

Emerging Non-Volatile Memory

A 2022 Market Update

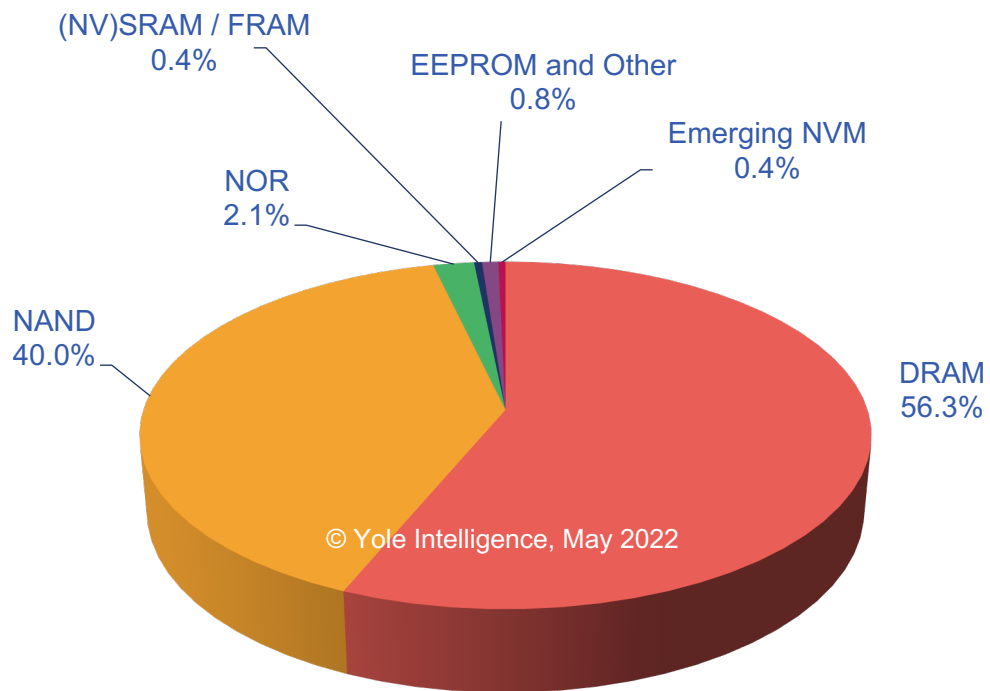
Simone Bertolazzi, Ph.D.

Senior Technology and Market Analyst

- Overview of the Memory Market
 - Established and emerging memory markets
- Emerging Non-Volatile Memory (ENVM)
 - Stand-alone ENVM – Focus on PCM, ReRAM and STT-MRAM
 - Embedded ENVM – Business and market trends
- Conclusions and Outlook

