

# Next-Generation Memory Technology and Market Trends

**Presenter:**

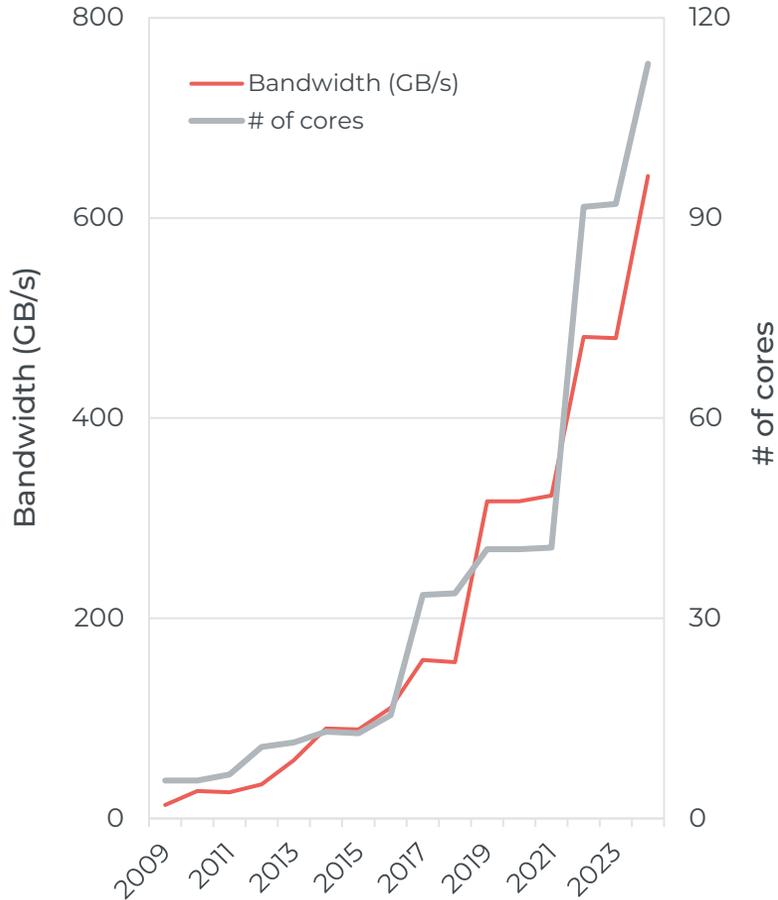
**Simone Bertolazzi, Ph.D.**

Principal Analyst at Yole Intelligence

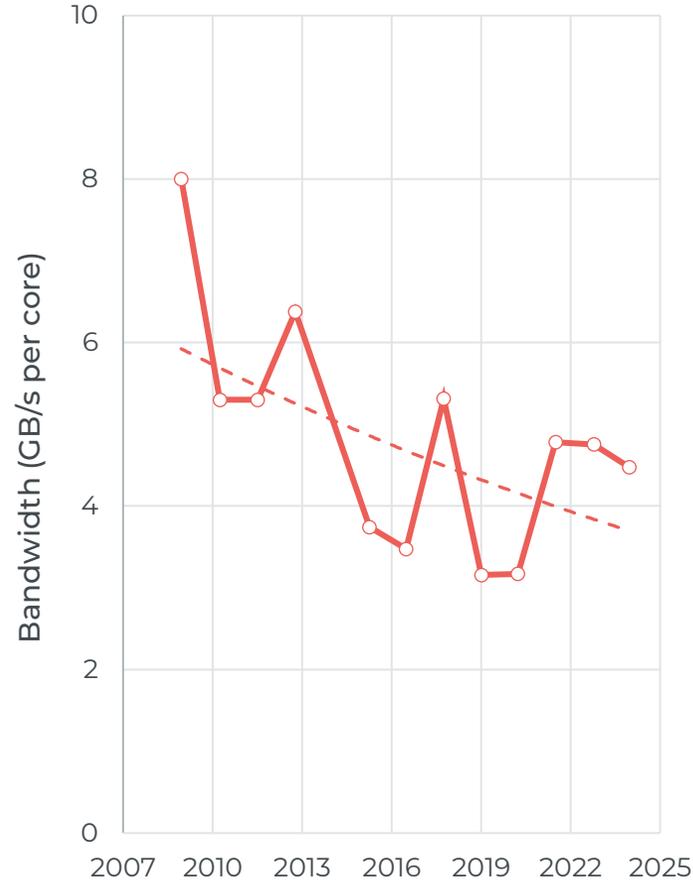
# MEMORY AND COMPUTING TECHNOLOGY LANDSCAPE

Memory is struggling to keep pace with fast-growing data generation and computing demand

