

# Emerging Non-Volatile Memory

## A 2023 Market Update

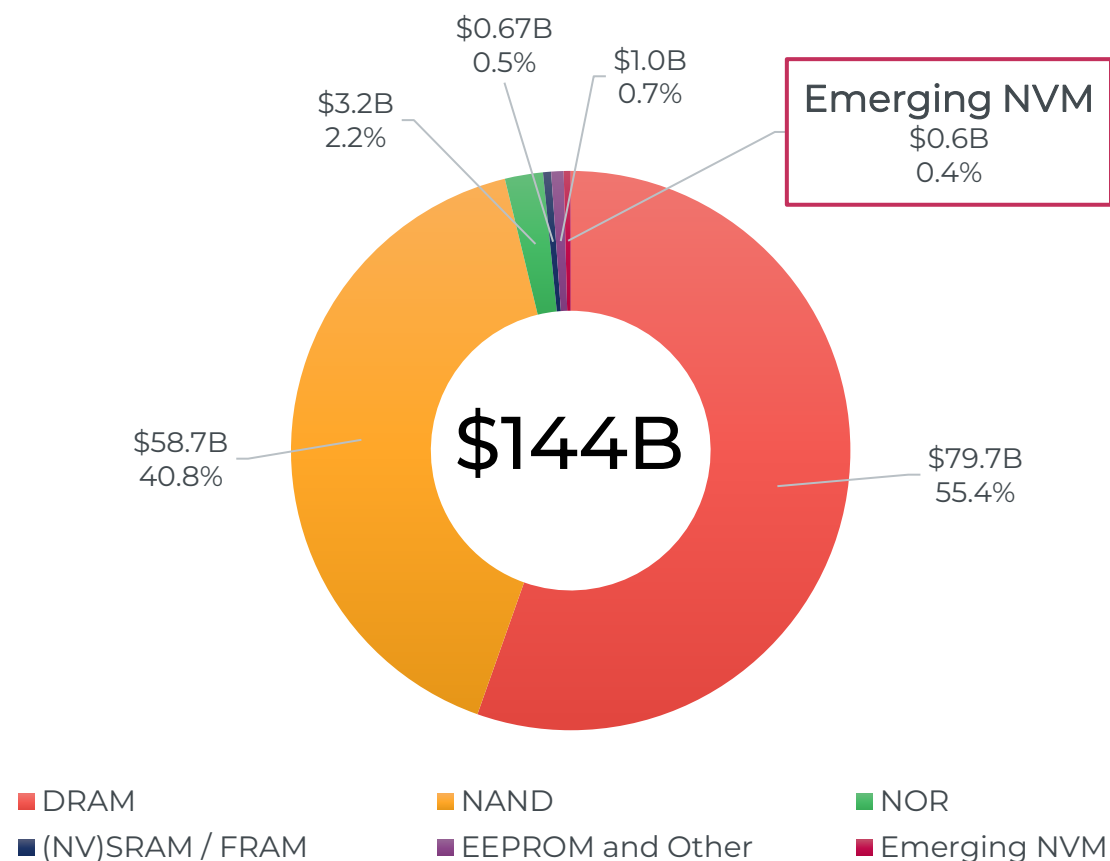
**Presenter:**

**Simone Bertolazzi, Ph.D.**

Principal Technology and Market Analyst at Yole Intelligence

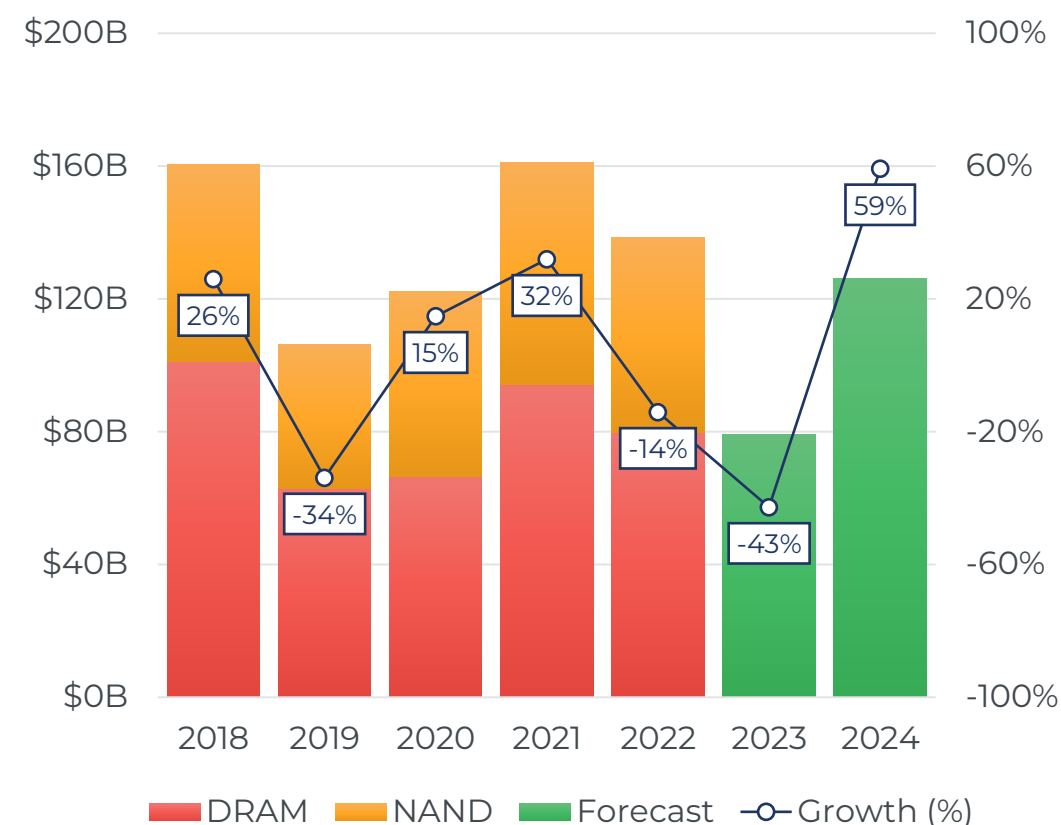
# Stand-Alone Memory Market – Overview

## 2022 memory market - breakdown