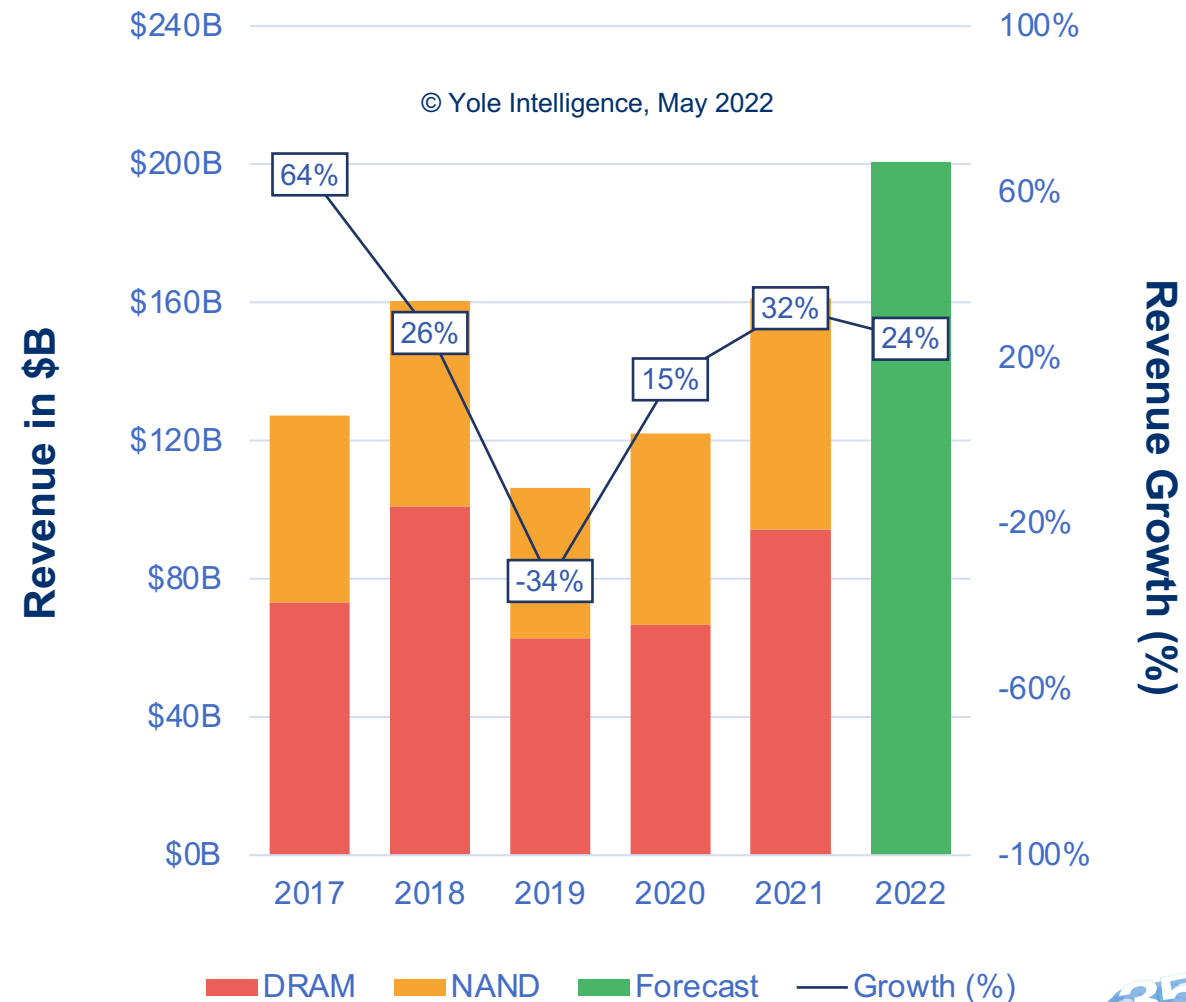
Stand-Alone Memory Market – Overview

2021 memory market - Breakdown by technology



Total stand-alone market in 2021 ≈ \$167B

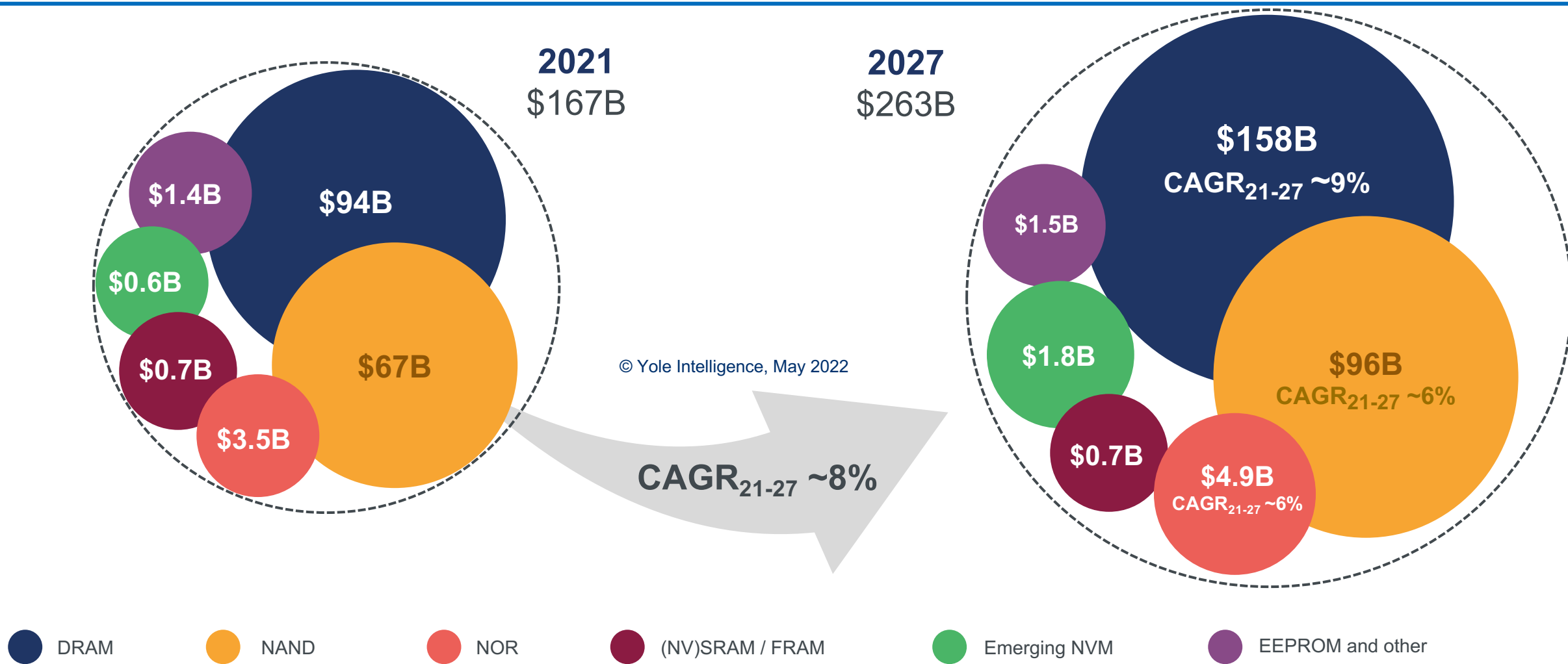
Source: "Status of the Memory Industry 2022" report by Yole Group



2021-2027 Memory Market Evolution



Flash Memory Summit



NAND and DRAM are expected to account for 36% and 60% of the 2027 memory market, respectively.