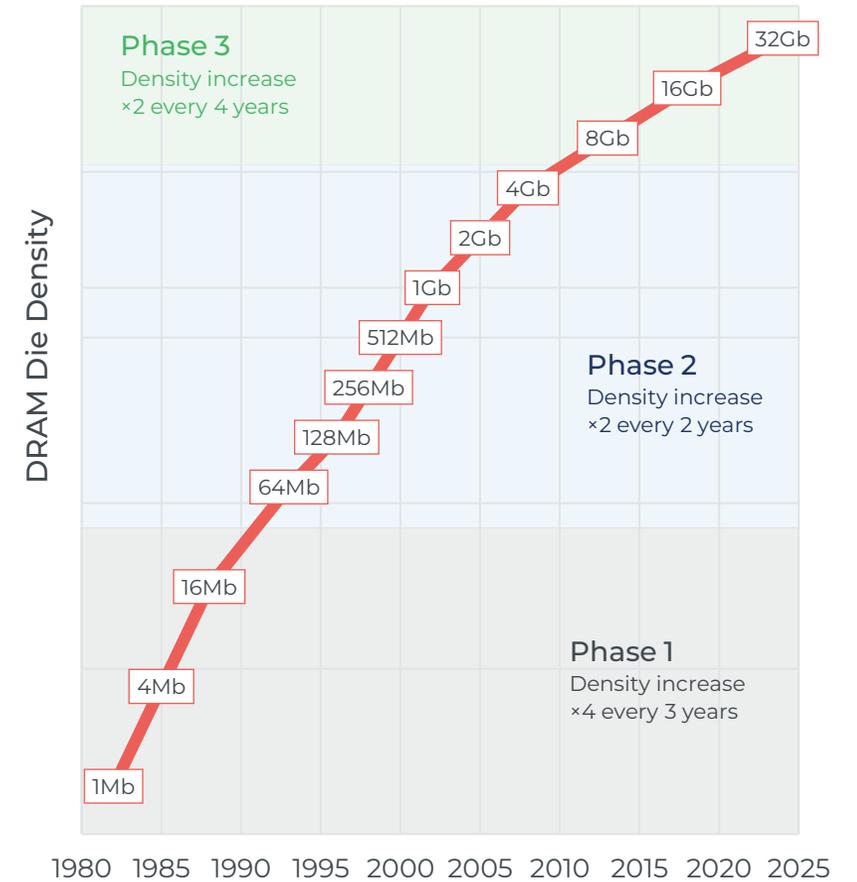
Compute demand is accelerating



Bandwidth per core is decreasing



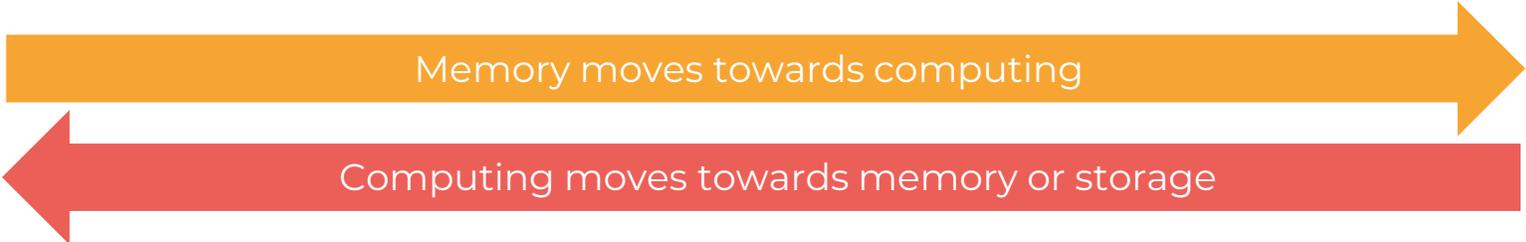
Memory content is growing but DRAM scaling has slowed down





### HBM, Chiplets, Near- or In-Memory Computing

Low latency is the most important feature. Mainly for applications requiring high bandwidth.



### DRAM-based processing in memory

**SAMSUNG**

*Samsung AXDIMM solution*

### Computational storage

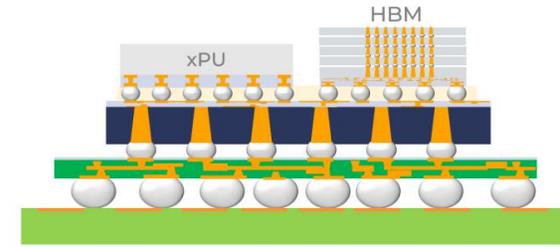
**SAMSUNG**

*Samsung computational storage drive solution*

Data is more important for the application. Mainly for data-intensive applications.

# HIGH-BANDWIDTH MEMORY (HBM)

## Product Development Overview

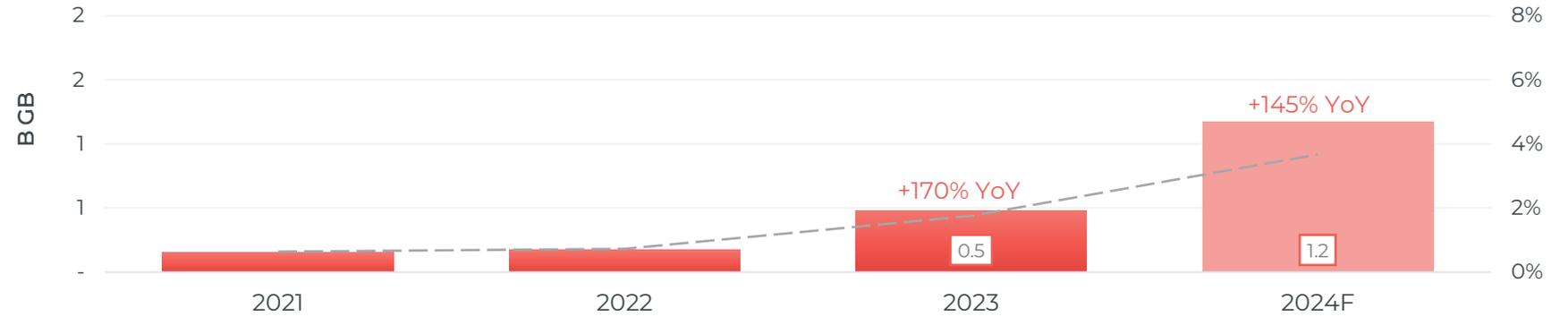


HBM generation	HBM	HBM2	HBM2E	HBM3	HBM3E	HBM4/4E (expected)
Players with market products		Flarebolt Aquabolt Aquabolt-XL (PIM)	Flashbolt 	Icebolt 	Shinebolt 	
Year of first product release	2014	2018	2020	2022 - 2023	2024	2026
Typical number of dies per stack (Main packaging approach)	4Hi (TSV & microbumps)	4-8Hi (TSV & microbumps)	4-8Hi (TSV & microbumps)	8-12Hi (TSV & microbumps)	8-12Hi (TSV & microbumps)	12-16Hi (Hybrid bonding for ≥16Hi)
Max capacity per stack	1GB	4-8GB	8-16GB	16-24GB	24-36GB	36-64GB
Die density (Typical process)	2Gb (2x)	8-16Gb (2y, 2z)	16Gb (1y, 1z) <sup>(2)</sup>	16Gb (1z)	24Gb (1a, 1b/1β)	24-32Gb (1b/1β, 1c/1γ)
Max data rate	1Gbps	2-2.4Gbps	3.2-3.6Gbps	5.6-6.4Gbps	8.0-9.8Gbps	≥ 9Gbps
Effective bus width	1,024	1,024	1,024	1,024	1,024	2,048
Max bandwidth per stack	128GB/s	205-307GB/s	460GB/s	819GB/s	1.2TB/s	≥ 2TB/s