by technology



*\*Note: Stand-alone memory revenues include chips and wafers, as well as memory modules and solid-state drives sold by IDM memory companies.*

## NAND and DRAM market evolution



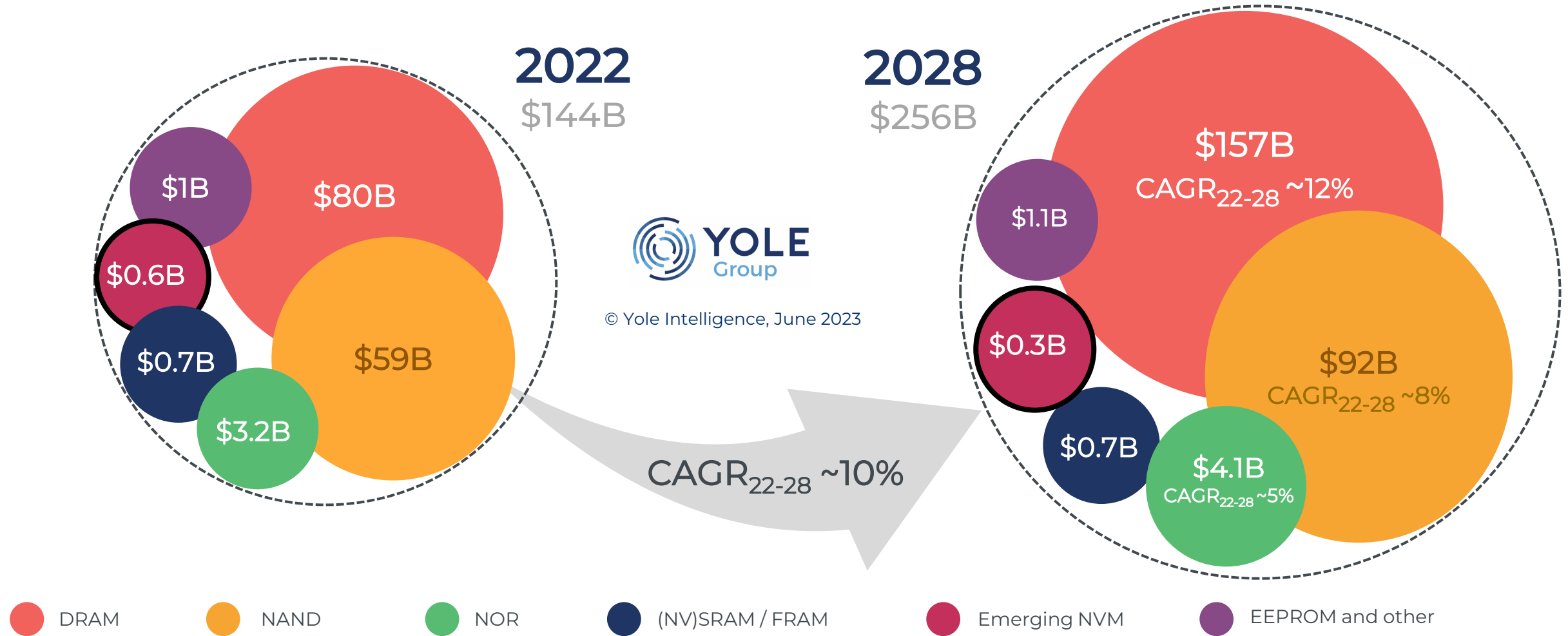
Source: "Status of the Memory Industry 2023" report by Yole Intelligence