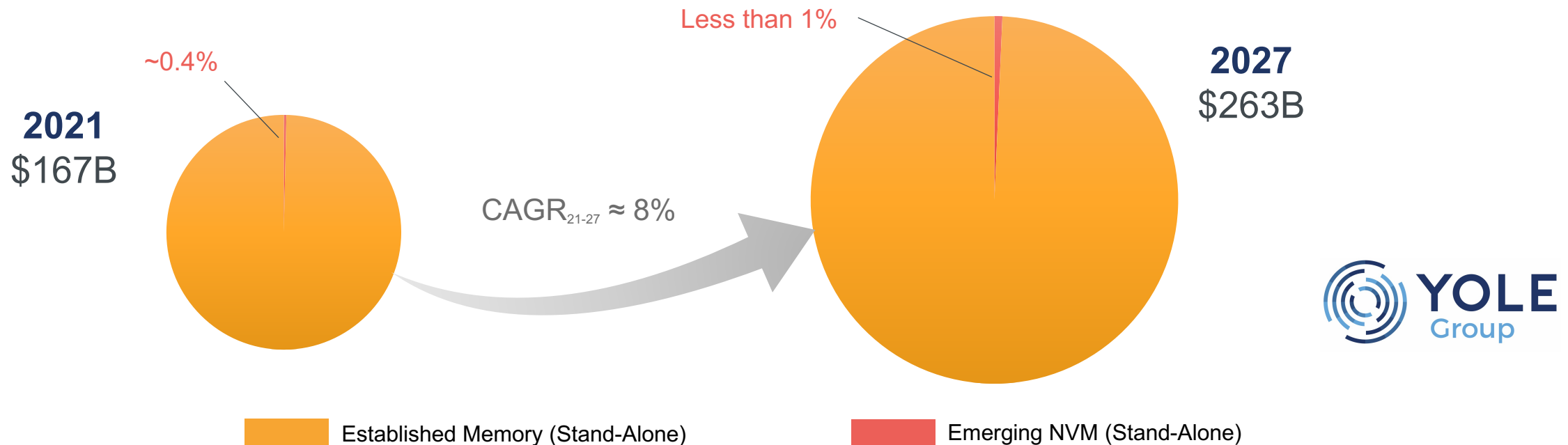
Source: "Status of the Memory Industry 2022" report by Yole Group

Stand-Alone Memory Market – Emerging vs. Established



Flash Memory Summit

- Flash NAND and DRAM will maintain their leading positions over the next five years, thanks to new technical solutions enabling further scalability.
- Emerging NVM – including PCM, MRAM, and RRAM – will remain less than 1% of the total stand-alone memory market by 2027.



Source: "Status of the Memory Industry 2022" report by Yole Group

Stand-Alone Emerging NVM Market $CAGR_{21-27} \sim 23\%$

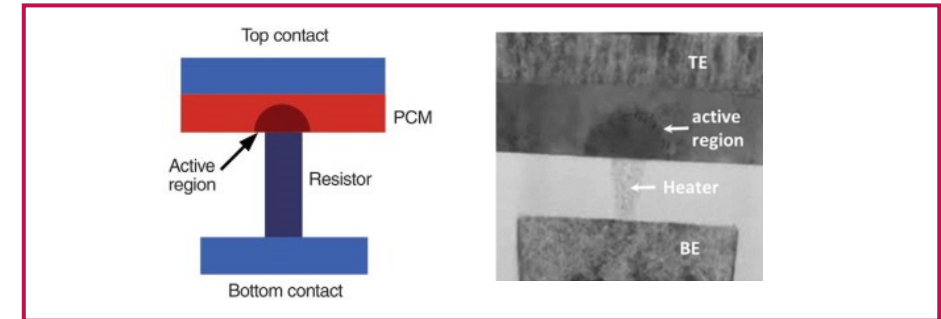
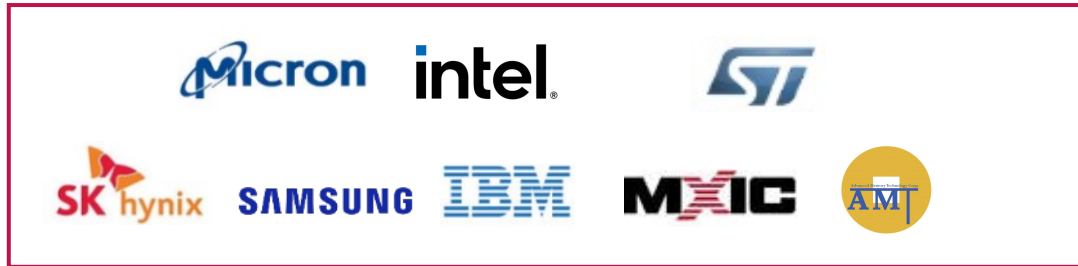
Stand-Alone Established Memory Market $CAGR_{21-27} \sim 8\%$

