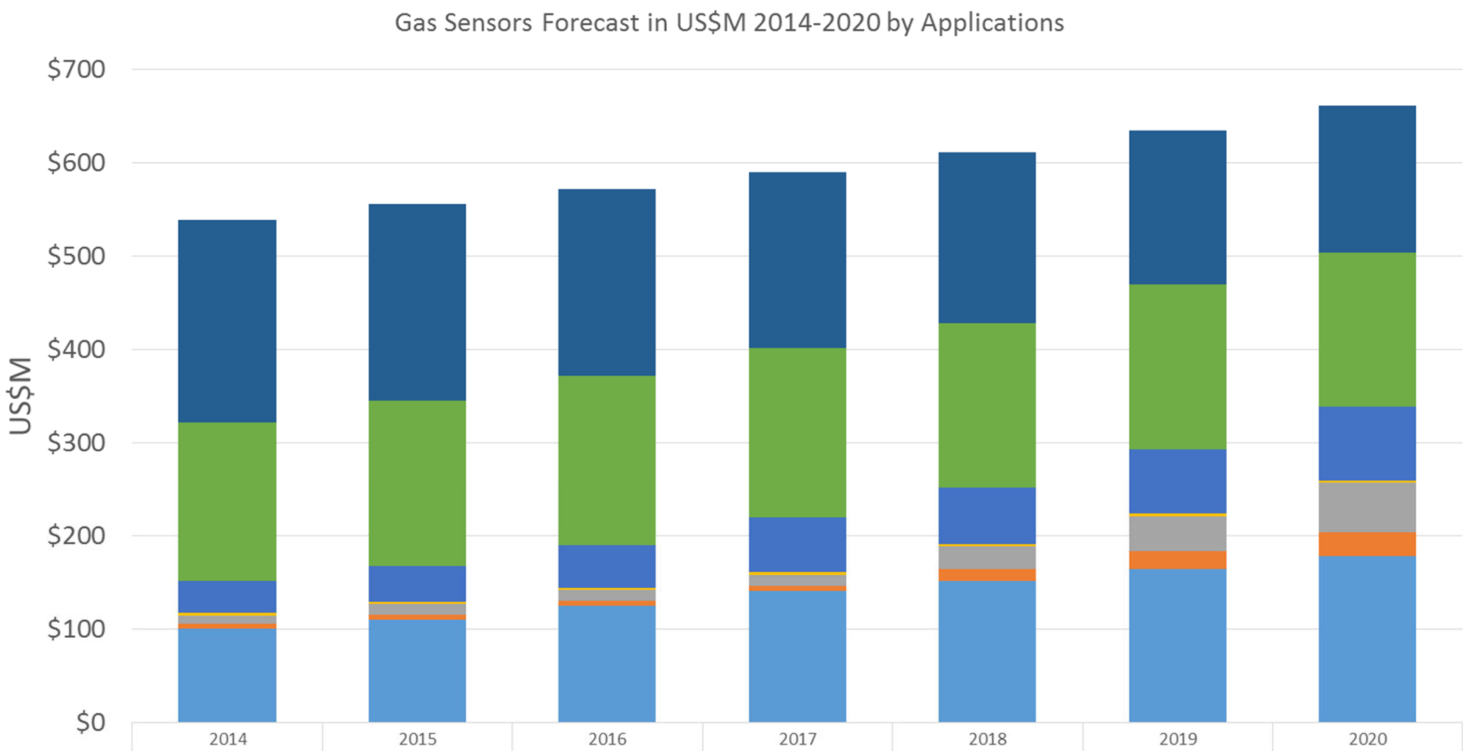
Yole Développement © February2016


From Technologies to Market
Gas Sensors report 2016
YOLE Développement
© 2015

GAS SENSORS MARKET FORECAST

Gas sensors market will grow from $540M in 2014 to $765M in 2020

- 6% CAGR in value with consumer / environment having the highest growth



	2014	2015	2016	2017	2018	2019	2020
Industrial	$217	$210	$199	$188	$183	$164	$158
Transport	$170	$177	$182	$182	$176	$177	$165
Environment	$34	$39	$46	$59	$61	$70	$79
Defense	$2	$2	$2	$2	$2	$3	$3
Consumer	$9	$11	$11	$12	$24	$38	$53
Medical	$5	$6	$6	$6	$12	$19	$26
Building	$100	$111	$125	$141	$152	$164	$178

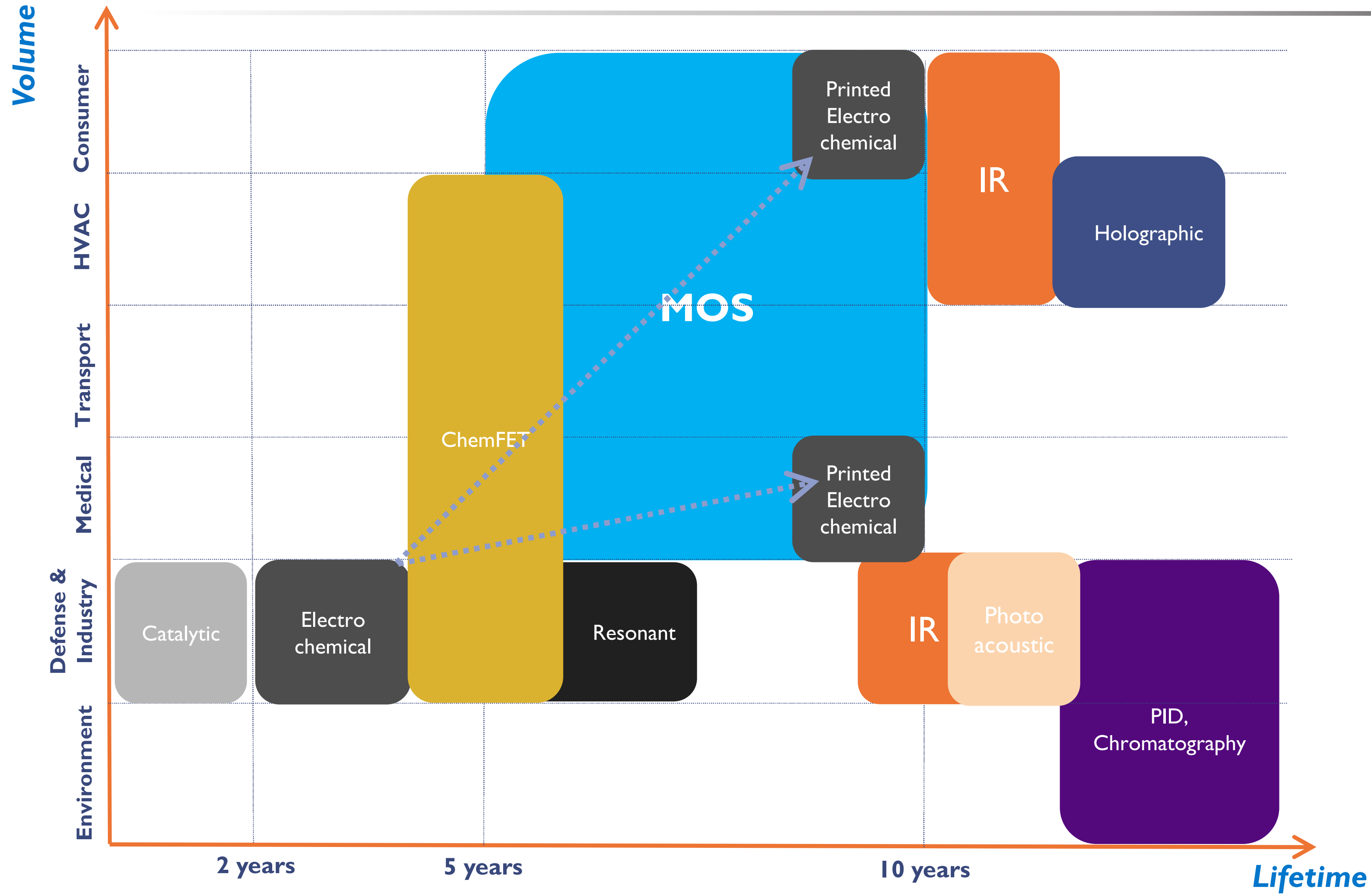
YOLE Développement

CHEMICAL GAS SENSORS/ LIFETIME VS. APPLICATIONS

MOSFET is the technology with most applications

Growing importance of MOS for consumer & transport

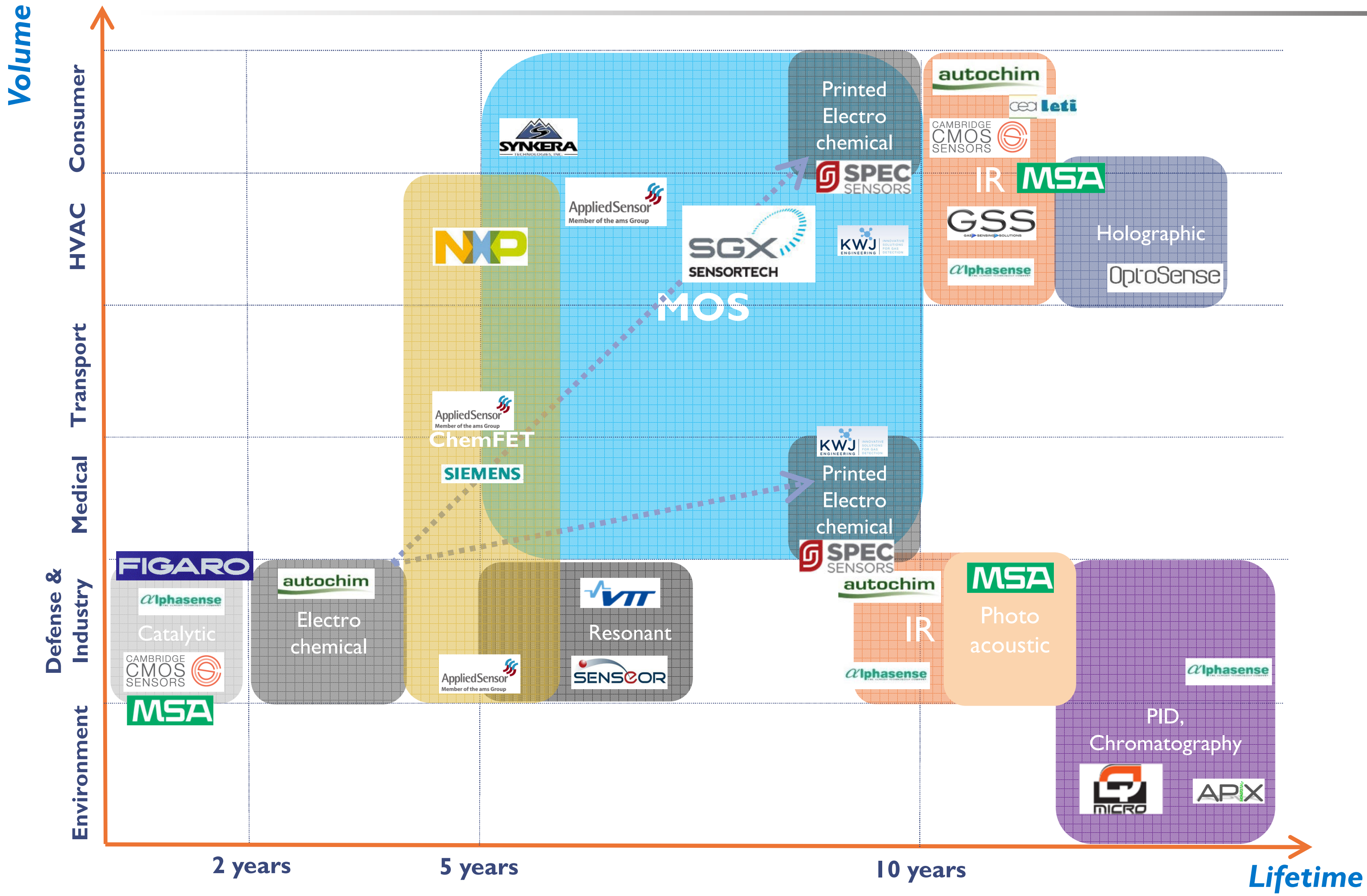
IR still predominant in HVAC & industry



GAS SENSORS PLAYERS EXAMPLES

Strong competition with few players > $50M sales at sensor level

New comers from the IC are entering the game (e.g. NXP)

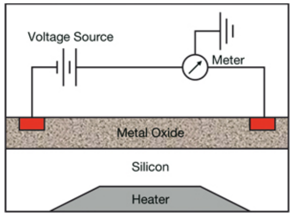


WHY GOING MEMS OR PRINTED?