# 2022-2028 Stand-Alone Memory Market Evolution

## Breakdown by technology



Flash Memory Summit



Source: "Status of the Memory Industry 2023" report by Yole Intelligence

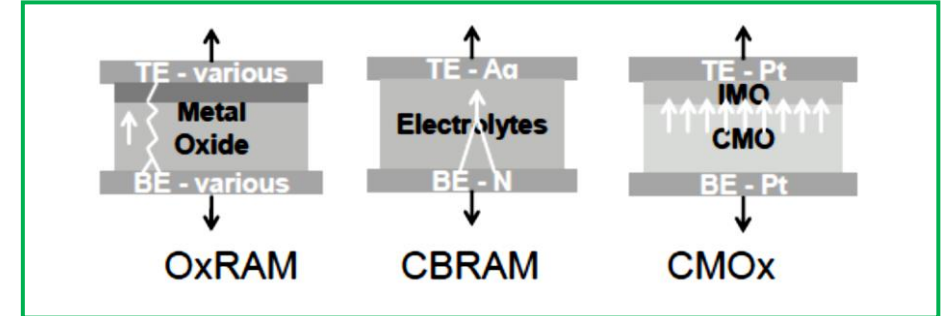
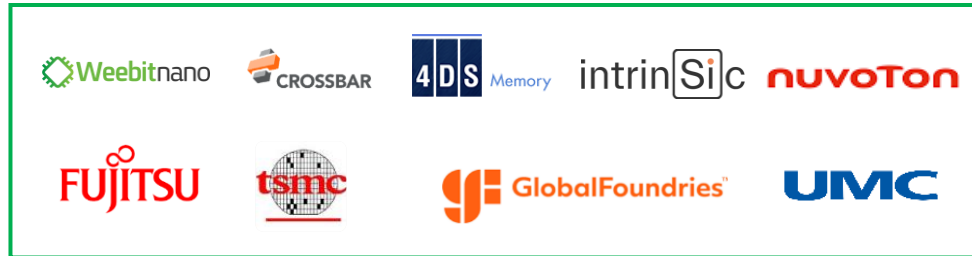
# Emerging NVM – Key Players and Technologies