Emerging NVM – Key Players and Technologies

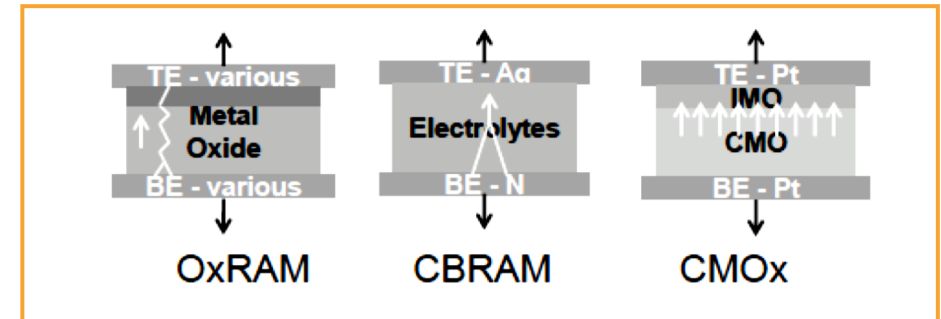


Flash Memory Summit

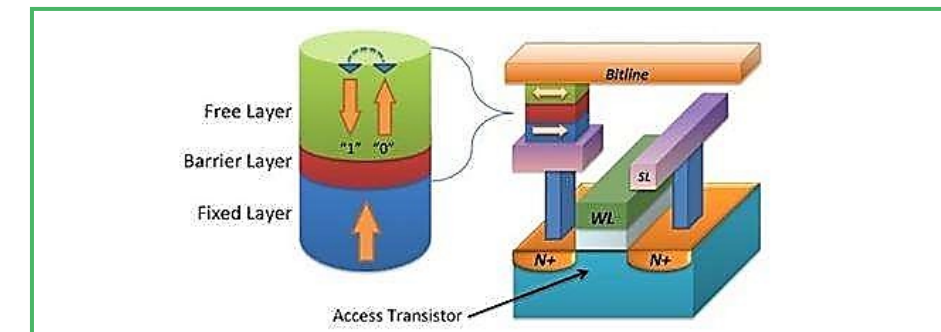
PCM: phase-change memory



RRAM: resistive random-access memory

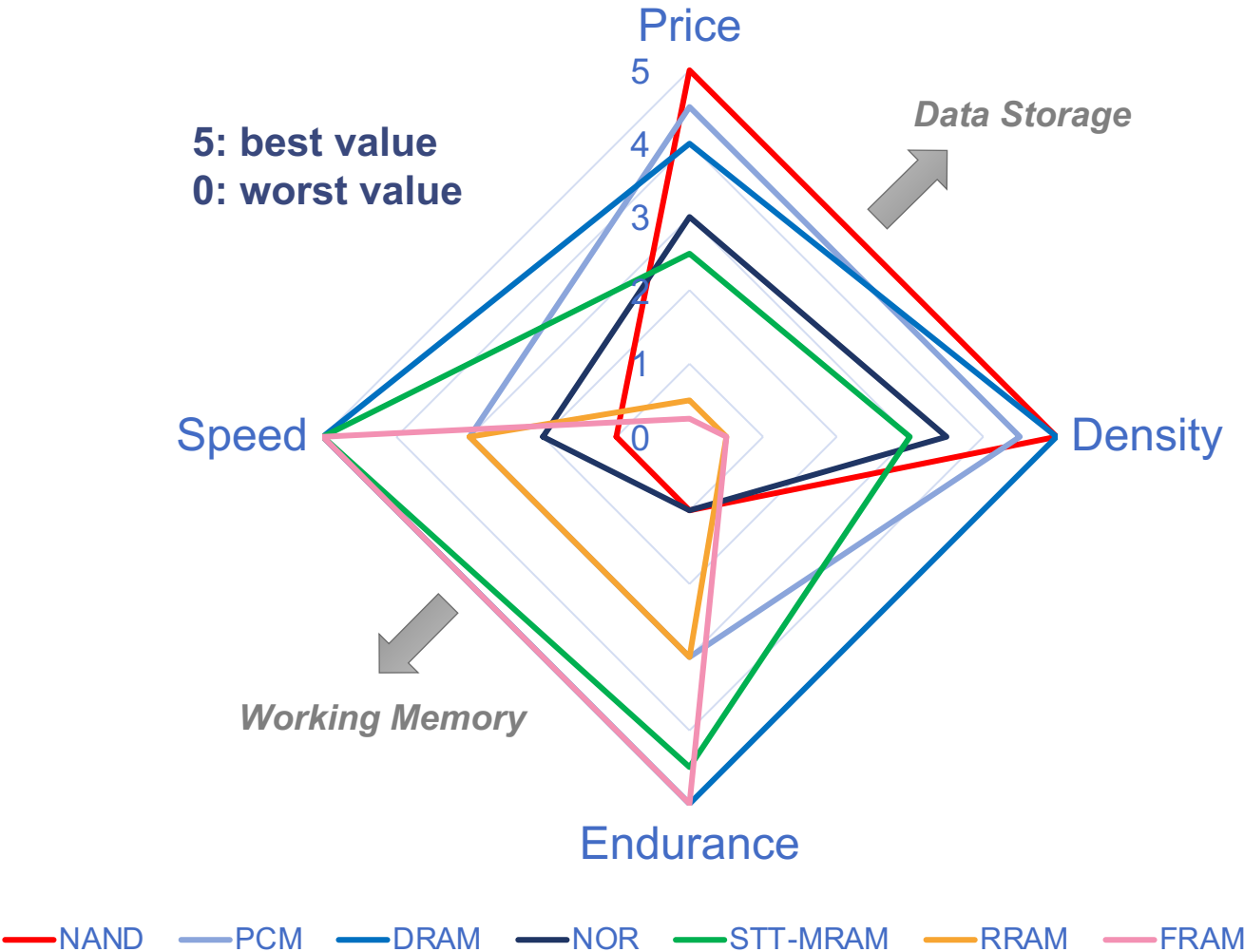


STT-MRAM: spin-transfer torque magnetic RAM