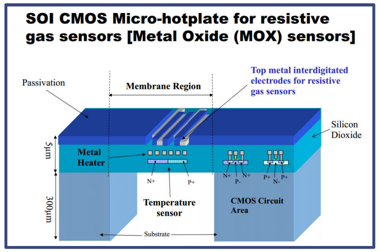
Gas sensors are undergoing manufacturing shifts

MEMS & printing allow smaller & cheaper dies

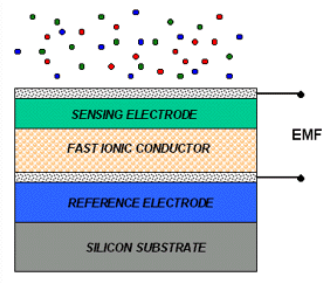
MOS gas sensor:
- Sensing principle: Gas absorption at the surface of heated oxide (200-250°C) that result in change of electrical resistance related to sample gas concentration
- Manufacturing technology: semiconductor process (CMOS)



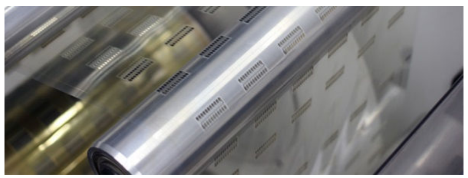
MEMS MOS gas sensor:
- Sensing principle: same than left
- Manufacturing technology: use of Si micromachining (MEMS) to create a cavity below the sensor
- Advantage compared to MOS (left): 50% size reduction and cost reduction



Electrochemical gas sensor:
- Sensing principle: Electrochemical reaction between sensing & counter electrodes creates a current proportional to target gas concentration
- Manufacturing technology: semiconductor process



Printed Electrochemical gas sensor:
- Sensing principle: same than left
- Manufacturing technology: use printing electronics processes (e.g. screen printing)
- Advantage compared to electrochemical sensor (left): low cost (<$1) achievable



From Technologies to Market

New technologies & architectures for efficient Data Centers

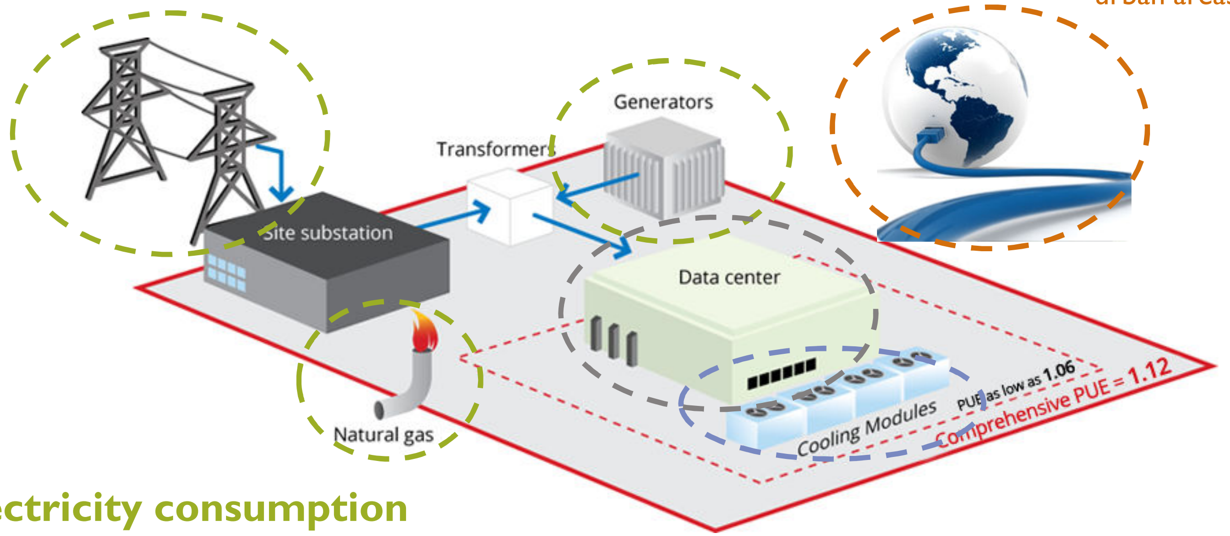
YOLE Développement

Report

MAIN 4 CHARACTERISTICS

- **Requirements on extremely high (24/7) data availability and security**
  - Solutions implemented to ensure “ALWAYS-ON state” - uninterrupted power supply, redundancy - System resilient to failure and enabling rapid recovery after failure
  - System protected against human and natural detrimental influence

- **Huge amounts of data**
  - Increasing need for bandwidth
  - Interconnexions between servers are done thanks to being at the same physical site
  - Data Centers need to be close to big urban areas



- **Very high electricity consumption**
  - A proximity of a point access to very high electrical power is required
  - Multi-sourcing is obligatory for safety reasons
  - Strong trends towards the use of renewable electricity sources (hydro, PV, wind…)
  - Ways to reduce the consumption are actively researched

- **High concentration of heat**
  - All the concentrated electronics generate huge amount of heat in a closed space
  - Large cooling systems have to be installed

DATA CENTER CHALLENGES

The main priority for Data Center owners is always reliability and life-time of components!!

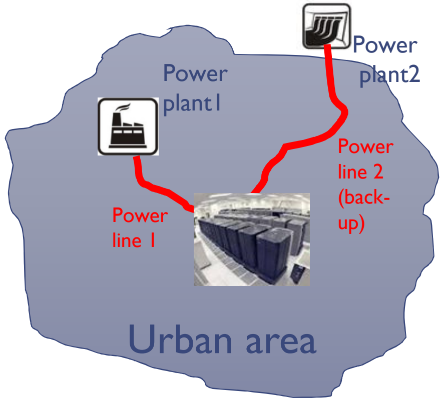
Use of “green” electricity

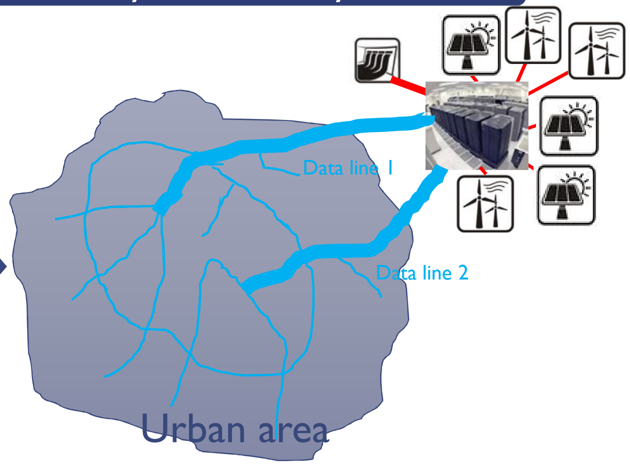
Fuel-fired power plants

Renewables

Data storage and access security

Proximity to customer → Proximity to electricity source





- Network of high information density optics fiber cables
- Low land cost and lower labor cost than in urban areas
- Possibility to grow thanks to the available space
- Possibility to use multiple renewable energy source thanks to available space and no conflict with habitations
- Improved power quality due to the combination of multiple electricity sources.

Enhanced cooling solutions

Increased system packing density (W/m²)

SUPPLY CHAIN

Equipment

Server

UPS/Power equipment

Cooling system

Photonics

Architecture

Containers

Data Center owners

Social network & eBusiness providers

DATA CENTRES CHALLENGES

The 3 big data centre challenges: distance, bandwidth & energy!

- To face the increasing demand in bandwidth, data centers face huge challenges:
  - Distance:
    - Distance is expanding (sometimes beyond 1 km for multimode optical fiber). Some light sources (e.g.VCSELs are limited)
  - Bandwidth:
    - Bandwidth is increasing: from 25Gb/s to 100Gb/s to 400Gb/s
  - Power consumption:
    - Energy consumption: data Center requires ~25MW of Power and in 2013, data centres consumed more than 5% of US electricity. So low power consumption solutions are required.
    - Interconnects account for a major part of power consumption.
    - Cooling will become significant and any new interconnect solution must take less power.
    - One Google Search is about 1kJ.

Optical interconnects is the solution to cope with current data centers challenges.

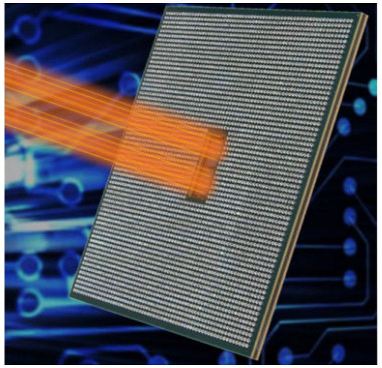
YOLE Développement

DATA CENTRE NETWORKING

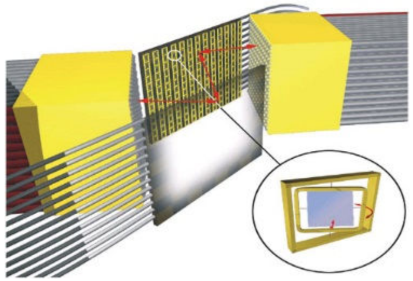
Where optics is cool!

Just a few examples of photonic solutions that will reduce power.

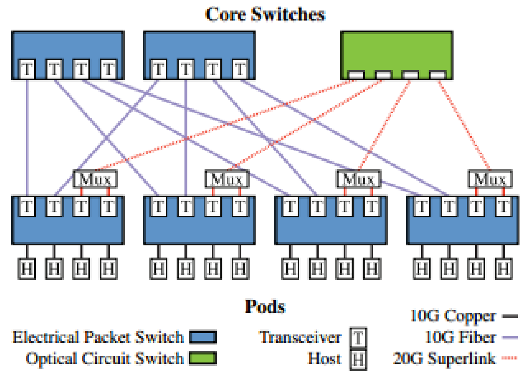
Router ASIC with integrated optics (Compass-EOS)



OOO routers (Calient)



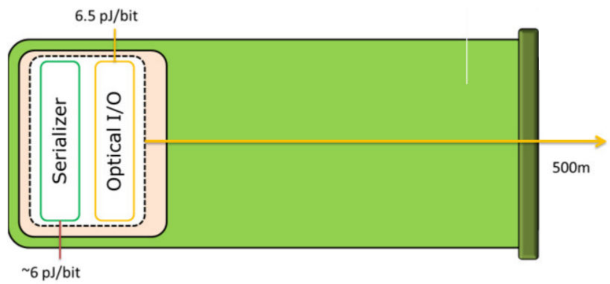
Hybrid optical/electrical switching (UCSD)



AOC (Finisar)

Active Optic interconnect (TE Connectivity)

Si photonics and closer integration (Luxtera)



PHOTONICS IN DATA CENTRES

Silicon Photonics is the next big thing!

Silicon photonics is the short term answer to data centre issue: POWER!