*Non-exhaustive lists*

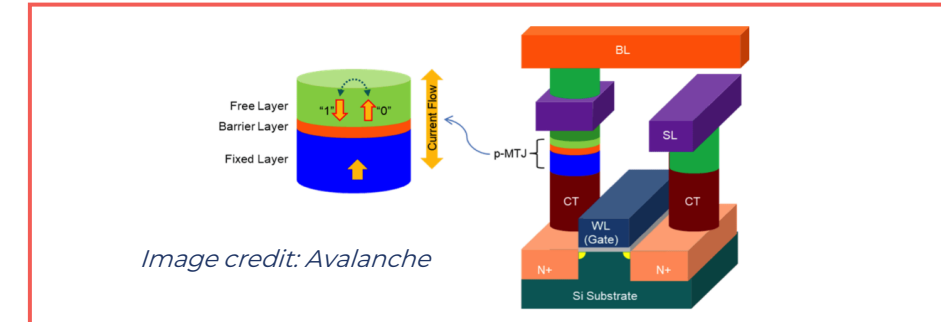


Flash Memory Summit

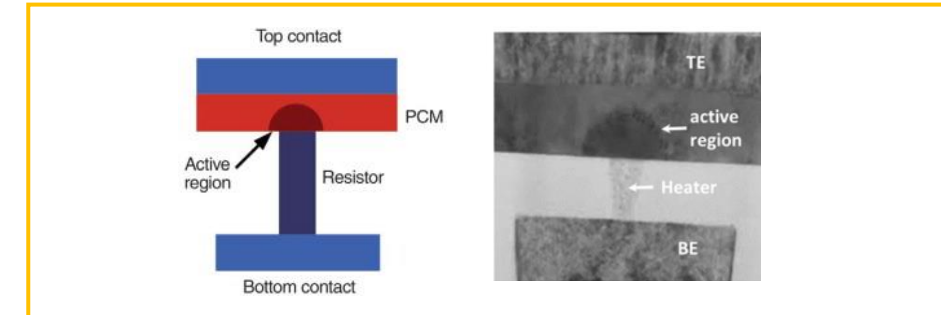
## RRAM: Resistive Random-Access Memory



## STT-MRAM: Spin-Transfer Torque Magnetic RAM



## PCM: Phase-Change Memory



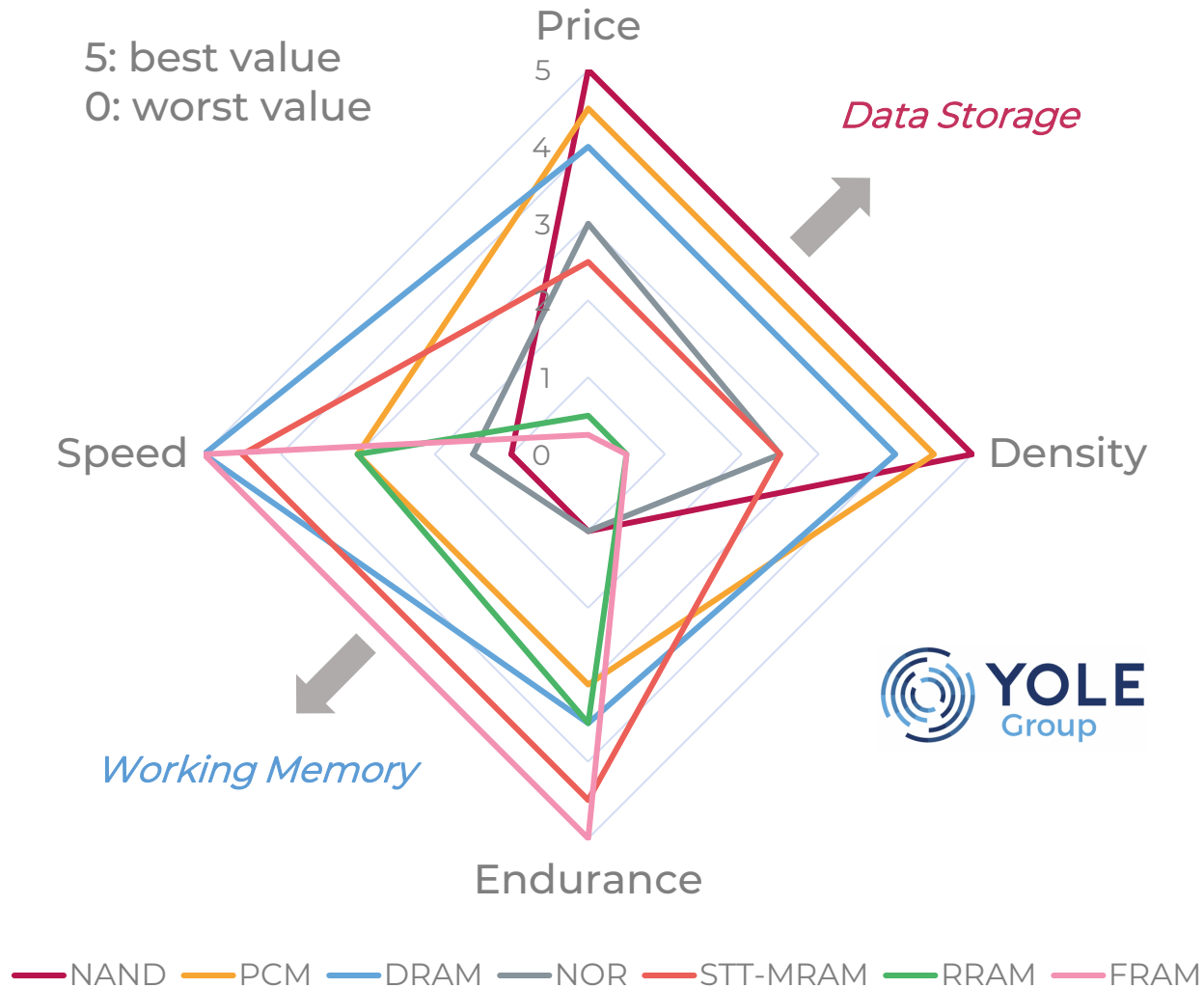
In July 2022, Intel announced winding down the Optane memory business. As of Q2-2023, neither Micron nor Intel is manufacturing or promoting 3D XPoint technology.

# Emerging NVM – Key Players and Technologies

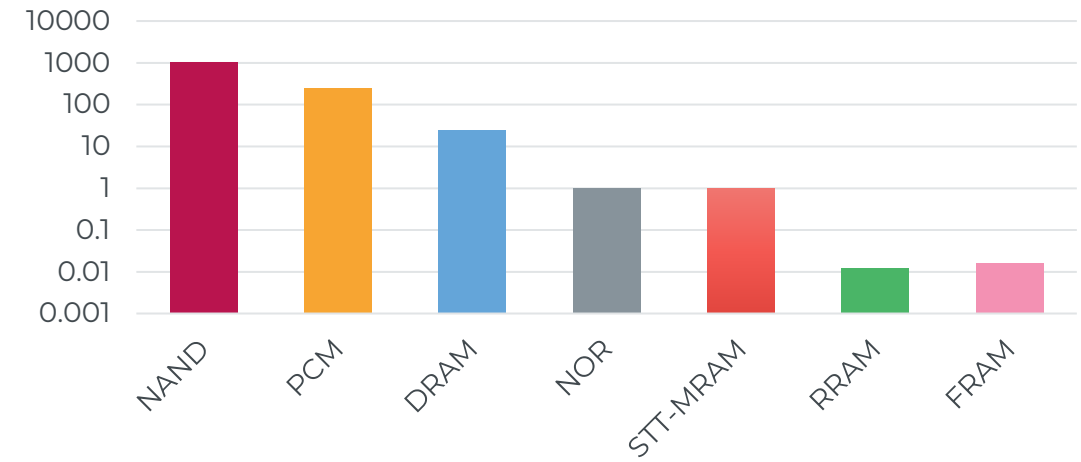
## Price and performance in commercial stand-alone products