# HIGH BANDWIDTH MEMORY (HBM) MARKET

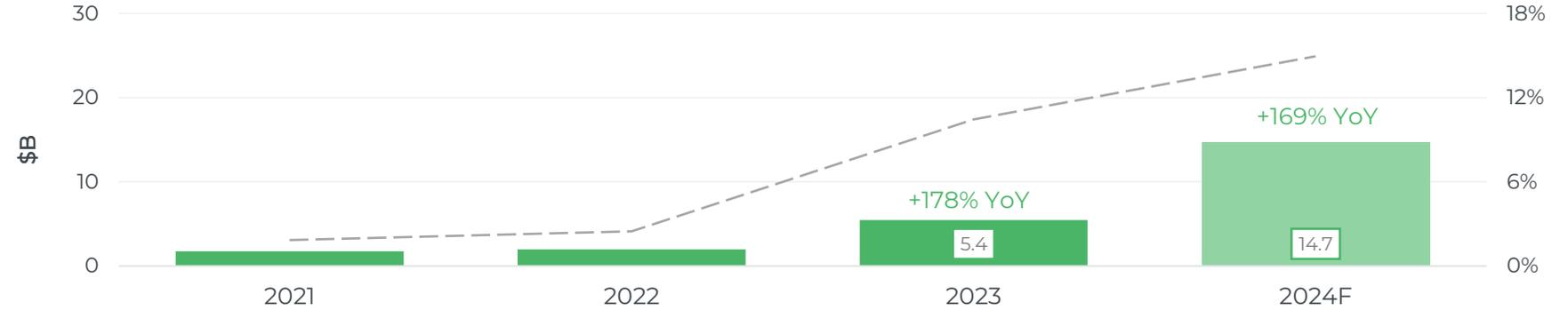
## Bit shipments (B GB)

■ HBM bit shipments (B GB)  
CAGR<sub>23-29</sub>~48%  
- - - HBM share of DRAM market (%)



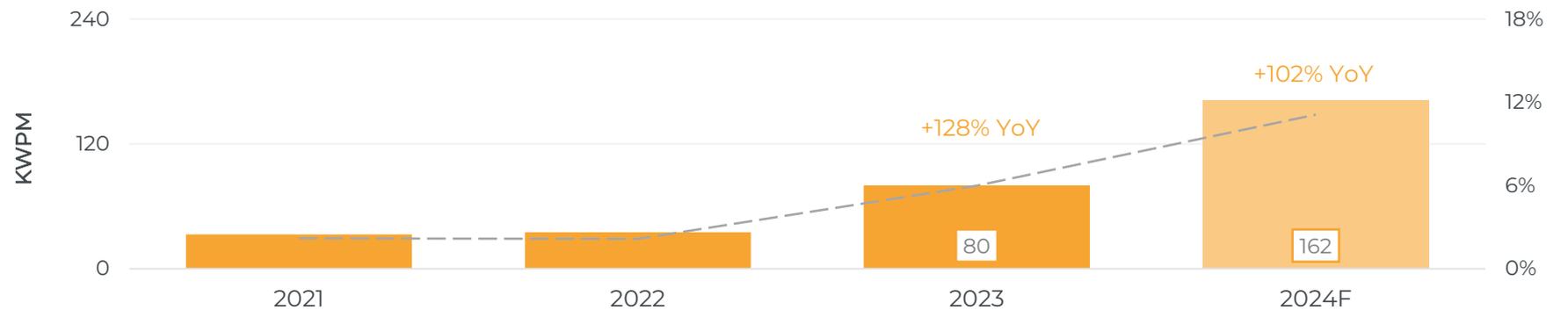
## Revenue (\$B)

■ HBM revenue (\$B)  
CAGR<sub>23-29</sub>~41%  
- - - HBM share of DRAM market (%)



## Wafer Production (K WPM)

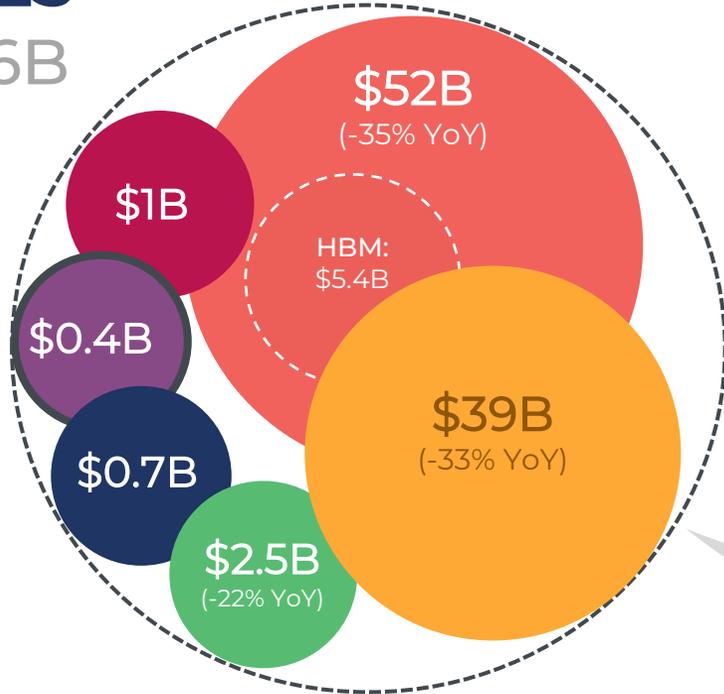
■ HBM wafer production (KWPM)  
CAGR<sub>23-29</sub>~24%  
- - - HBM share of DRAM market (%)