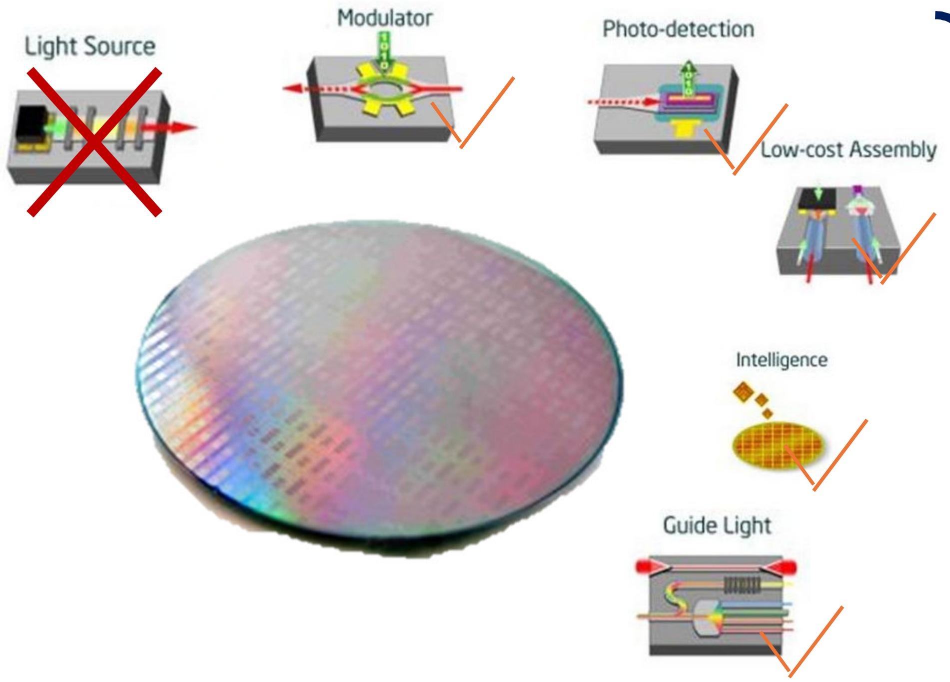
- Silicon photonics involves the use of silicon semiconductors as the medium for optical signals, allowing much faster digital signaling than is currently possible with traditional electron-based semiconductor devices.
- Si photonics offers the advantages of a silicon technology: low cost, higher integration, more functionalities embedded, higher interconnect density. It gives 3 main advantages:
  - Low power consumption – in particularly compared to copper-based solutions which is expensive with high electrical consumption.
  - Reliability – important for data centres where rack servers life time is 2 years and often replaced.
  - Last but not least, it is Si technology, with benefits of functions integration, low manufacturing cost and high density.
- Back in 2006, VOA have been the first Si photonics products on the market
- Today still few Si photonics products are on the market : VOA, AOC and Transceivers from Luxtera, Kotura/Mellanox, Cisco/Lightwire.
- Over the near term, Si photonics chips will be deployed in high-speed signal transmission systems, which far exceed the capabilities of copper cabling: Data Centers and High Performance Computing (HPC).
- As Si photonics evolves and chips become more sophisticated, we expect to see the technology used more in processing tasks such as interconnecting multiple cores within processor chips to boost access to shared cache and busses.

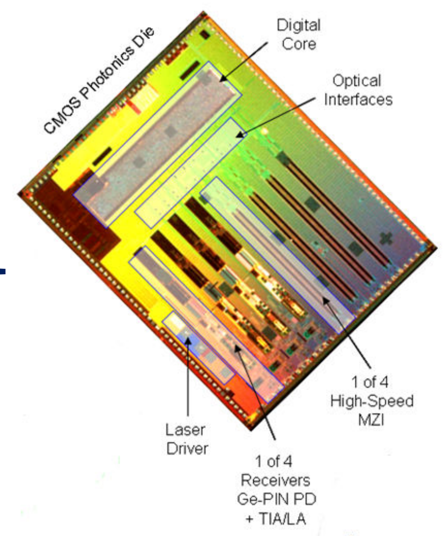
WHAT IS SI PHOTONICS

Silicon photonics is …

- A disruptive technology: new breed of monolithic opto-electronic devices in a potential low cost Si process.
- The vision: to deliver optical connectivity everywhere, from the network level … to chip-to-chip.

Today, except for the light source, many optical functions can be embedded at the SOI wafer level.



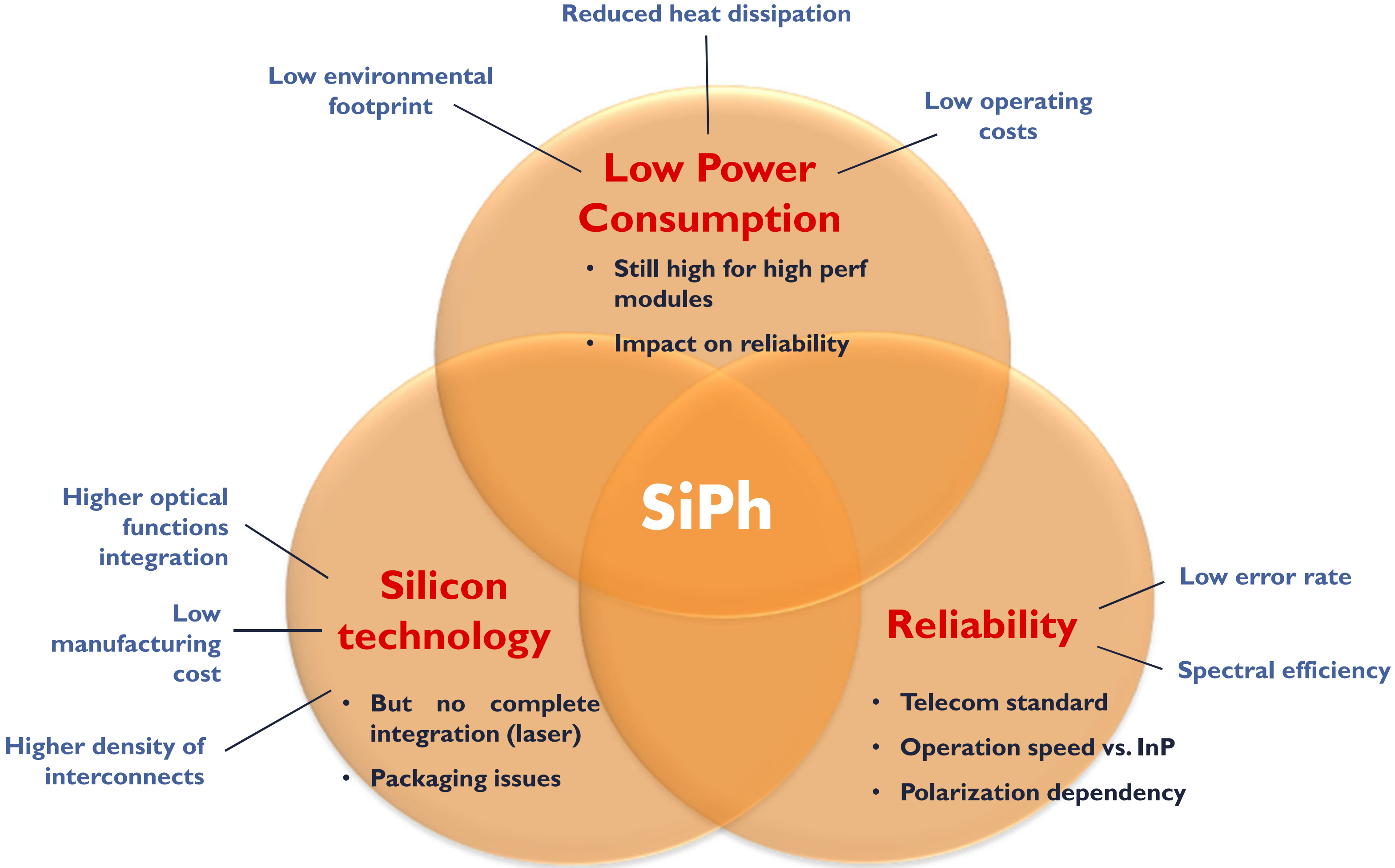


Source Luxtera

INTRINSIC SI PHOTONICS ADVANTAGES

Si photonics mixes CMOS & optics advantages

Power target for photonics is 1 fJ/bit!



From Technologies to Market

Infrared detectors market 2015
From motion sensors to large arrays

YOLE Développement

Report

NEW KEY PRODUCTS INTRODUCED SINCE TWO YEARS

Incumbent IR detector technologies have been dynamic + a new pyroelectric CMOS sensor is about to enter on the market

<u>Systems</u>

Irisys Gazelle 2

FLIR TCX

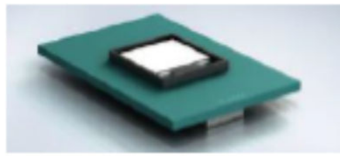
Pyreos Handheld Spectrometer

<u>Sensors</u>

Heimann 32x32 and 8x8
with new design

IR Lynx 64x64

Excelitas 32x32
New design

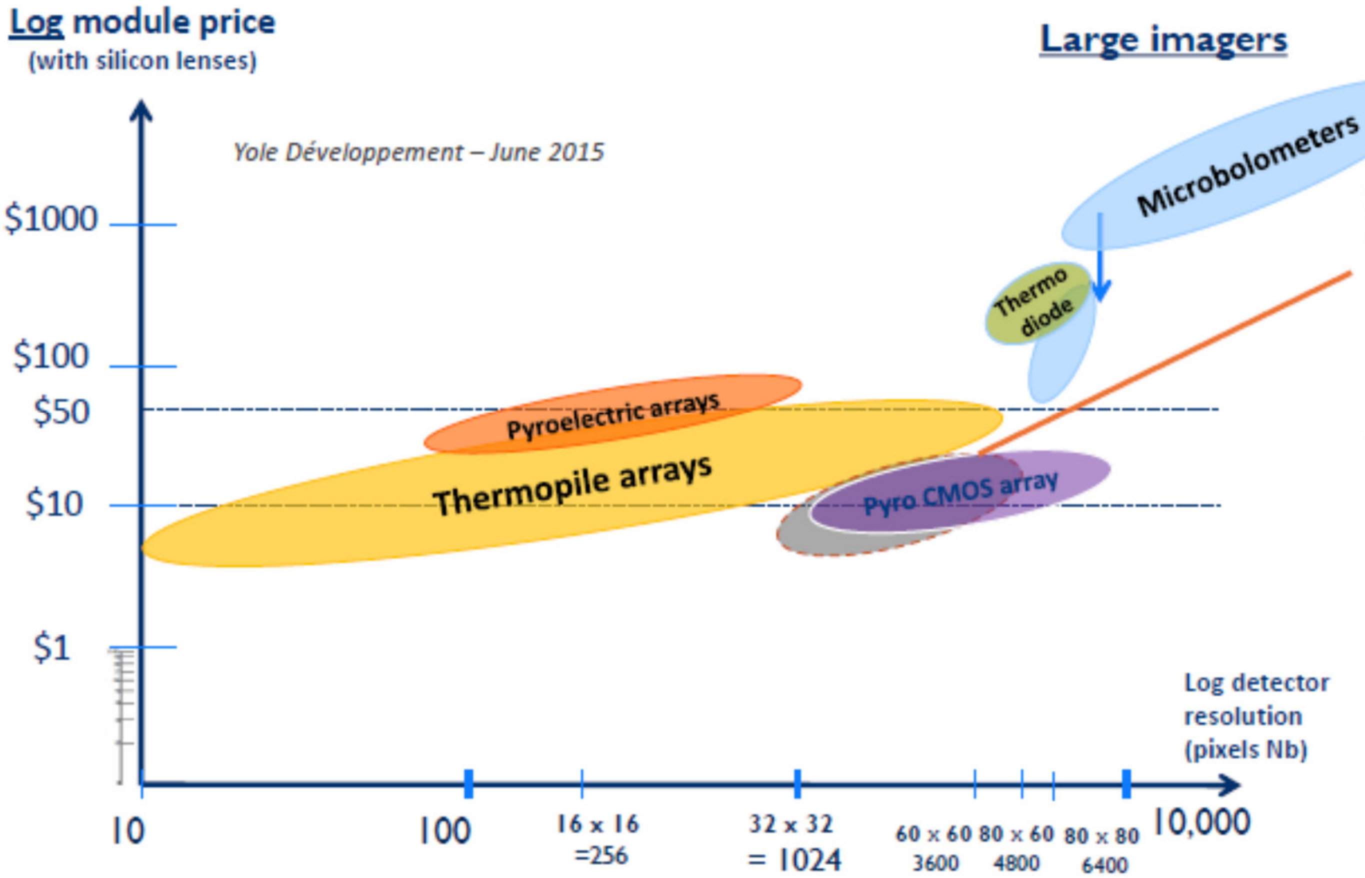


Bosch 82x62

FLIR Lepton 80x60

LARGE ARRAYS TECHNOLOGIES FOR SMART BUILDINGS APPLICATIONS

New technologies are entering on the market (thermodiode, Pyro CMOS). Pyro CMOS is well positioned in terms of price/resolution



Smart buildings applications

- Cost target : the lowest is the best. Below $ 10 is a significant threshold to reach large adoption. Thermopiles and pyros CMOS arrays are well positioned.
- Resolution target : the highest is the best. High resolution will enable wider surface covered and more available functions. Thermopiles focus on 32x32 in order to reduce the cost. IR imaging technologies focus on 80x60 because they originally were present on much higher resolution. Those expensive technologies will need to reduce strongly their cost in the future to enter on the market.