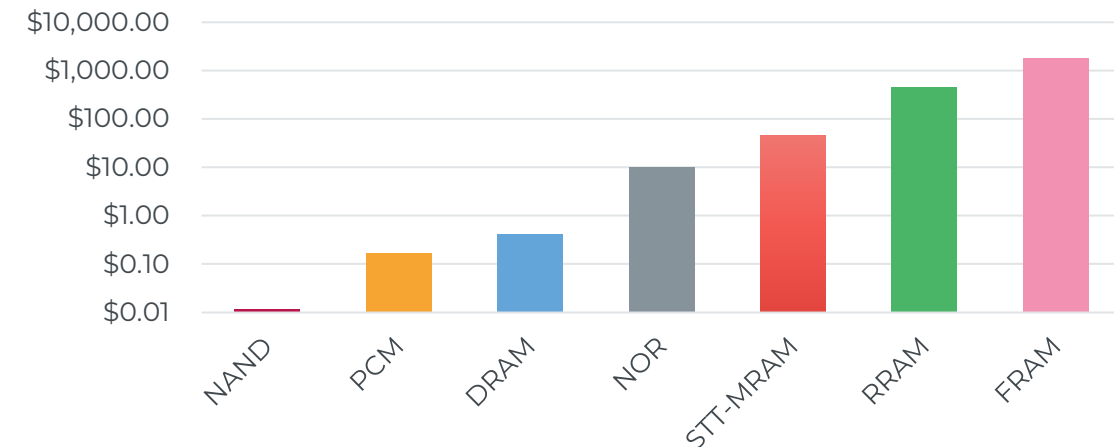
Flash Memory Summit



2022 Density Position  
(Max. values. Gb per die)



2022 Price Position (\$/Gb)

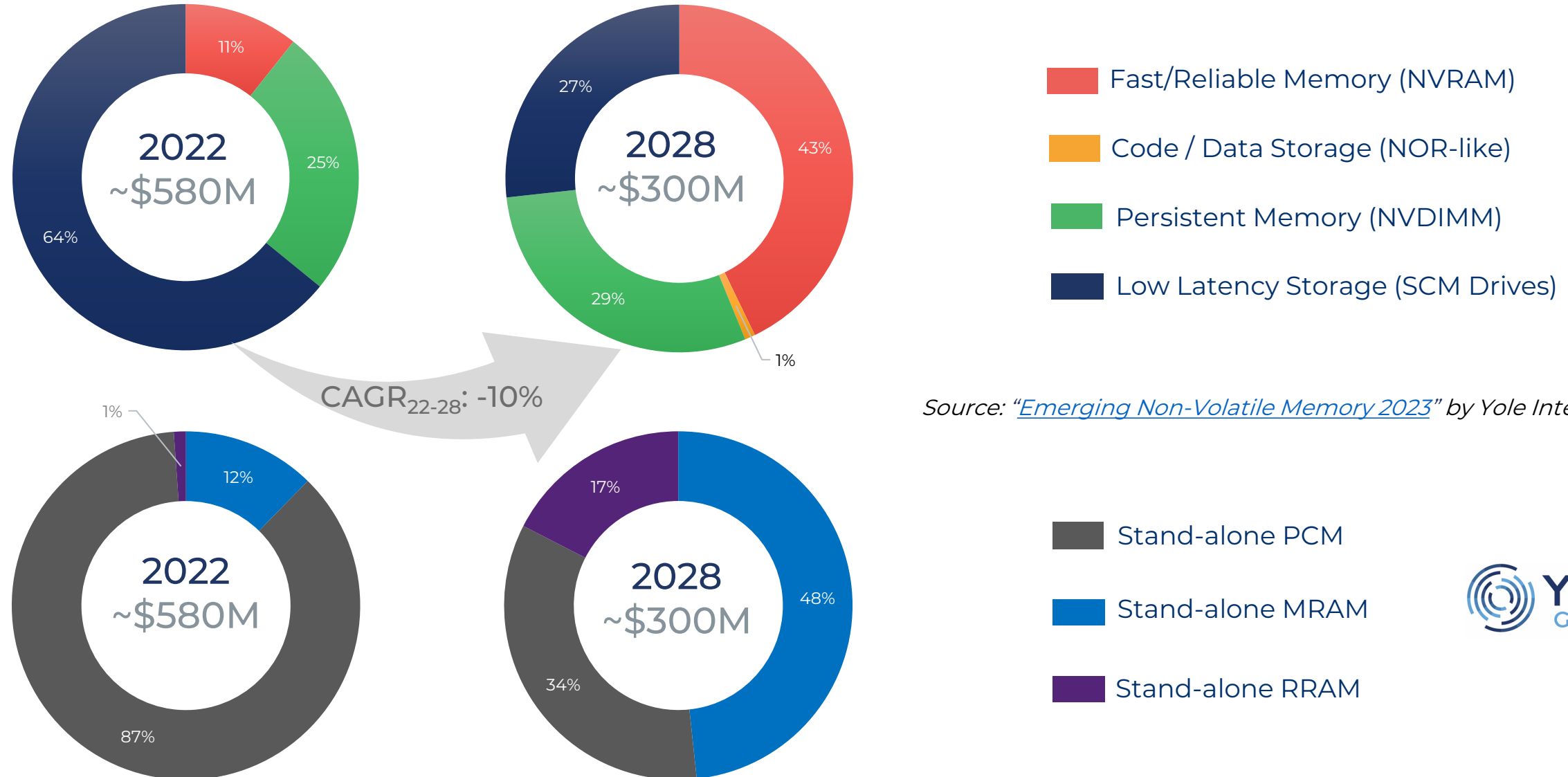


Source: "Emerging Non-Volatile Memory 2023" report by Yole Intelligence

# 2022-2028 Stand-Alone Emerging NVM Market



Flash Memory Summit



Source: "[Emerging Non-Volatile Memory 2023](#)" by Yole Intelligence

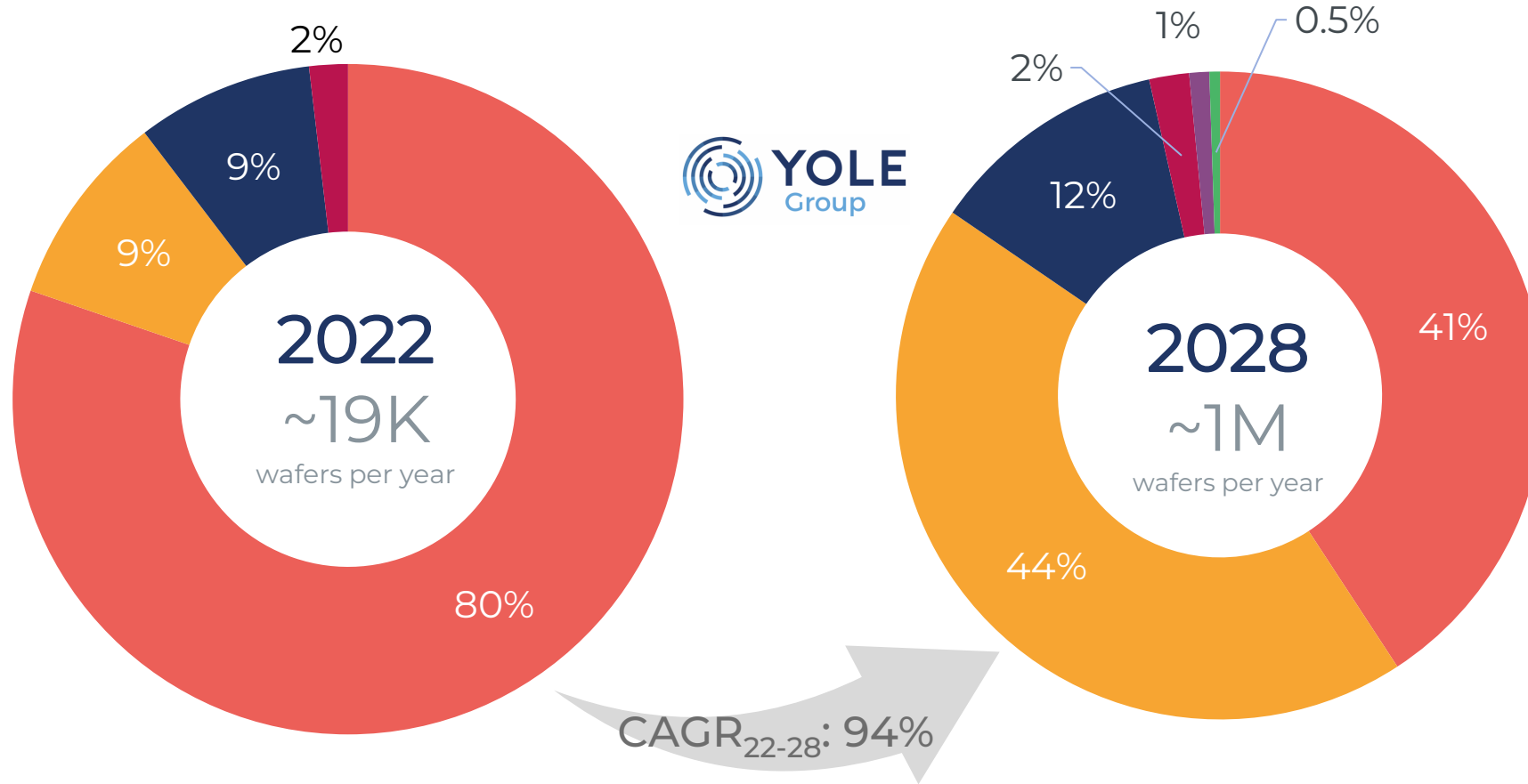


# 2022-2028 Embedded Emerging NVM Market

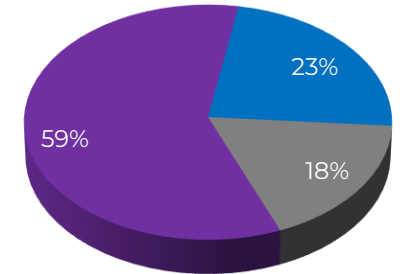
## Wafer Volume Evolution (12" equivalent)



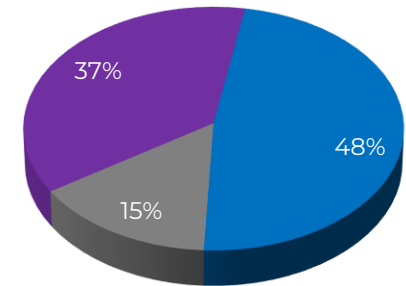
Flash Memory Summit



2028 Wafer Mix



2028 Revenue Mix (~\$2.7B)








■ eMRAM ■ ePCM ■ eRRAM

- NVM for Analog IC
- NVM for ASIC and Other
- NVM for CIS (Buffer RAM)
- NVM for Cache Memory for (x)PU
- NVM for MCU
- NVM for Near- and In- Memory Computing

# Embedded Emerging NVM Players

## Overview of strategic alliances towards mass adoption

- Automotive applications will fuel the market growth of embedded emerging NVM from ~2025