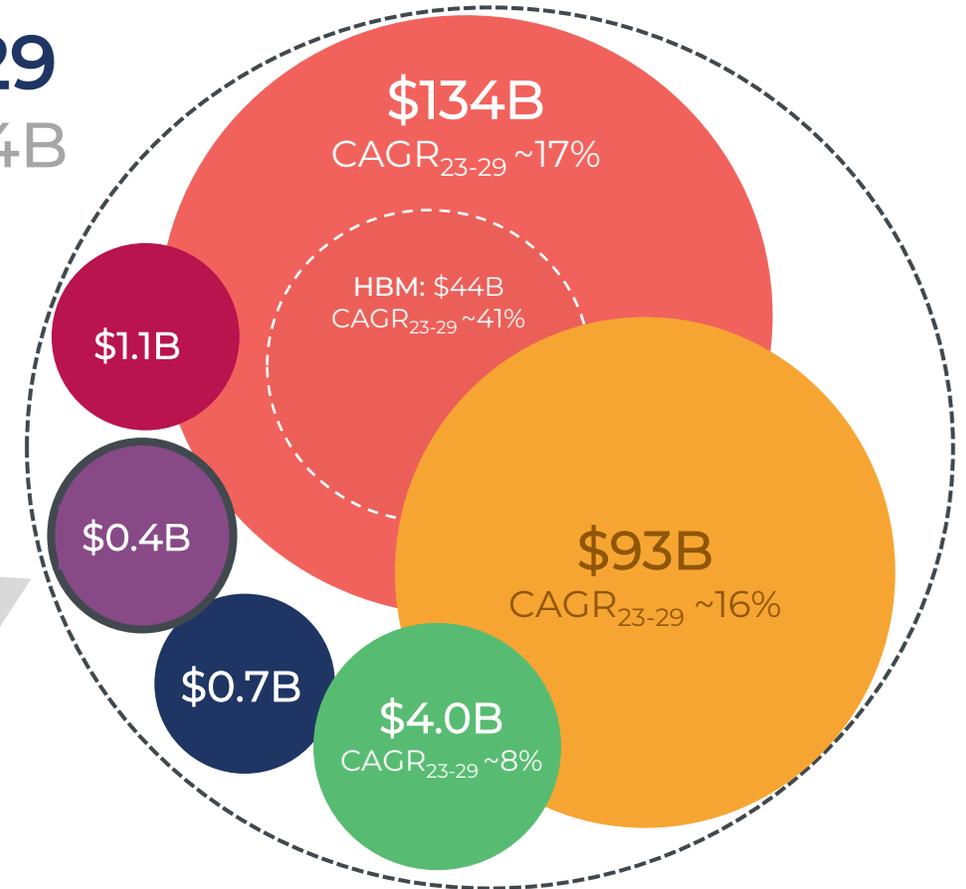
# SEMICONDUCTOR MEMORY MARKET FORECAST

## Breakdown by technologies

**2023**  
\$96B



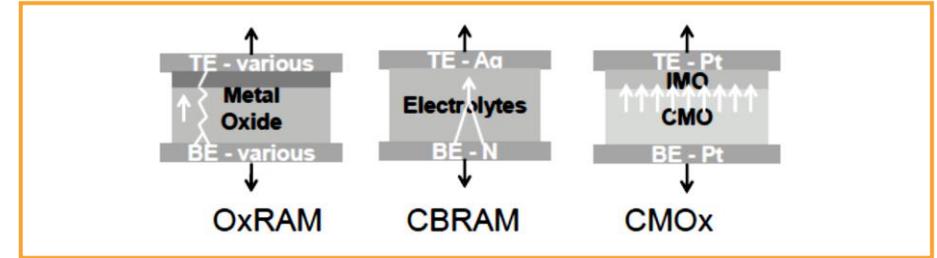
**2029**  
\$234B



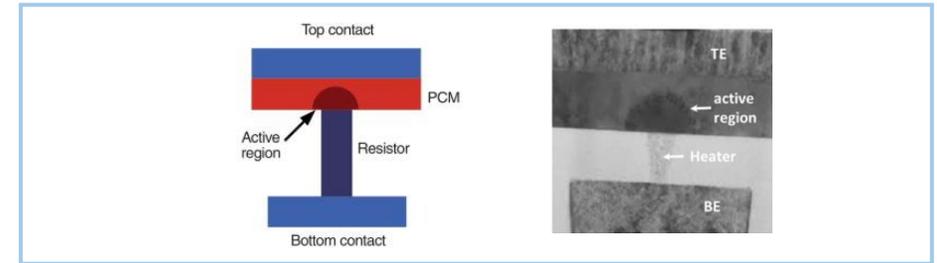
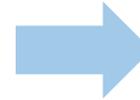
- DRAM
- NAND
- NOR
- (NV)SRAM / FRAM
- Emerging NVM
- EEPROM and other

# EMERGING NVM TECHNOLOGIES AND PLAYERS

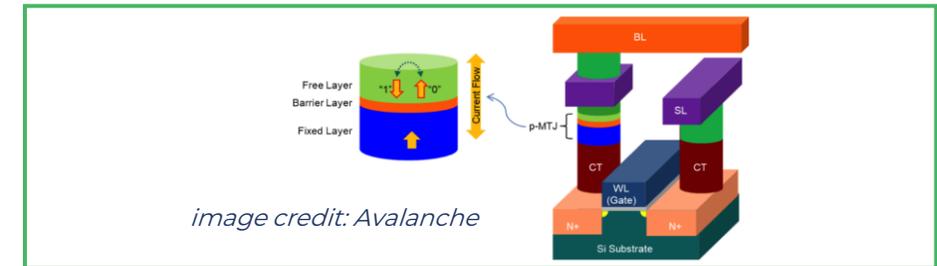
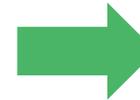
## RRAM: resistive RAM