CURRENT INFRARED DETECTOR TECHNOLOGIES

Overview

<u>IR imaging technologies</u>

Small Pyroelectrics (crystal or ceramic)

A pyroelectric sensor is a sensor that uses natural or artificial pyroelectric material.
Most common pyroelectric sensors <u>use a few pixels (1 to 4).</u>
Application: widely used in low-end motion detection or gas & fire detection

Key players: Excelitas, Nicera, Murata

2014 market: $123M

Pyroelectric arrays (ceramic, thin film or CMOS based)

New pyroelectric technologies have been developed by specific companies with a strong focus on the development of arrays (1x8 to 64x64 pixels)

Applications: People counting, gas & flame detection, spectroscopy

Key players: Irisys, Pyreos, IR lynx

2014 market: $ 5 M

Thermopile

Thermopiles use dominantly silicon material and are used to measure temperature level or gaz concentration

Applications: thermometer and pyrometer, gas and flame detection

Key players: Excelitas Heimann, Nicera, Melexis, Dexter Research
2014 market: $50M

Thermopile arrays

Thermopile arrays have been introduced initially by Heimann and Excelitas and are available from (1x8 to 64x80 pixels)

Applications: HVAC, appliances, automotive, smart buildings

Key players: Excelitas, Heimann, Melexis, OMRON

2014 market: $22M

Silicon Thermodiode

Silicon thermodiodes have been developed by Bosch for imaging purpose and could be used for detection in the future.

Applications: smart building

Key players: Bosch

Microbolometer imagers

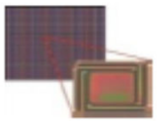
Microbolometers today are IR imagers and not detectors. Several manufacturers plan to develop microbolometer detectors to open new applications. ULIS introduced the first 80x80 sensor

Applications: smart building

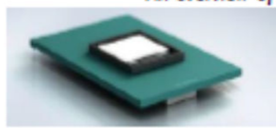
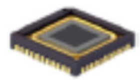
Key players: Ulis, FLIR

An overview of the IR imaging industry is provided in this report







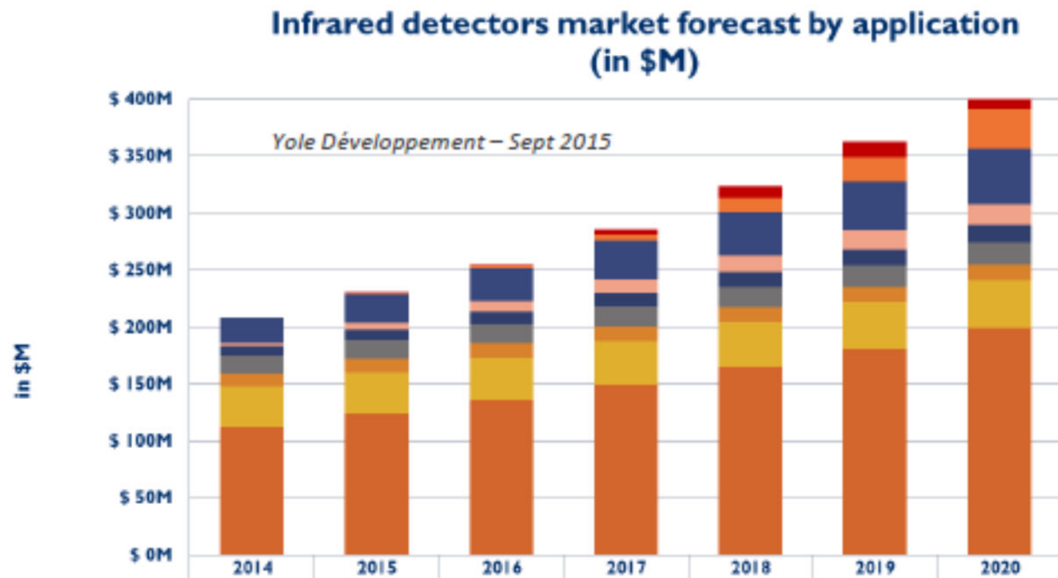




INFRARED DETECTOR MARKET FORECAST BY APPLICATION

Market forecast in revenues (in $ M)

CAGR 2015–2020 will be +13 % in $

- Motion detection is by far the dominant application in revenue along with low-end temperature sensors in 2014.
- HVAC and other medium arrays applications will become the second IR detector business in 2020 with 14% CAGR.
- First notable sales of large arrays (>32x32) for smart buildings are expected to begin in 2016, and are expected to grow at a 132 % rate.
- Mobile device spot thermoter will the other fast growth application to reach $ 29 M in 2020.



	2014	2015	2016	2017	2018	2019	2020	CAGR 2015-2020
TOTAL	$ 209M	$ 230M	$ 255M	$ 286M	$ 324M	$ 363M	$ 420M	13%
Mobile devices : spot thermometer	$ 0.0M	$ 0.2M	$ 0.4M	$ 5M	$ 11M	$ 14M	$ 29M	187%
Smart building	$ 0M	$ 0.5M	$ 2M	$ 5M	$ 12M	$ 21M	$ 34M	132%
HVAC and other medium formats	$ 23M	$ 26M	$ 29M	$ 33M	$ 38M	$ 43M	$ 49M	14%
People counting for retail	$ 3M	$ 6M	$ 9M	$ 12M	$ 15M	$ 17M	$ 19M	26%
Spectroscopy	$ 8M	$ 9M	$ 11M	$ 12M	$ 13M	$ 14M	$ 15M	10%
Gas & fire detection	$ 15M	$ 16M	$ 17M	$ 17M	$ 18M	$ 19M	$ 19M	4%
High end temperature measurement	$ 12M	$ 12M	$ 12M	$ 13M	$ 13M	$ 13M	$ 13M	2%
Low end temperature measurement	$ 35M	$ 36M	$ 37M	$ 39M	$ 40M	$ 41M	$ 42M	3%
Motion Detection	$ 113M	$ 124M	$ 136M	$ 150M	$ 165M	$ 181M	$ 199M	10%

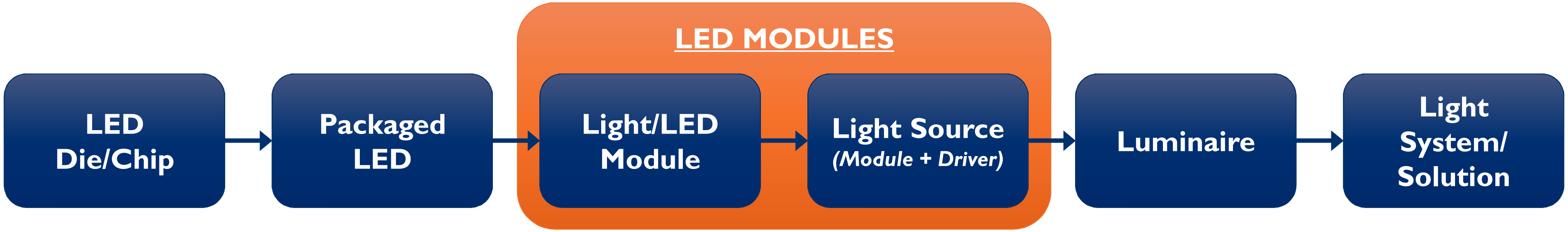
From Technologies to Market

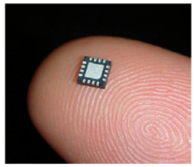
LED Lighting Module Technologies

YOLE Développement

EXECUTIVE SUMMARY

LED Module in the Global LED Value Chain





Lumileds

Philips Lighting

- From LED chip to LED lighting system, several steps of value drive the lighting industry. LED modules represent a bridge between the packaged LED offer and the luminaire shaped product.
- A significantly integrated LED package reduces the level of know-how necessary for lighting manufacturers, thereby enabling conventional lighting system manufacturers to have easier access to the technology.
- Basically, we can consider an LED module as a unit containing one or more LEDs with mechanical and optical components.
    - It may contain additional components (e.g., connectors, resistors, ESD protection devices, lenses…).
    - Generally, LED module is considered a replaceable item for use in a luminaire.
- An LED module represents a component/sub-system optimized for a given application scope.

EXECUTIVE SUMMARY

The Different Types of LED Modules - Positioning

Middle Power LED Module:

- The middle power LED is a solution offering low power consumption and high flux.

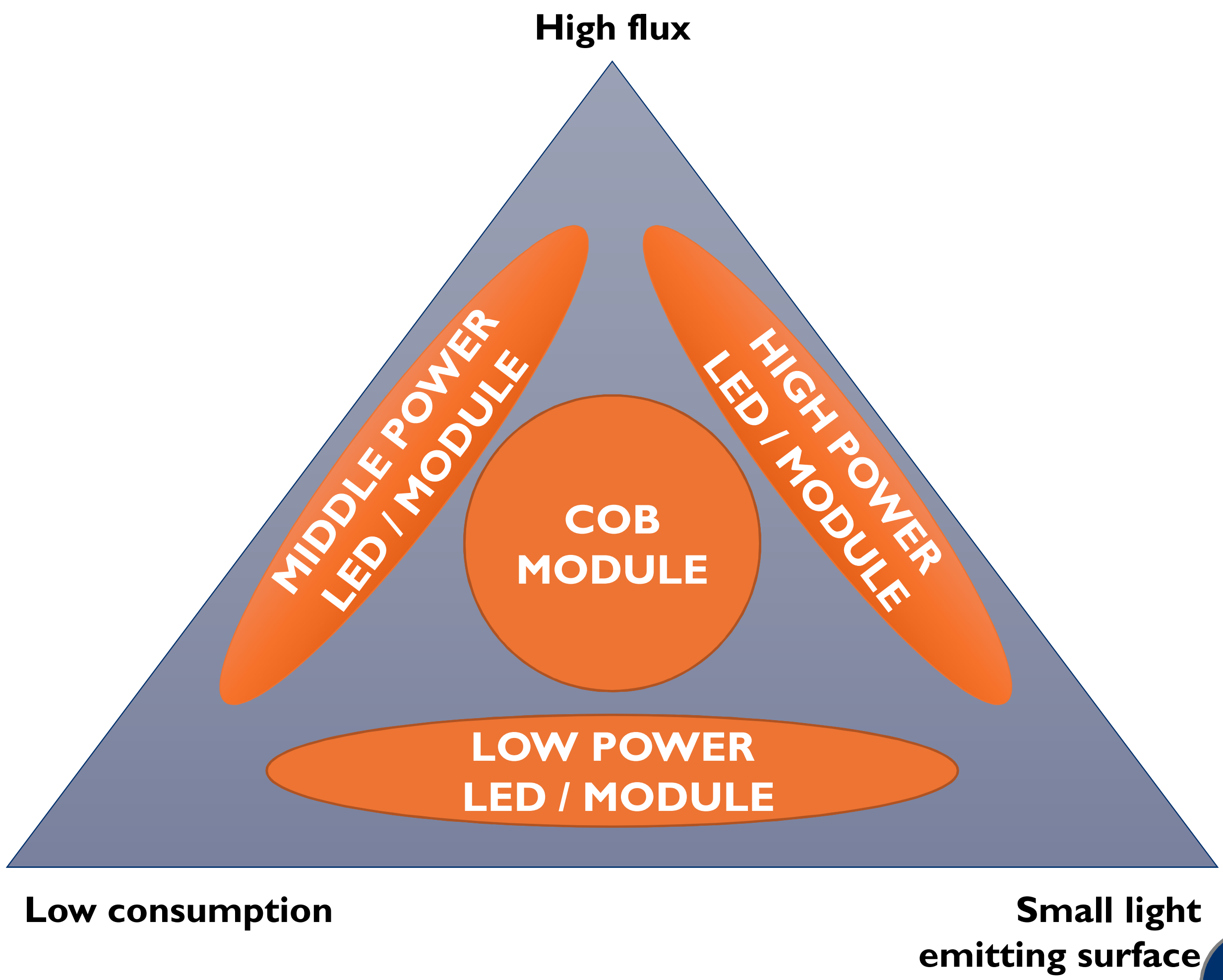
High Power LED Module:

- The high power LED is a solution offering small lighting emitting surface and high flux.