Foundry / IDM					
RRAM Players	<p>Bulk 28/22nm</p> <p>First auto MCU adopter:</p> <p> @28nm</p>	<p></p> <p>22nm FD-SOI <sup>(1)</sup></p>		<p></p> <p>Bulk 28 / 22nm</p>	
(STT-)MRAM Players	<p>Bulk 22nm</p> <p>FinFET 16/12 nm</p> <p>First auto MCU adopter:</p> <p> @16nm</p>	<p></p> <p>22nm FD-SOI</p> <p>FinFET 12nm</p>	<p></p> <p>28nm FD-SOI</p> <p>FinFET 14nm</p>	<p></p> <p>Bulk 28/22nm</p>	
PCM Players		Non-exhaustive lists			<p>FD-SOI</p> <p>28nm / 18nm <sup>(2)</sup></p> <p>First auto MCU adopter:</p> <p> @28nm</p>

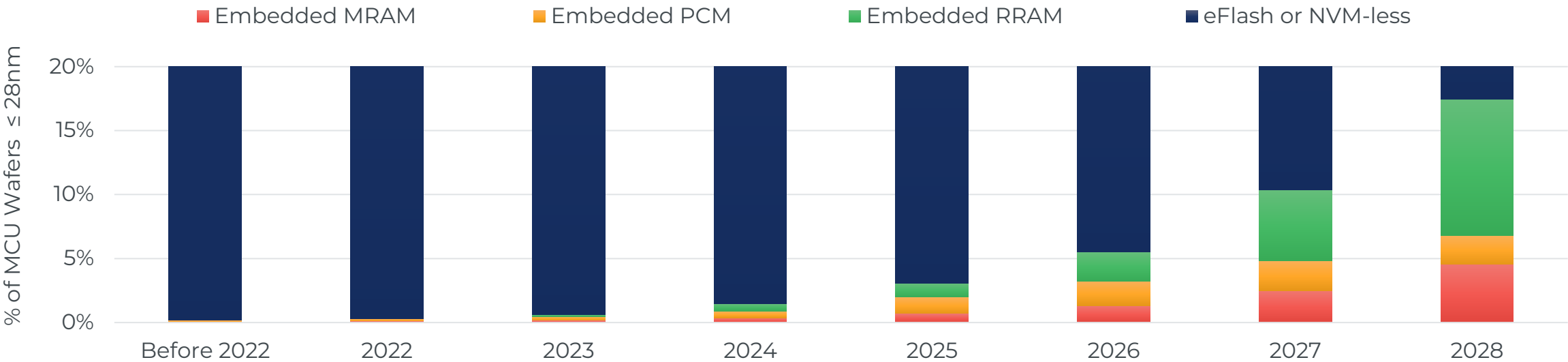
● Production ready    ● In development

Notes: (1) GlobalFoundries acquired CBRAM from Renesas in early 2023. (2) In collaboration with Samsung Foundry for 18nm.

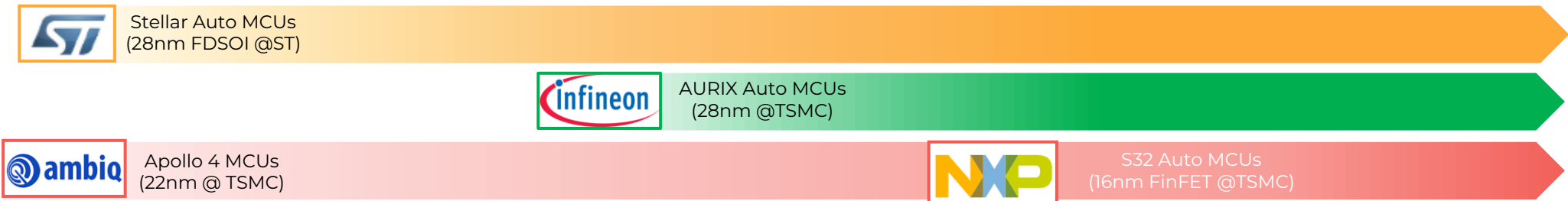


# Embedded Emerging NVM for Microcontrollers

Focus on MCU wafers manufactured at nodes  $\leq 28\text{nm}$ \* – Breakdown by NVM technology (%)



Timeline  
for key MCU  
suppliers



\*MCUs wafers manufactured at 28nm account for ~1% the total MCU wafer volume in 2022 (i.e., 500K out of 50M 12" equivalent wafers per year).

Sources: [“Emerging Non-Volatile Memory 2023”](#) and [“MCU Market Monitor”](#) by Yole Intelligence

# New Emerging NVM Technologies and Players



Flash Memory Summit

- New memory types are currently in R&D, such as ferroelectric technologies (e.g., FeFET, FTJ), Spin Orbit Torque (SOT) MRAM, Voltage Controlled Magnetic Anisotropy (VCMA) MRAM, Nanotube RAM (NRAM), Correlated Electron RAM (CeRAM), and more recently ULTRARAM based on a triple-barrier resonant-tunneling (TBRT) structure.