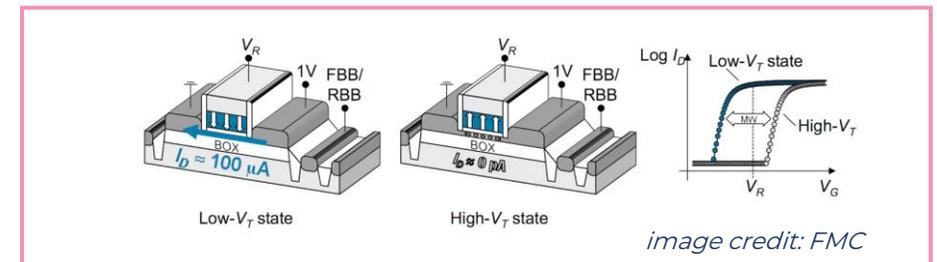
## PCM: phase-change memory



## STT-MRAM: spin-transfer torque magnetic RAM



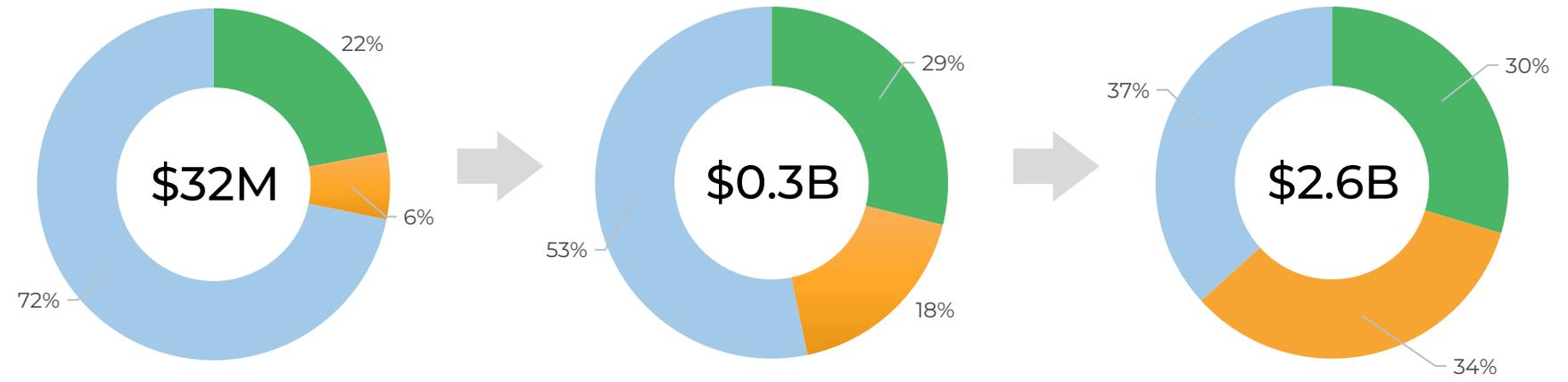
## High-κ oxide FRAM: ferroelectric RAM



# 2023-2029 EMBEDDED EMERGING NVM MARKET EVOLUTION

## Revenue (US\$M) by technology

- eMRAM
- eRRAM
- ePCM



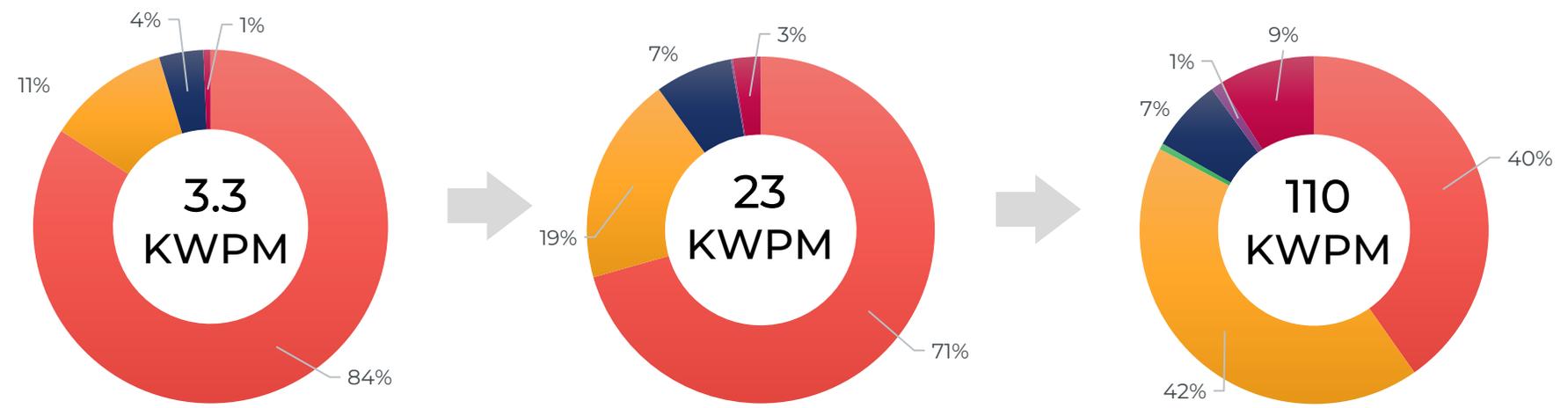
Revenue CAGR<sub>23-29</sub> ~ 109%

## Wafer Volume (KWPM) by application

- Analog IC
- MCU
- CIS (buffer RAM)
- ASIC and other
- Cache memory for (x)PU (incl. chiplet)
- Near- and in-memory computing