COB LED Module:

- The COB module architecture is a solution offering good compromise between size of the light emitting surface, flux power and power consumption.

➔ The choice of the right LED module solution depends on requirements at application level, cost level (…).



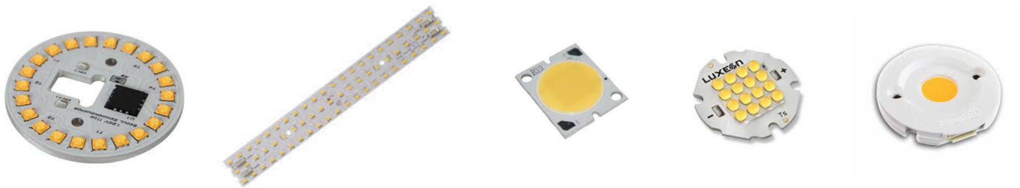
EXECUTIVE SUMMARY

LED Modules and Performances

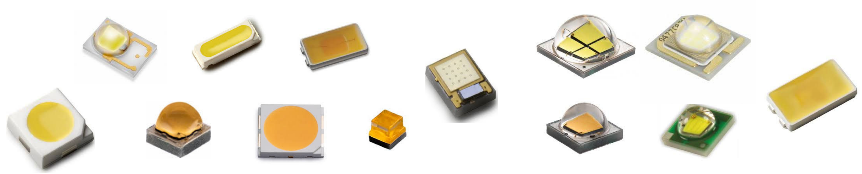
LED module can be considered equivalent to lamp!

LED LIGHTING SYSTEMS

LED MODULES



LED SUPPLY CHAIN



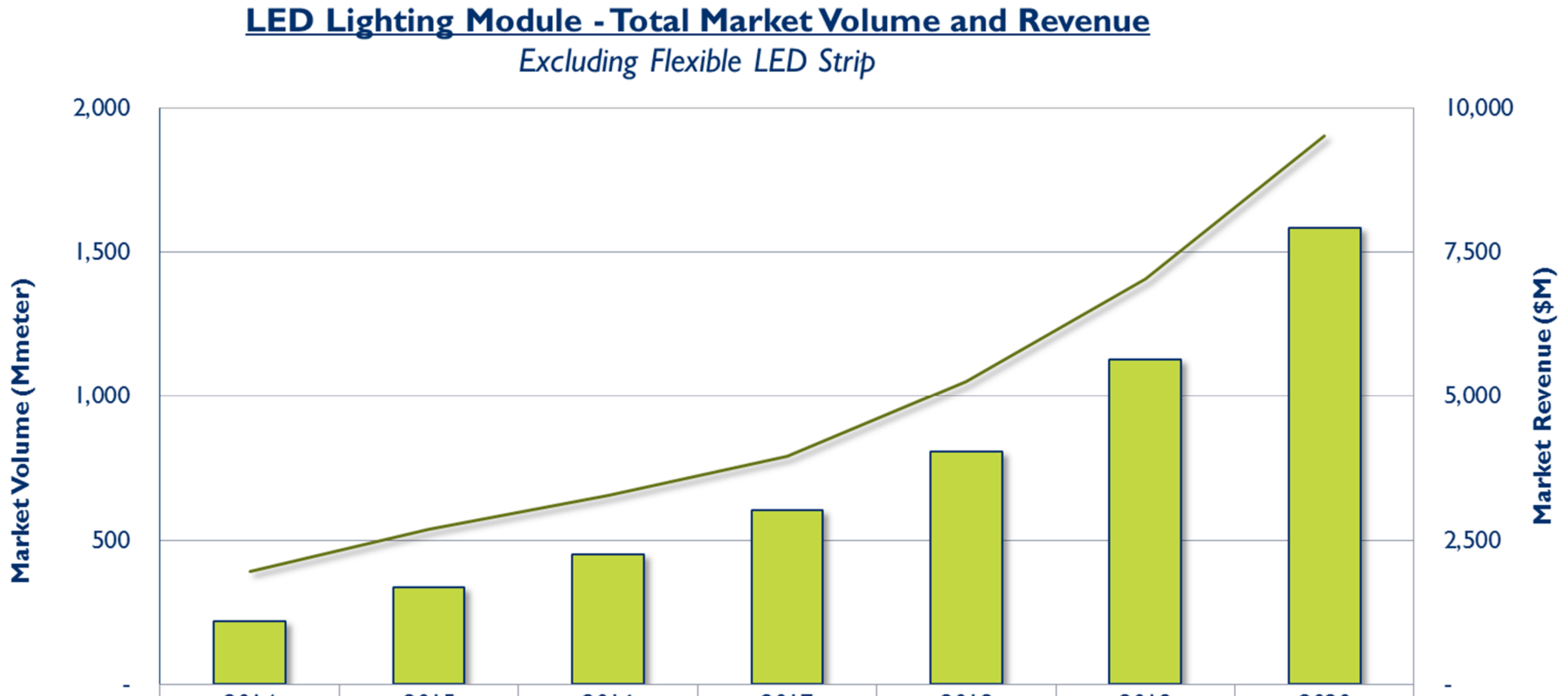
LED modules significantly contribute to the system performances, quality and safety.

LED modules become a target for performances and quality (i.e., technical specifications) regarding LED production / manufacturing.

EXECUTIVE SUMMARY

LED Lighting Module Market Trends

In 2014, the LED lighting module market represented a size of ~$2B. It should grow to a size of ~$9.5B by 2020.

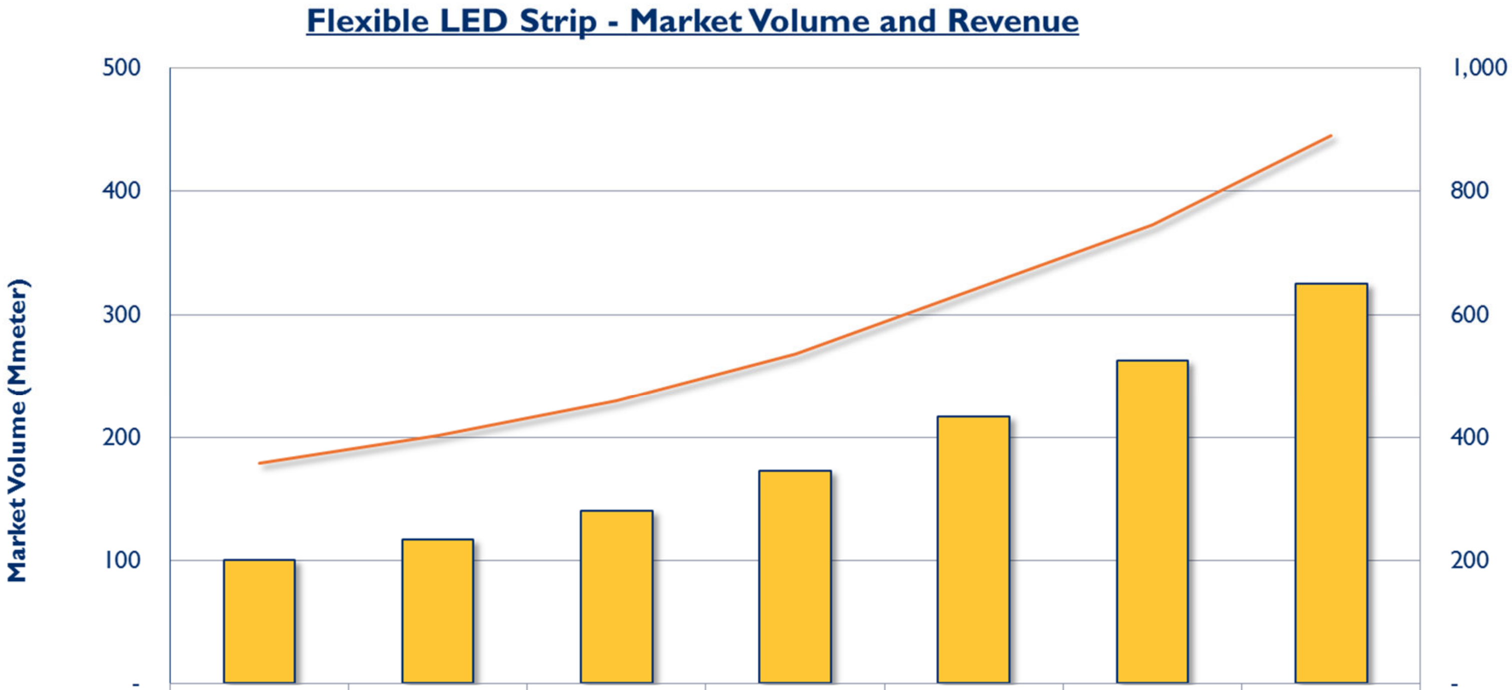


	2014	2015	2016	2017	2018	2019	2020
Market Volume (Munits)	220.3	335.4	452.0	602.6	806.9	1,125.8	1,584.9
Market Revenue ($M)	1,956.2	2,687.4	3,271.0	3,950.0	5,247.3	7,038.9	9,511.9

EXECUTIVE SUMMARY

LED Lighting Module Market Trends - The Case of Flexible LED Strips

In 2014, the flexible LED strip market represented a size of ~$360M. It should grow to a size of ~$900M by 2020.



	2014	2015	2016	2017	2018	2019	2020
Market Volume (Mmeter)	100.1	117.3	140.5	172.6	217.0	262.7	325.2
Market Revenue ($M)	358.1	403.0	460.0	536.7	640.4	745.0	891.0

YOLE Développement

EXECUTIVE SUMMARY

The SSL Chasm

LED module allow to bridge the SSL chasm and accelerate penetration of LED technology in lighting applications.

What LED Manufacturers Produce

- Packaged Emitters
- Components
- Less than 200 lm
- Technology Focused
- Proprietary Standards
- Short Product Life Cycles
- Long Product Lifetime

The "SSL Chasm"

Thermal Management
Drivers
Metrology
Encapsulation
Phosphors
Micro Optics
Light Engines
Color Management
(…)

What Lighting Manufacturers Use

- Bulbs and Luminaires
- Lighting Systems
- More than 500 lm
- Industry Standards
- Long Product Life Cycle
- Vast Bulb Replacement Market

New technologies, business models and industries are developed to enable Solid State Lighting (SSL) → Vertical / Horizontal integration and consolidation facilitate and speed up the process!