Novel Ferroelectric Memories	SOT-MRAM	VCMA-MRAM	CeRAM	NRAM	ULTRARAM
    	     	  			

Non-exhaustive lists

# Summary & Outlook



- The exit of Intel from the Optane business has dramatically changed the market perspectives for **stand-alone emerging NVM**.
  - If no new **100Gb-class technologies** will be introduced in the coming years, the stand-alone emerging memory market will be limited to less than \$300M.
  - The **Compute Express Link (CXL)** interface with support for persistent memory will be a sweet spot for connecting stand-alone emerging memory technologies.
- Prospects remain bright for **embedded emerging NVM**
  - The MCU market segment is taking off driven by ongoing technology migrations towards nodes smaller than 40nm.
  - The adoption of ePCM (28nm FDSOI) by STMicroelectronics, eRRAM (28nm at TSMC) by Infineon, and eMRAM (16nm FinFET at TSMC) by NXP for automotive applications confirms the growing maturity, as well the sound dynamics and prospects for embedded emerging NVM.
  - By 2028 ~1M wafers (12" equivalent) with embedded emerging NVM (ePCM, eMRAM or eRRAM) will be shipped in a market worth ~\$2.7B.

# Acknowledgements – Yole’s Memory Team

<b>Walt Coon</b> VP of NAND and Memory Research	<b>Mike Howard</b> VP of DRAM and Memory Research	<b>Simone Bertolazzi, PhD</b> Principal Technology and Market Analyst - Memory	<b>Thibault Grossi</b> Senior Technology and Market Analyst - Memory	<b>Diego Alfaro, PhD</b> Technology and Market Analyst - Memory	<b>Belinda Dube</b> Senior Technology and Cost Analyst – Memory & Integrated Circuits
					
<ul style="list-style-type: none"><li>› <b>Experience</b> 15+ years in memory<ul style="list-style-type: none"><li>› <b>At Yole</b> NAND</li></ul></li><li>› <b>Education</b> MBA Bachelor of Science in Chemical Engineering Bachelor of Arts in Finance</li></ul>	<ul style="list-style-type: none"><li>› <b>Experience</b> 15+ years in memory<ul style="list-style-type: none"><li>› <b>At Yole</b> DRAM</li></ul></li><li>› <b>Education</b> MBA Bachelor of Science in Chemical Engineering Bachelor of Arts in Finance</li></ul>	<ul style="list-style-type: none"><li>› <b>Experience</b> 15 years in emerging semiconductor devices<ul style="list-style-type: none"><li>› <b>At Yole</b> Memory</li></ul></li><li>› <b>Education</b> Ph.D. in Nanoelectronics M.Sc. in Micro &amp; Nanotechnology M.Sc. in Engineering Physics</li></ul>	<ul style="list-style-type: none"><li>› <b>Experience</b> 15+ in electronic procurement (semiconductor, PCBA and software)<ul style="list-style-type: none"><li>› <b>At Yole</b> Memory</li></ul></li><li>› <b>Education</b> M.Sc. in Electronic and Computing science</li></ul>	<ul style="list-style-type: none"><li>› <b>Experience</b> 5+ years in emerging semiconductor devices<ul style="list-style-type: none"><li>› <b>At Yole</b> Memory</li></ul></li><li>› <b>Education</b> Ph.D. in Nanoelectronics and Nanotechnology M.Sc. in Electronic Integrated Systems</li></ul>	<ul style="list-style-type: none"><li>› <b>Experience</b> 5+ years in memory and integrated circuits<ul style="list-style-type: none"><li>› <b>At Yole SystemPlus</b> Memory</li></ul></li><li>› <b>Education</b> M.Sc. in Nanoelectronics and Nanotechnology</li></ul>

# Yole Group Memory Products

*Non-exhaustive list*



[NAND Market Monitor](#)



[Status of the Memory Industry 2023](#)



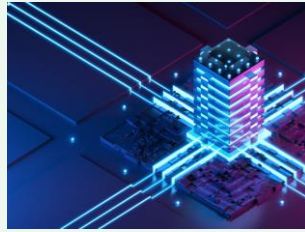
[Solid-State Drives 2023](#)



[Memory Packaging 2023](#)



[DRAM Market Monitor](#)



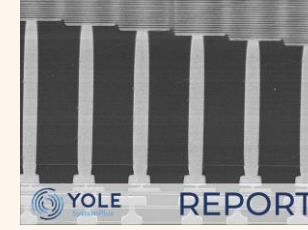
[Emerging Non-Volatile Memory 2023](#)



[DRAM Modules 2023](#)



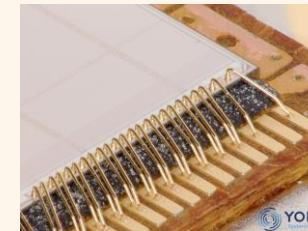
[Memory for Automotive 2022](#)



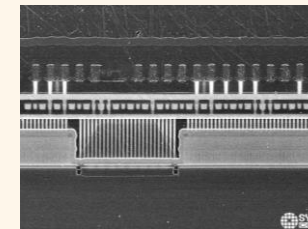
[YMTC 232-layer 3D NAND Memory](#)



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



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



[LPDDR5 Memory Comparison 2022](#)

# Thank you for your attention

Simone Bertolazzi, Ph.D.

[simone.bertolazzi@yolegroup.com](mailto:simone.bertolazzi@yolegroup.com)