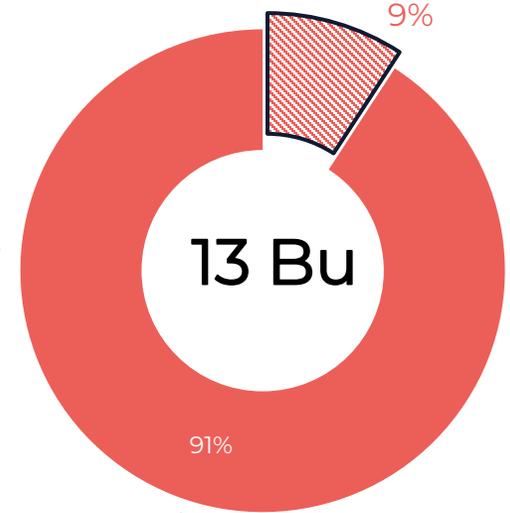
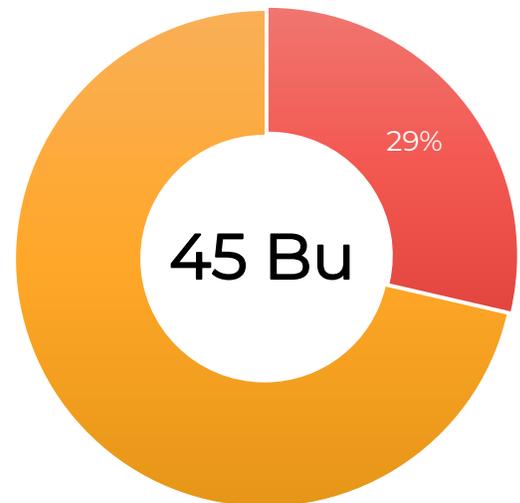
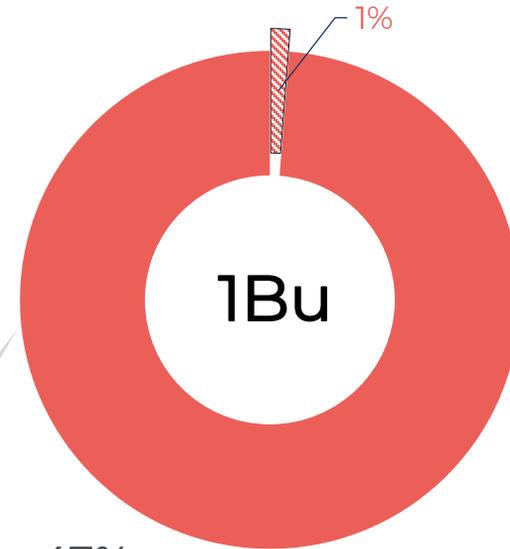
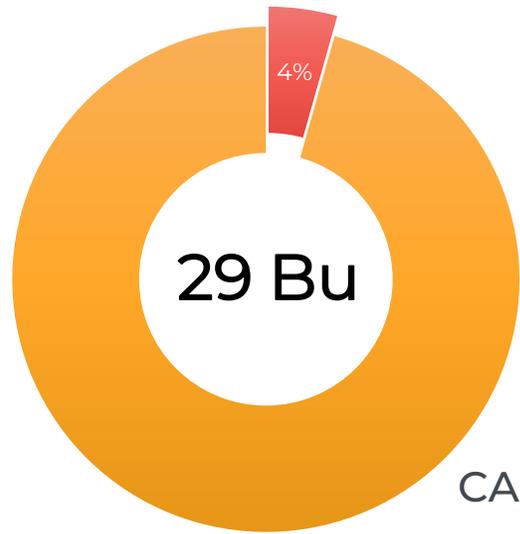
Wafer Volume CAGR<sub>23-29</sub> ~ 80%



# MCU MARKET TRENDS – PENETRATION OF EMERGING NVM

MCU Market Volume (All MCUs)

MCU Market Volume (MCUs ≤28nm)