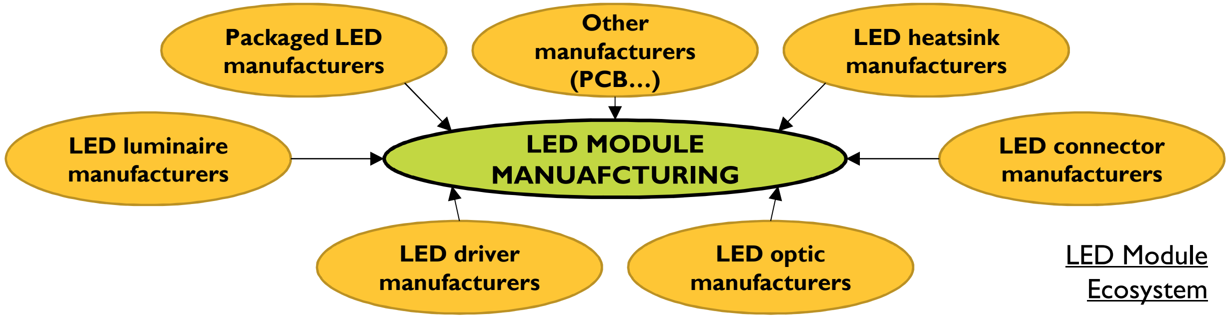
YOLE Développement

EXECUTIVE SUMMARY

LED Lighting Module Industry Trends - Origin of Players

Most of the LED module manufacturers are coming from the packaged LED field.

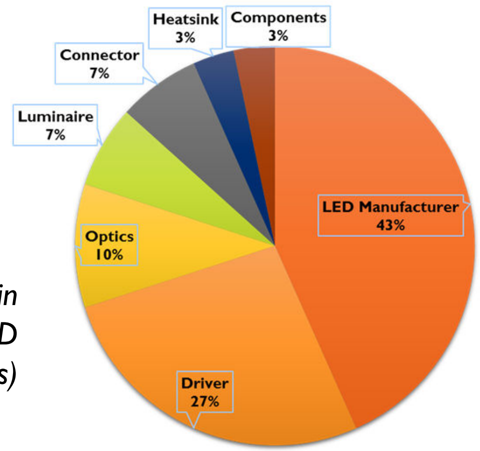
- Many players can manufacture LED modules as such activity is relying mostly on assembly expertise.
- Main players involved in the LED module manufacturing are:
  - Packaged LED manufacturers.
  - LED luminaire manufacturers.
  - LED driver manufacturers.
  - LED optic manufacturers.
  - LED connector manufacturers.
  - LED heatsink manufacturers.
  - Other manufacturers (PCB…).



LED Module Ecosystem

- Main analyzing more deeply the origin of LED manufacturers, it seems that a majority of LED module manufacturers are coming from the packaged LED industry.

The analysis is based on the identification of main players involved in LED module manufacturing and sale (sample of more than 40 LED lighting module manufacturers)



Analysis of origin of LED module manufacturers

From Technologies to Market

OLED for Lighting

Technology, Industry and Market Trends

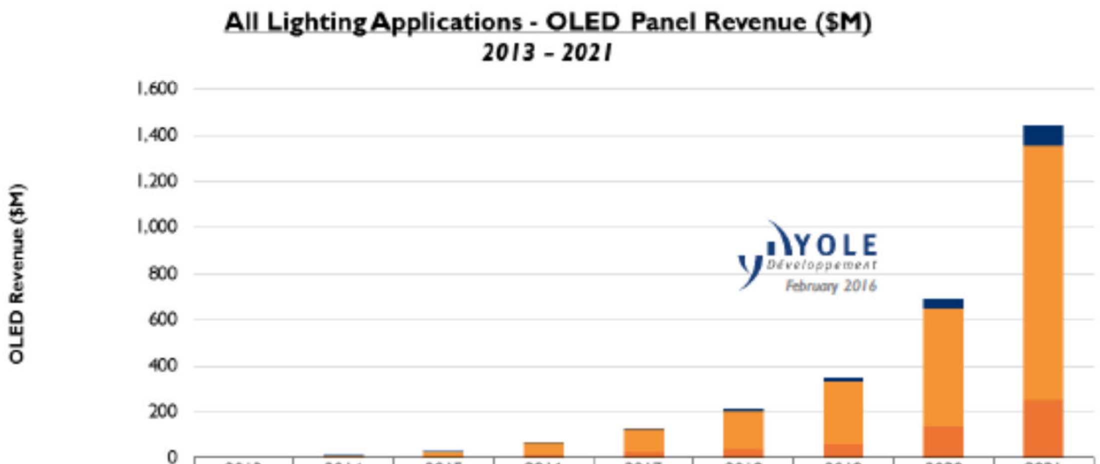
2016 Report

YOLE Développement

EXECUTIVE SUMMARY - APPLICATIONS AND MARKET SEGMENTS OF OLEDS

EXECUTIVE SUMMARY - TOTAL OLED LIGHTING MARKET OPPORTUNITY (1/2)

Lighting applications could represent a business opportunity for OLED device of ~$1,450M by 2021.



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Niche Lighting	$0	$1	$2	$4	$6	$10	$18	$41	$88
General Lighting	$1	$8	$28	$54	$98	$163	$274	$517	$1,103
Automotive Lighting	$-	$-	$-	$12	$25	$40	$59	$134	$251
Total	$1	$8	$30	$69	$129	$213	$351	$693	$1,442

- Niche lighting applications could be part of the spark required to trigger the OLED lighting market.
- As OLED represent still an emerging technology for lighting applications, such niches could help to develop the production scale momentum and create the marketing window demonstrating the advantages and possibilities of the technology for customers. However, to develop such strategy (i.e.: niche market strategy), investment will have to be done at the application level in order to identify applications for which OLED may provide an added value.

EXECUTIVE SUMMARY - OLED LIGHTING INDUSTRY (4/4)

OLED lighting panel developers and suppliers

Most OLED lighting panel manufacturers are still focused on rigid panels for general lighting (white light).

	General lighting	Automotive lighting	Niche lighting
Rigid	OSRAM Opto Semiconductors; Lumiotec; OLEDWorks; Astron FIAMM; BLACKBODY Light by Design; Pioneer + Mitsubishi Chemical MPOL; ASON Technology Co., Ltd. エイソンテクノロジー株式会社; FIRST O-LITE; Visionox; Kaneka; Sumitomo Chemical; NeoView Kolon; LG Display; Fraunhofer FEP	OSRAM Opto Semiconductors; Pioneer	OLEDWorks; Pioneer + Mitsubishi Chemical MPOL; LG Display; Sumitomo Chemical
Flexible	LG Display; Konica Minolta	OSRAM Opto Semiconductors; Astron FIAMM	

Recent mergers and acquisitions: ***Lumiblade by OLEDWorks and OLED business from LG Chem by LG Display.***

EXECUTIVE SUMMARY - TOTAL OLED LIGHTING MARKET OPPORTUNITY (2/2)

Can boom OLED display market help to increase penetration rate of the the technology for lighting applications?

OLED technology push

- OLED lighting panels are thin, lightweight, glare-free (…).
- But is there a real demand for them?
- The common argument why OLED lighting market is not strongly growing is the HIGH COST.
- Many players focus therefore on innovative materials and processes to drive the cost down.

OLED lighting market pull

What is the customers' perception of the OLED lighting differentiating added value?

OLED display market pull

The growing demand for OLED displays could help to pay the cost of development of OLED equipment and materials and reduce the cost of OLED materials due to high volume production.

Will a join technology effort for OLED display and lighting could result in lower manufacturing cost and therefore higher sales for OLED lighting panels?

OLED Display + OLED Lighting = OLED Lighting + Display ?

Solid State Medical Imaging: X-Ray and Endoscopy

The Medical Image Sensors market is expected to double over the next five years. M&A are increasing. Discover how Medical Imaging is being reshaped!

Overview of the technical & economic requirements for Medical Imaging applications

October 2014

YOLE Développement

Le Quartz - 75 cours Emile Zola - 69100 LYON-Villeurbanne
Tel: +33 472 83 01 80 - Fax: +33 472 83 01 83
Web: www.yole.fr

Scope of the Report

Executive Summary

- **Endoscopy Sweet Spot**
  - Camera Pills
  - Disposable Endoscopes
  - Flexible Endoscopes
  - Rigid Endoscopes

- **X-Ray Imaging Sweet Spot**
  - X-Ray imagers for intra-oral imaging
  - X-Ray imagers for 2D extra-oral imaging
  - X-ray 3D CBCT extra-oral imaging
  - X-Ray imagers for 3D & large area imaging

- **Endoscopy Sweet Spot:**

The endoscopy application is fruitful in terms of innovative product development. These evolutions drive medical image sensor requirements.

- **X-Ray Imaging Sweet Spot:**

This application, more mature, represents the largest in terms of value and annual growth.

Medical Image Sensors
Market Segmentation
Executive Summary

		Direct Imaging / Hardware Dependant								Indirect Imaging / Software Dependant		
Application		Microscopy	Endoscopy				X-Ray based methods			MRI	Ultrasound Imaging	Nuclear Medicine
Standalone	Disposable		Camera pills	Disposable endoscopes								
Standalone	Re-usable				Flexible endoscopes	Rigid endoscopes	X-Ray imagers for intra-oral imaging	X-Ray imagers for 3D & large area imaging			Doppler ultrasound	
Integrated into a large system		Microscopes					X-Ray imagers for 2D extra-oral imaging		CT	MRI system		PET Scan

Optical Imaging **X-ray Imaging**

- **This report will focus exclusively on direct Imaging applications.**
- **Microscopy is excluded from that report because is hardly ever used in vivo, primarily it is used in vitro.**
- **Indirect imaging applications will not be developed in this report as their evolution rather relies on software processing optimization.**

Image Sensor Technologies by Market

Executive Summary

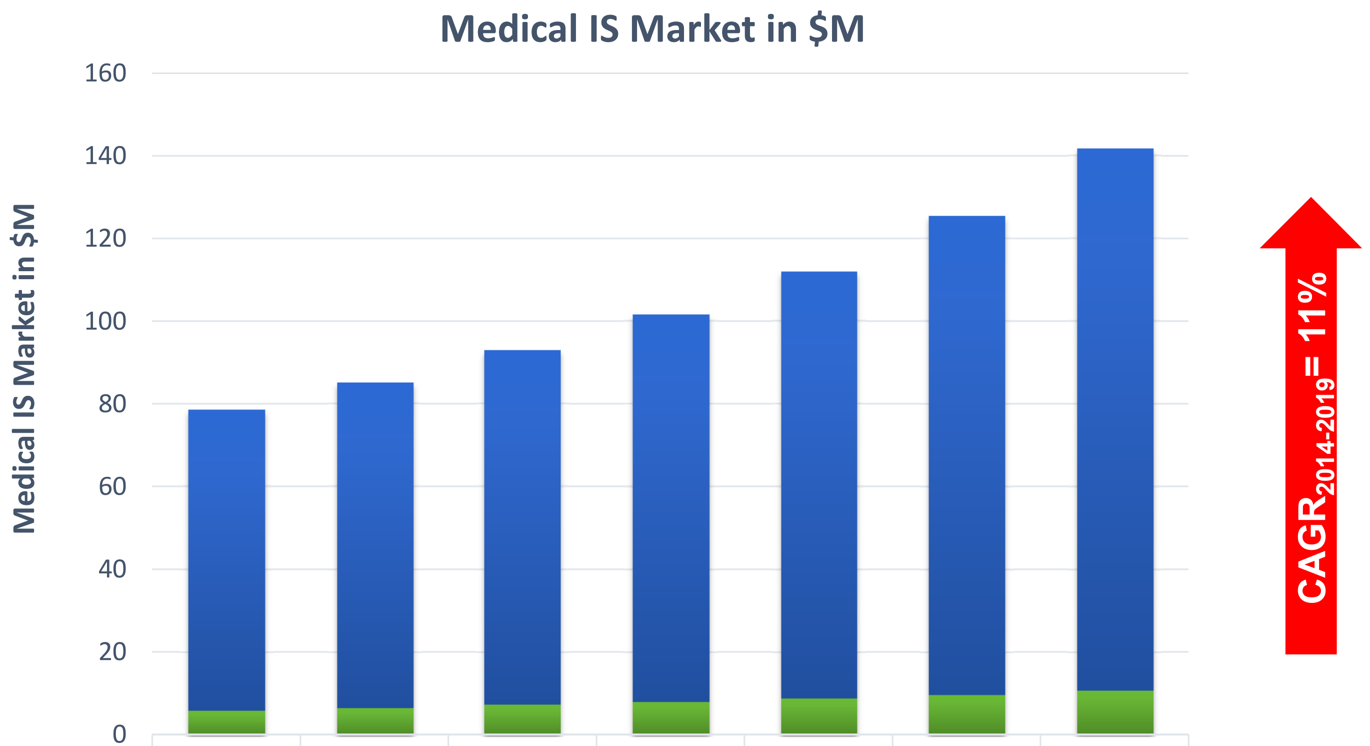
The table below links applicative markets and Medical Image Sensor (MIS) technologies:

		CCD MIS	CMOS MIS	A-Si MIS
Endoscopy Application	Camera pills market	X	X	
	Disposable endoscopes market		X	
	Flexible endoscopes market	X	X	
	Rigid endoscopes market	X	X	
X-Ray Imaging Application	intra-oral imaging market		X	
	X-ray 3D CBCT extra-oral imaging	X	X	X
	2D extra-oral market	X		
	3D & large area market	X	X	X

Global Medical Image Sensors Market (in M$)

For Endoscopy and X-Ray Imaging

Executive Summary



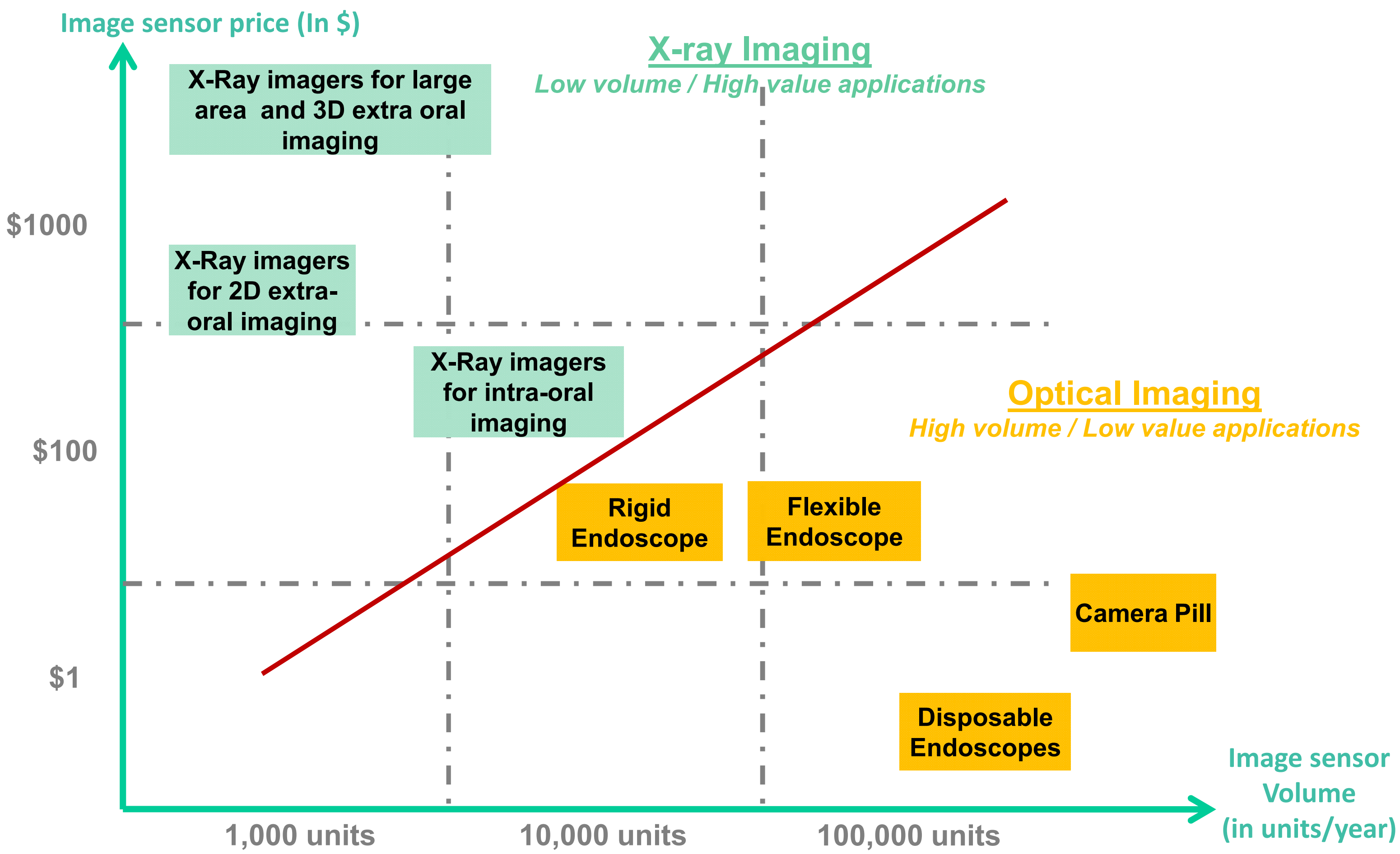
	2013	2014	2015	2016	2017	2018	2019	$CAGR_{2014-2019}$
X-Ray IS Market in $M	72.7	78.7	85.6	93.7	103.1	115.9	131.0	11%
Endoscopy IS Market in $M	5.9	6.5	7.3	8.1	8.8	9.7	10.8	11%

The global Medical Image Sensor market will grow from $79M in 2014 to $142M in 2019.

Image Sensors Positioning

Price/Volume Mapping

Executive Summary

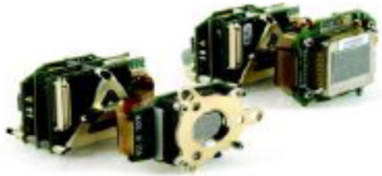



From Technologies to Market
Uncooled
Infrared Imaging
Technology & Market
Trends 2015
-
Commercial & Military Applications
YOLE
Développement
Report

DEFINITIONS

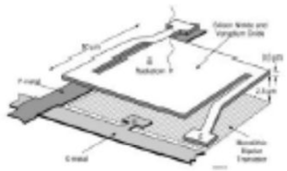
- An infrared thermal camera is a thermal system which converts infrared (IR) radiation into a visible image.
- An IR camera's main parts are:

Camera

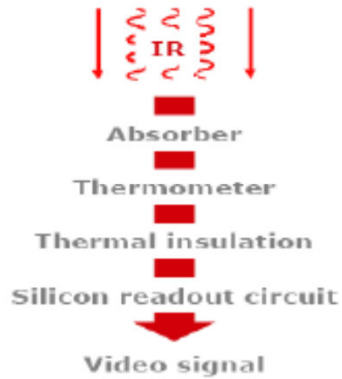


Camera core (with electronics and sometimes IR lenses)

Imager/sensor (Uncooled Focal Plane Array - UFPA)



Pixel (Each sensor is an array of thousands of pixels)



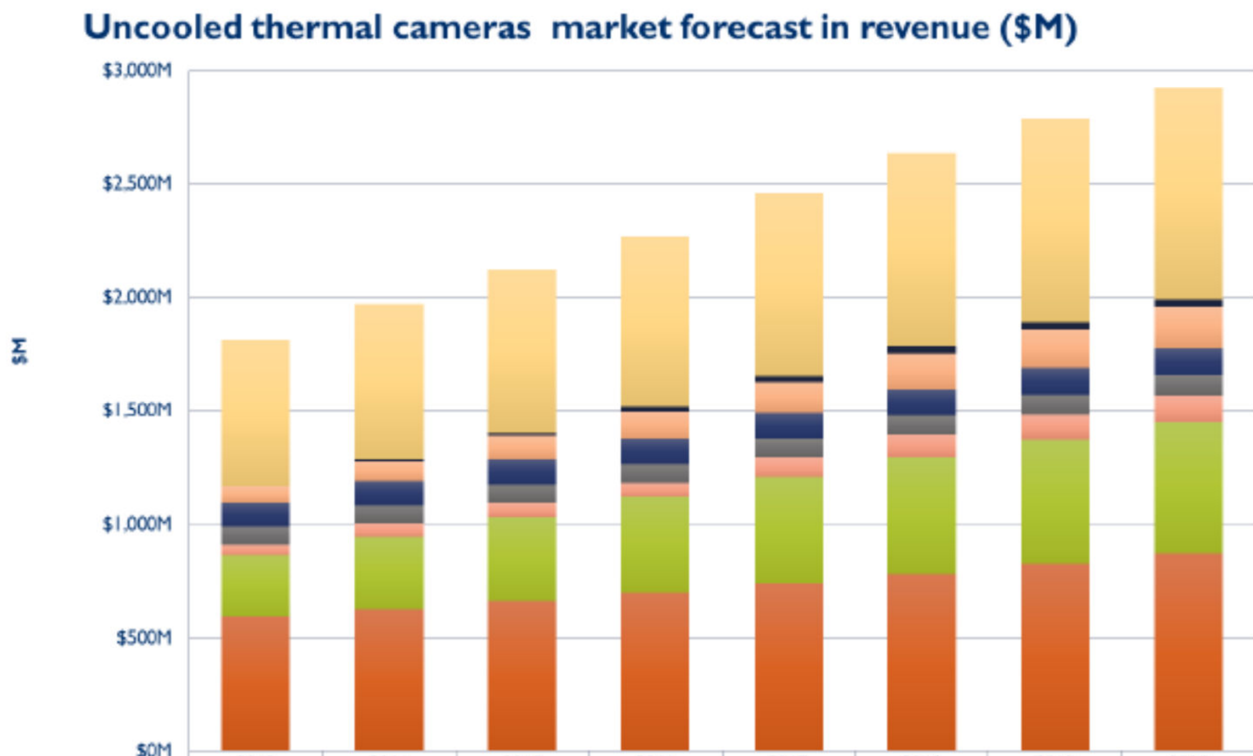
- **Cores are modules that include imagers + electronics, and sometimes lenses. Without lenses, it's also called a "vid engine".**
- **Imagers are also called UFPA (Uncooled Focal Plane Arrays) or IR sensors. Detectors provide only a detection sig (no image) and are covered in Yole's 2013 report on the IR detector market and technology trends.**
- **An imager can have various formats (1024 x 768 to 16 x 16) and pixel pitch (usually from 12µ - 40µ in 2014).**

UNCOOLED THERMAL CAMERAS

Market forecast in revenue ($M) – Nominal scenario

CAGR 2015 - 2020 growth (+ 6.7%) is driven by military recovery at almost constant price and high commercial volumes

- Market came back to a growth phase in 2014 (+9% revenues) after bad 2012 and 2013 years, thanks to stabilization of the military business earlier than expected and dynamic commercial business.
- Market will exceed $3 B by 2020, fueled strongly by Surveillance (+$229M), Military (+$207M), Thermography(+$200 M+), and PVS ($82M+) compared to 2014.