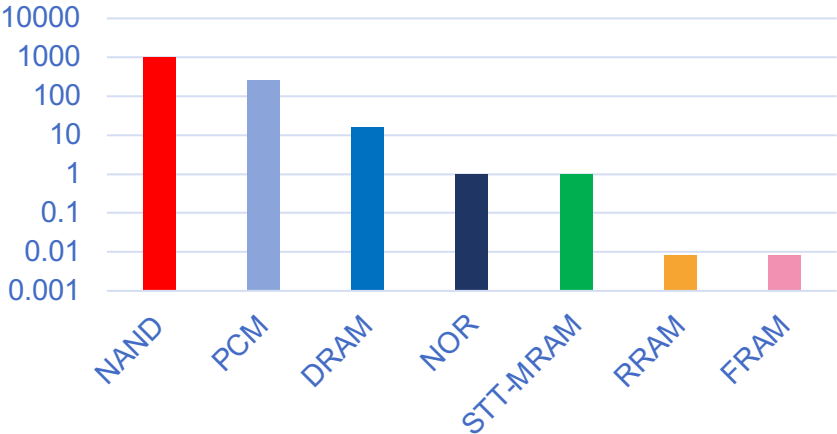


Stand-Alone Memory – Technology Comparison

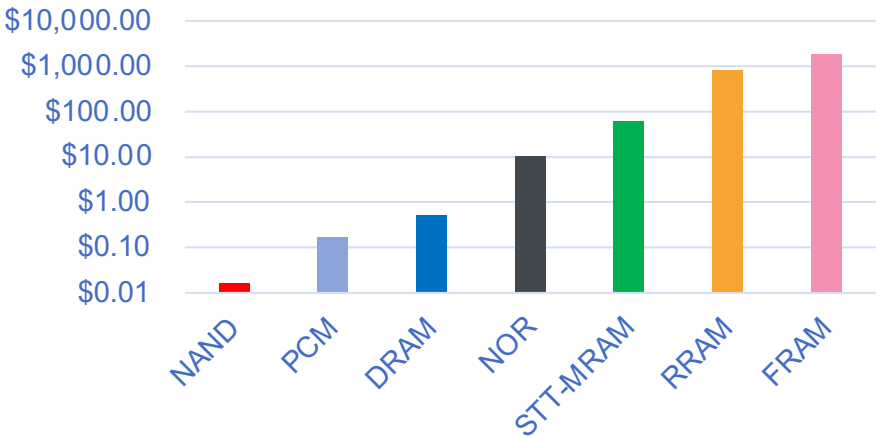
2021 performance of commercial products



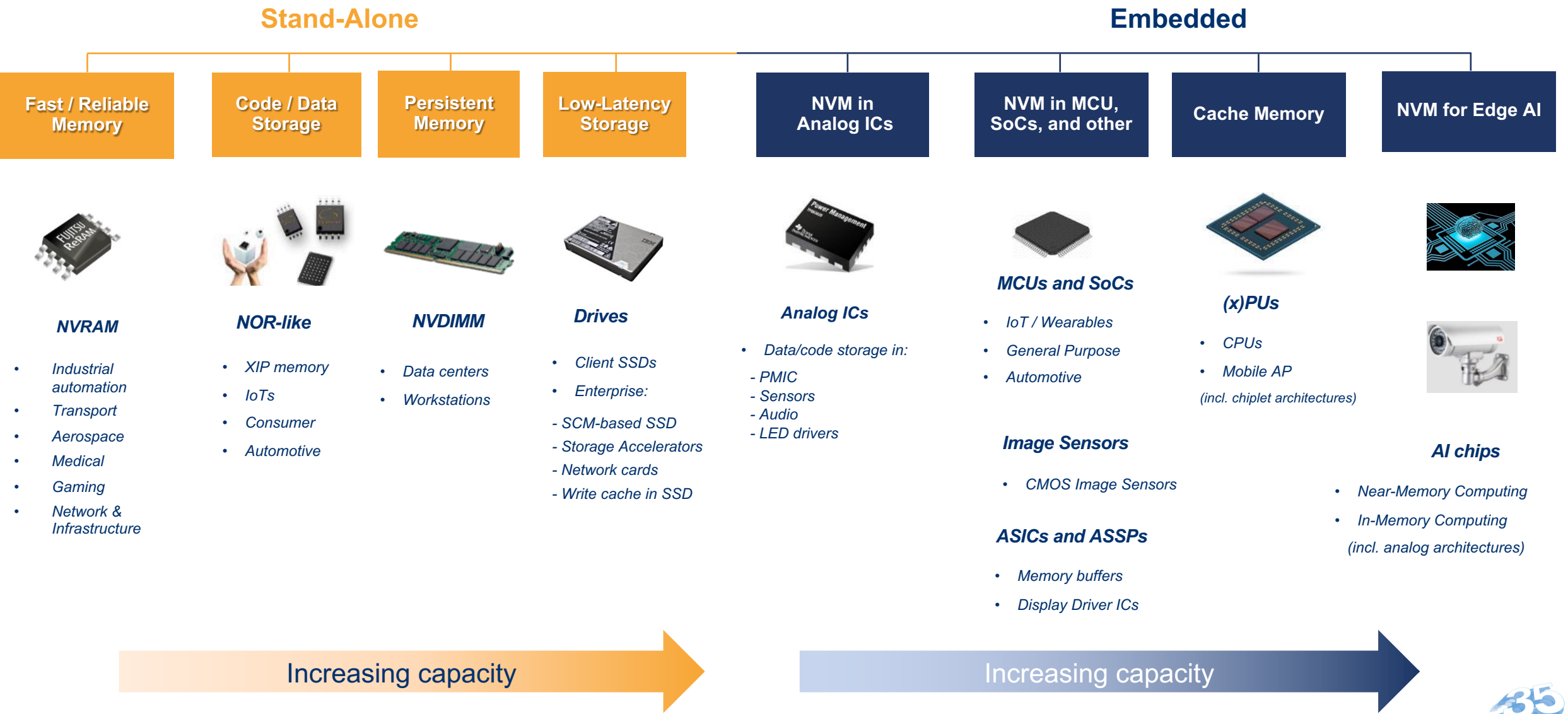
2021 Density Position
(Max. values. Gb per die)