- MCU ≤ 28 nm  
CAGR<sub>23-29</sub> ~ 47%
- MCU > 28 nm

- ▨ Emerging eNVM  
CAGR<sub>23-29</sub> ~ 105%
- eFlash or NVM-less

CAGR<sub>23-29</sub> ~8%

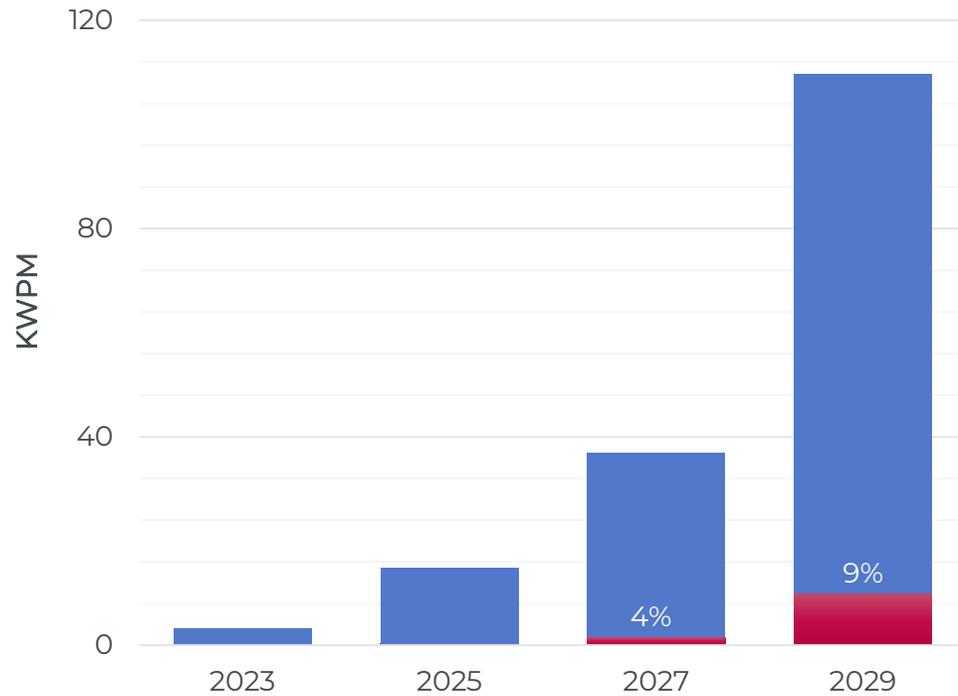
CAGR<sub>23-29</sub> ~47%



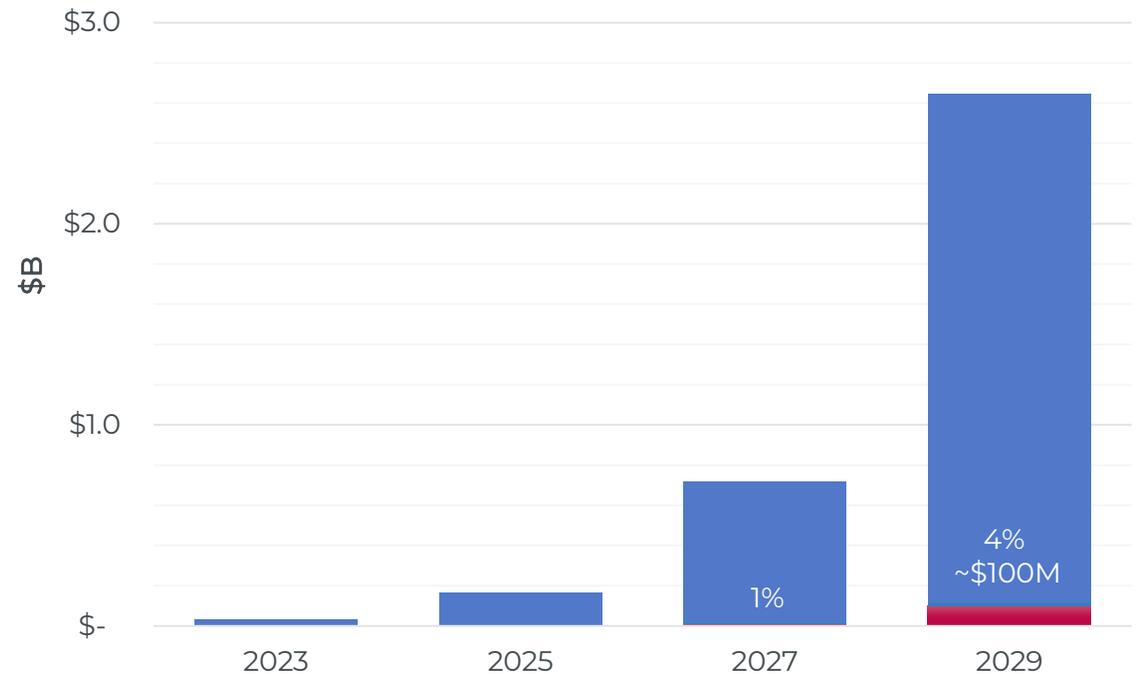
# NEAR- AND IN-MEMORY COMPUTING – PENETRATION OF EMERGING NVV

Market opportunity for embedded emerging NVM (ePCM, eRRAM, eMRAM)

**Embedded Emerging NVM Market**  
Wafer Volume (KWPM)



**Embedded Emerging NVM Market**  
Revenue (\$M)

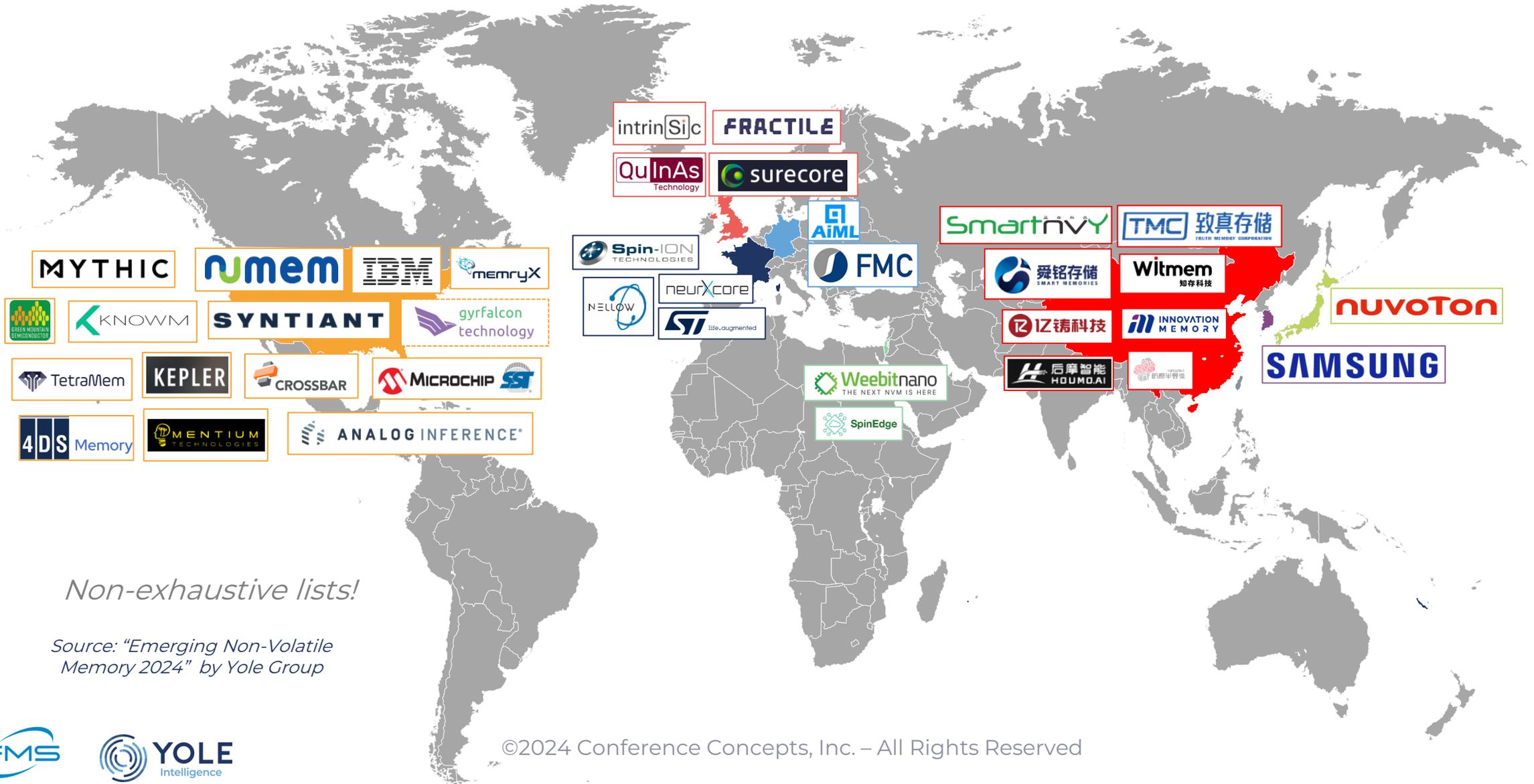


Resistive switching technologies with IMC architecture are expected to lead the market with more than 50% wafer volume share in 2029

- Near- and in-memory computing
- Other embedded applications

# NEAR- AND IN-MEMORY COMPUTING

The number of players focusing on edge-AI solutions based on embedded NVMs keeps growing!