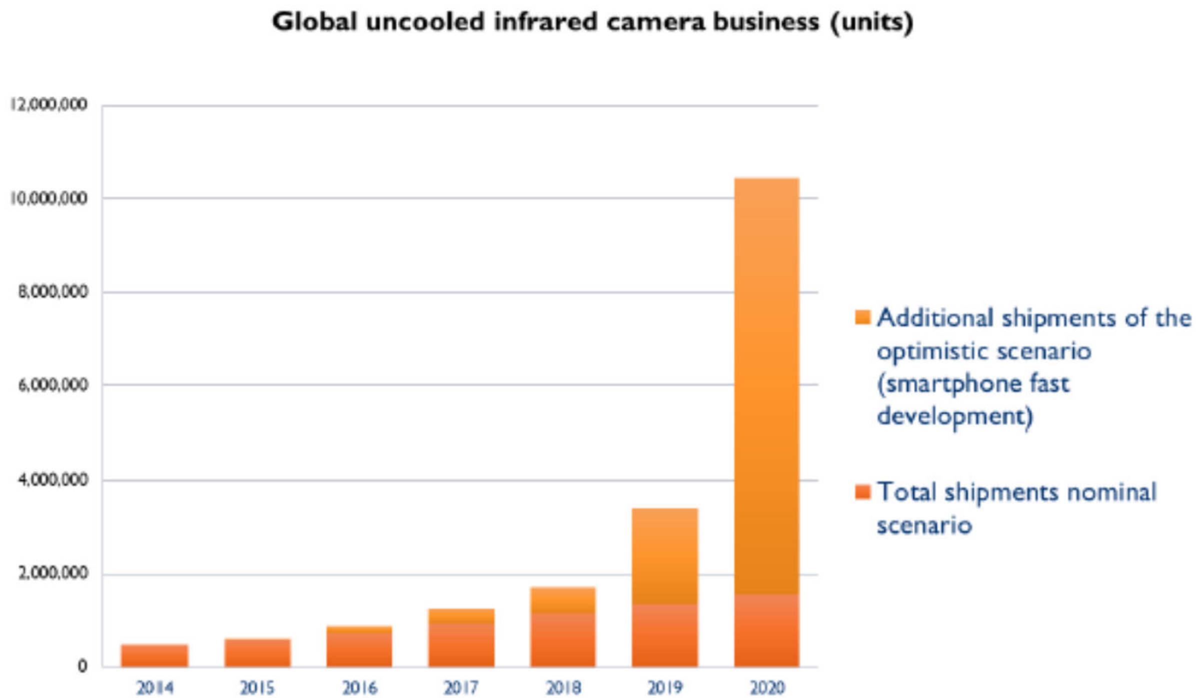
	2013	2014	2015	2016	2017	2018	2019	2020	CAGR 2015-2020
Total revenues	$1,814M	$1,981M	$2,133M	$2,281M	$2,476M	$2,656M	$2,809M	$2,946M	6.7%
Military total	$648M	$687M	$718M	$750M	$802M	$852M	$894M	$934M	5.4%
Smartphones	$0M	$8M	$13M	$18M	$25M	$32M	$34M	$32M	20.4%
Personal Vision Systems (PVS)	$70M	$85M	$103M	$120M	$138M	$155M	$167M	$181M	11.9%
Firefighting	$108M	$109M	$111M	$113M	$115M	$117M	$119M	$121M	1.7%
Maritime	$76M	$78M	$80M	$82M	$85M	$87M	$89M	$91M	2.6%
Automotive revenues	$46M	$60M	$63M	$62M	$85M	$100M	$109M	$113M	12.3%
Surveillance total	$273M	$319M	$369M	$418M	$466M	$510M	$548M	$579M	2.6%
Thermography total	$593M	$627M	$665M	$702M	$743M	$783M	$828M	$875M	9.4%
									5.6%

Commercial/ consumer markets

UNCOOLED THERMAL CAMERA

Market forecast in shipments (units): Comparison Nominal vs Optimistic smartphones scenar

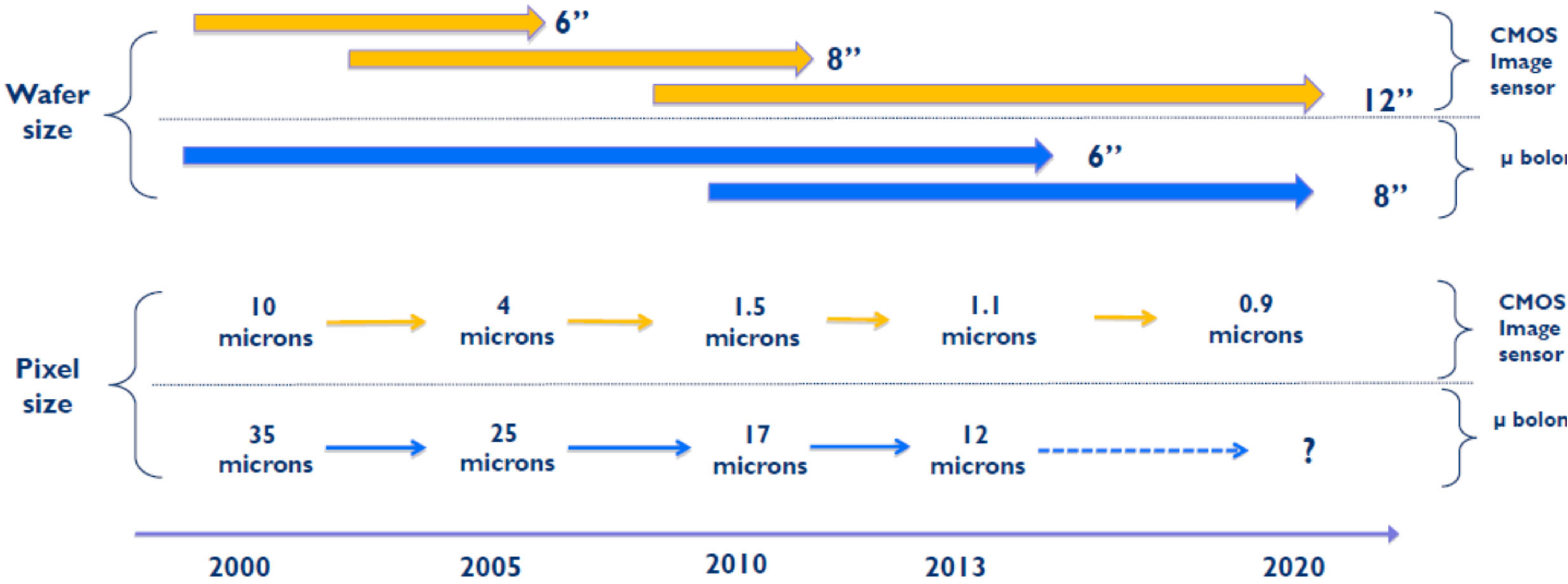
Optimistic scenario will be possible if sufficient cost reduction is achieved



	Nominal	Optimistic
Smartphone IR product sold	Plug in module	Plug in module and in 2019 IR camera core integrated into the phone
Smartphone price erosion	-15 %	- 44 %
Smartphone CAGR 2015-2020 in units	+ 41 %	+ 161%
Smartphone ASP 2020	$ 113	$ 14

COMPARISON WITH CMOS IMAGE SENSOR EVOLUTION (3/3)

- In 10 years, CMOS image sensor wafer surface has multiplied by four, and the pixel size divided by six!
- IR imaging pixel shrinkage is much slower with a pixel reduction by a factor of two in 10 years. Indeed, bandwidth is much more complex to manage than visible bandwidth.



HOW TO ACHIEVE A $10 CAMERA CORE ?

- With increasing market demand for Uncooled IR applications, manufacturers had to develop new cost-effective processes to increase unit production while lowering production costs, which in turn benefits market growth. This cost reduction was focused up to now at the sensor level and now is increasingly happening at the camera core level (sensor+electronics+optics) ie FLIR Lepton core. The biggest cost reduction target is for smartphone integration where cost is paramount.

- Steps to a $ 10 camera core :

- **New Applications**
- **Increased Volume**
- **Lower Price**

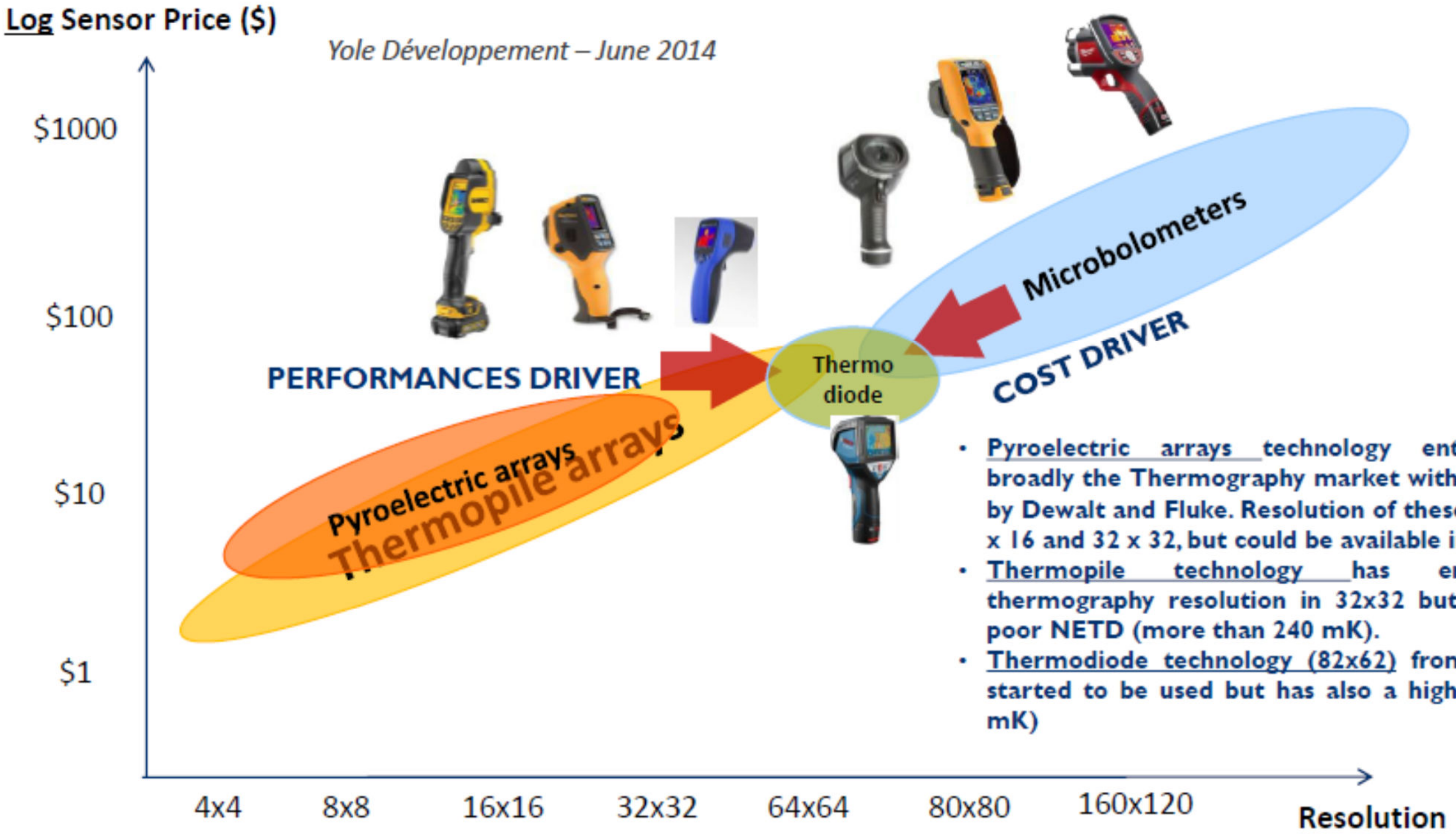
Larger Market Demand

New Manufacturing Approaches, i.e.

- **WLP/Pixel-Level Packaging**
- **WLO**
- **Low-Cost IR Window Material**
- **8" Wafer Size**
- **ASIC**
- **3D integration**

EVOLUTION FOR UNCOOLED IR IMAGERS IN THERMOGRAPHY CAMERAS

New technologies are entering the game in thermography where performance requirements are lower



- Pyroelectric arrays technology entered broadly the Thermography market with its ac by Dewalt and Fluke. Resolution of these arra x 16 and 32 x 32, but could be available in 47 x
- Thermopile technology has enterec thermography resolution in 32x32 but suffe poor NETD (more than 240 mK).
- Thermodiode technology (82x62) from Bos started to be used but has also a high NET mK)