2021 Price Position (\$/Gb)

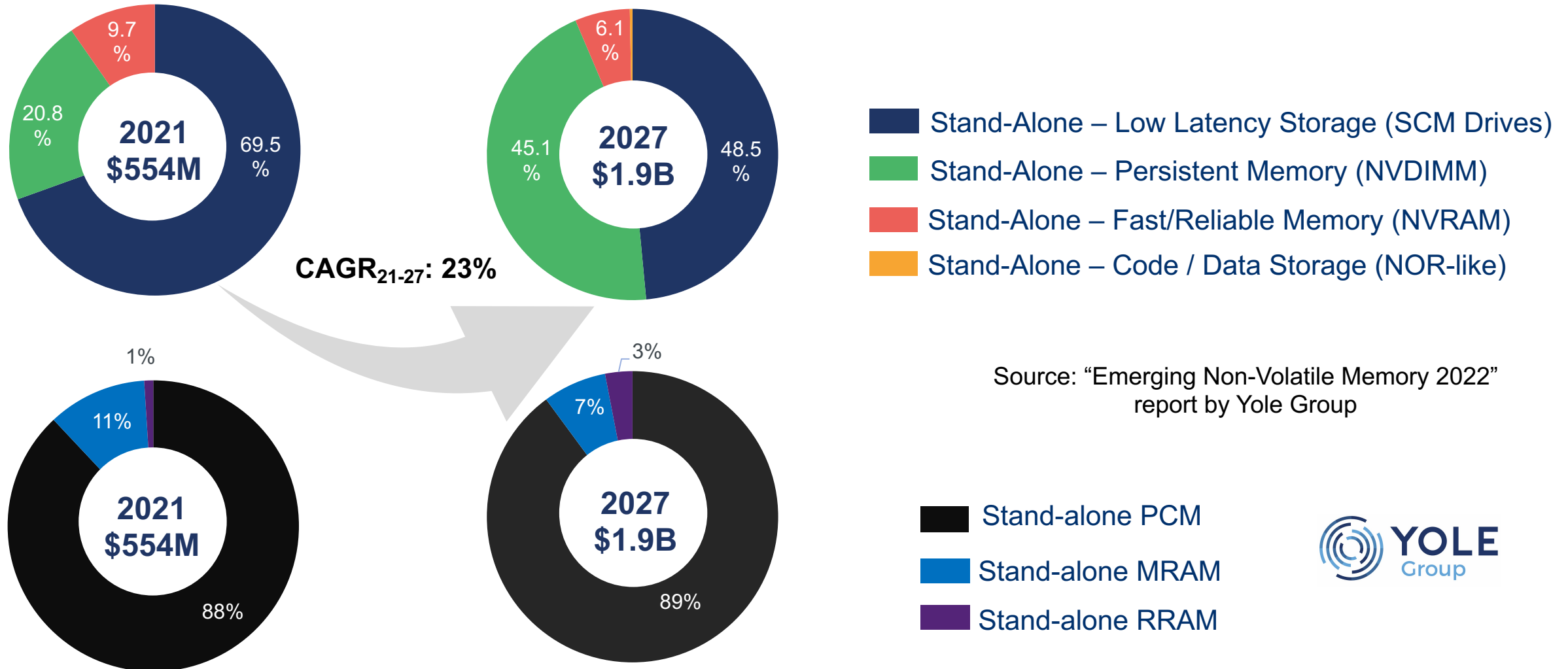


Applications for Emerging NVM



2021-2027 Stand-Alone Emerging NVM with Optane

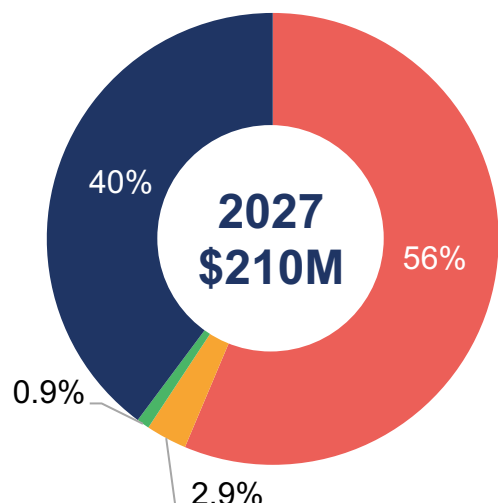
Yole's market forecast (May 2022) including Intel Optane products



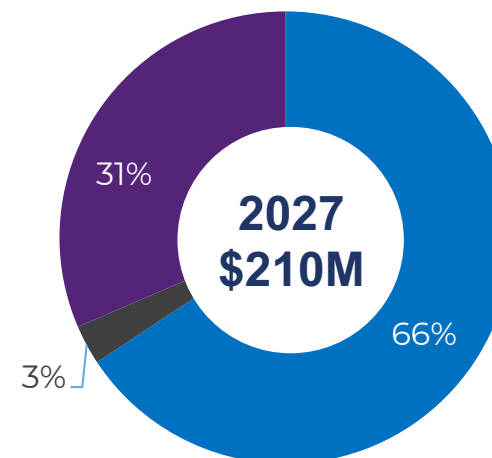
2027 Stand-Alone Emerging NVM Market Without Optane

Hypothesis: no new XPoint-like technologies will hit the market in the short term

- End of July 2022: Intel says it has initiated the winding down of its Intel Optane memory business.



- Stand-Alone – Low Latency Storage (SCM Drives)
- Stand-Alone – Persistent Memory (NVDIMM)
- Stand-Alone – Fast/Reliable Memory (NVRAM)*
- Stand-Alone – Code / Data Storage (NOR-like)