*Non-exhaustive lists!*

Source: "Emerging Non-Volatile Memory 2024" by Yole Group

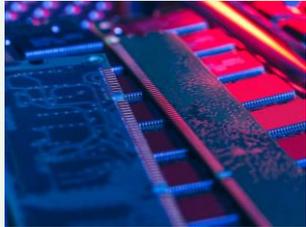
- Generative AI and high-performance computing (HPC) applications require ever-increasing memory bandwidth. HBM is the workhorse memory technology for AI workloads in data centers.
- The HBM market is soaring. Revenues are anticipated to climb from \$5.4B in 2023 to >\$14B in 2024, and future growth is poised to remain robust (CAGR<sub>23-29</sub> ~41%).
- Embedded emerging NVM technologies (MRAM, PCM, and RRAM) continue to gain momentum for code and data storage in microcontrollers (MCUs) and low-power SoCs ASICs for IoTs, wearables, and edge-AI devices.
- The lack of a cost-competitive eFlash solution at geometries smaller than 28nm is the main reason driving top foundries and IDMs to invest actively in embedded emerging NVM technologies to be integrated at nodes  $\leq$  28nm.
- We forecast that ~1.2 billion MCUs will incorporate embedded emerging NVMs in 2029 (i.e., ~9% of MCUs  $\leq$  28nm) .
- Emerging NVMs are being heavily investigated for low-power edge AI-devices with near- and in-memory computing (NMC / IMC) architectures. These technologies are progressively gaining maturity and are expected to start penetrating the edge-AI market from 2027.

# ACKNOWLEDGEMENTS

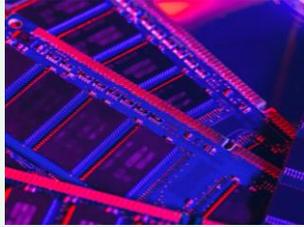
## Memory and Computing Analysts at Yole Group

<b>John Lorenz</b> Principal Analyst, Memory (DRAM)	<b>Thibaut Grossi</b> Senior Analyst, Memory (NAND)	<b>Simone Bertolazzi, PhD</b> Principal Analyst, Memory	<b>Josephine Lau</b> Senior Analyst, Memory	<b>Tom Hackenberg</b> Principal Analyst, MCU	<b>Adrien Sanchez</b> Senior Analyst	<b>Belinda Dube</b> Senior Analyst, Integrated Circuits	<b>Ying-Wu Liu</b> Analyst, Integrated Circuit
 <ul style="list-style-type: none"> <li>› <b>Experience</b> 15+ years in memory and computing (Micron Technology)</li> <li>› <b>At Yole</b> DRAM, processors</li> <li>› <b>Education</b> Bachelor of Science in Mechanical Engineering from the University of Illinois Urbana-Champaign (USA), with a focus on MEMS devices.</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 15+ in Electronic Procurement (Semiconductor, PC BA and software)</li> <li>› <b>At Yole</b> NAND</li> <li>› <b>Education</b> M.Sc. in Electronic and Computing science</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 15 years in emerging semiconductor devices</li> <li>› <b>At Yole</b> Memory</li> <li>› <b>Education</b> Ph.D. in Nanoelectronics (EPFL, Switzerland) M.Sc. in Micro &amp; Nanotechnology M.Sc. in Engineering Physics</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 10+ years in memory and storage industry</li> <li>› <b>At Yole</b> Memory</li> <li>› <b>Education</b> Bachelor of business marketing Passed chartered financial analyst level</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 20+ years in computing and microcontrollers</li> <li>› <b>At Yole</b> Computing</li> <li>› <b>Education</b> BSEE/BSECE from the University of Texas at Austin specializing in Processors and FPGAs.</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 5+ years in computing and AI</li> <li>› <b>At Yole</b> Computing</li> <li>› <b>Education</b> M.Sc. in Computing Science and AI M.Sc. in Business</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 5+ years in computing, memory and advanced packaging</li> <li>› <b>At Yole SystemPlus</b> Memory, Computing &amp; Advanced Packaging</li> <li>› <b>Education</b> M.Sc. in Nanoelectronics and Nanotechnology M.Sc. Electronics &amp; Instrumentation</li> </ul>	 <ul style="list-style-type: none"> <li>› <b>Experience</b> 8 years in the semiconductor industry</li> <li>› <b>At Yole SystemPlus</b> Computing</li> <li>› <b>Education</b> M.Sc. in theoretical physics M.Sc. in Integration, Security and Trust in Embedded systems</li> </ul>

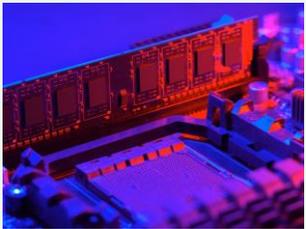
## Market Monitors and Reports



[NAND Market Monitor](#)



[DRAM Market Monitor](#)



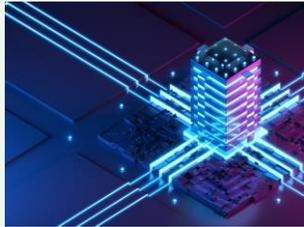
[Next-generation DRAM 2024 – Focus on HBM and 3D DRAM](#)



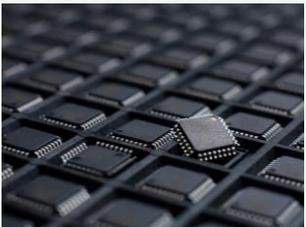
[Status of the Memory Industry 2024](#)



[Neuromorphic Computing, Memory and Sensing 2024](#)



[Emerging Non-Volatile Memory 2024](#)



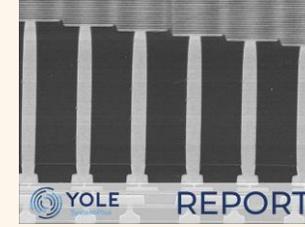
[Status of the Microcontroller Industry 2023](#)

*[2024 edition coming soon](#)*



[Memory-Processor Interface 2023 - Focus on Compute Express Link \(CXL\)](#)

## Technology, Process and Cost Reports



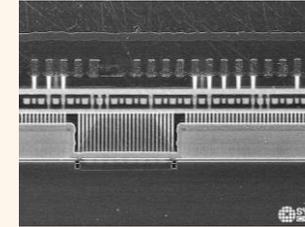
[YMTC 232-layer 3D NAND Memory](#)



[16Gb DDR5 DRAM Memory from Micron](#)



[Everspin Technologies Latest STT-MRAM in 28nm](#)



[LPDDR5 Memory Comparison](#)

*[LPDDR5X Memory Comparison coming soon](#)*

# Thank you for your attention

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