- Stand-alone PCM
- Stand-alone MRAM
- Stand-alone RRAM

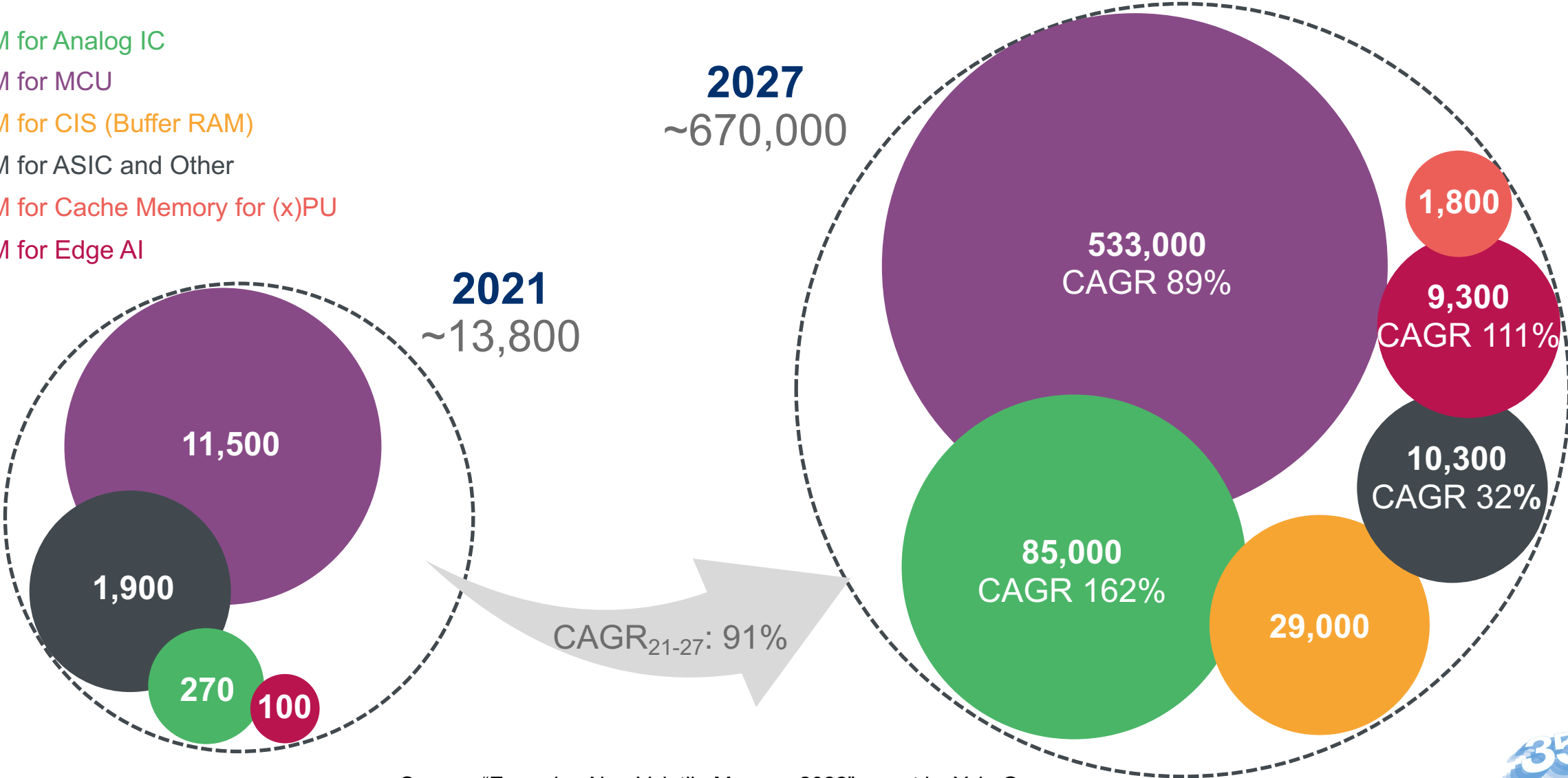
In the stand-alone MRAM market, leading players are positioning their products for **industrial and aerospace applications taking advantage of their superior NVRAM-like technical characteristics (e.g., reliability).*

2021-2027 Embedded Emerging NVM Market

Yole's wafer production forecast



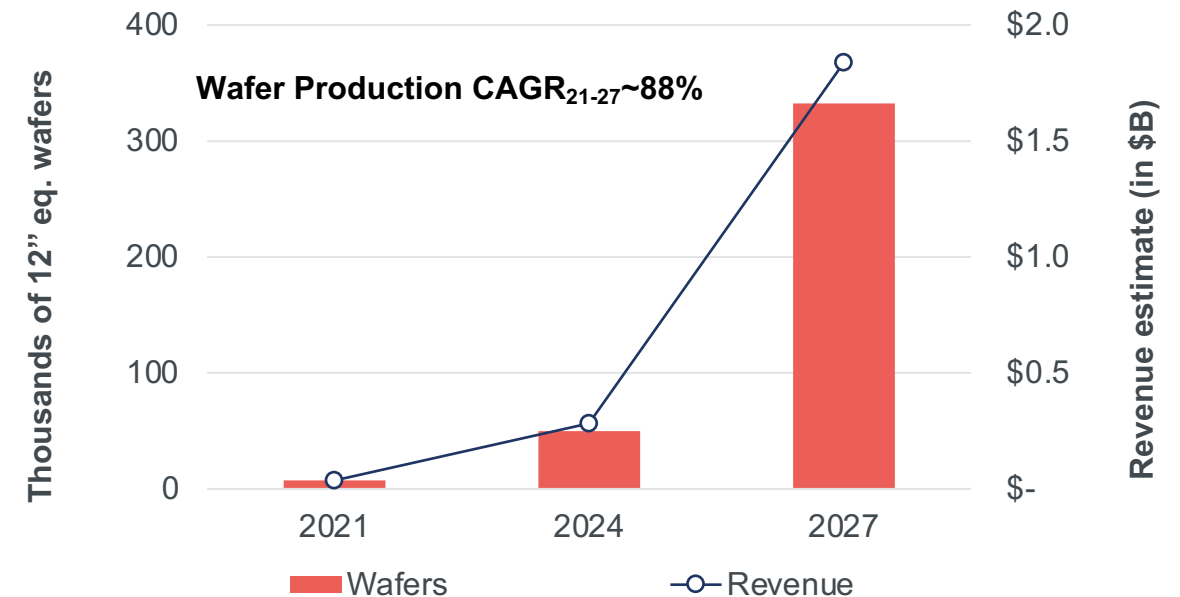
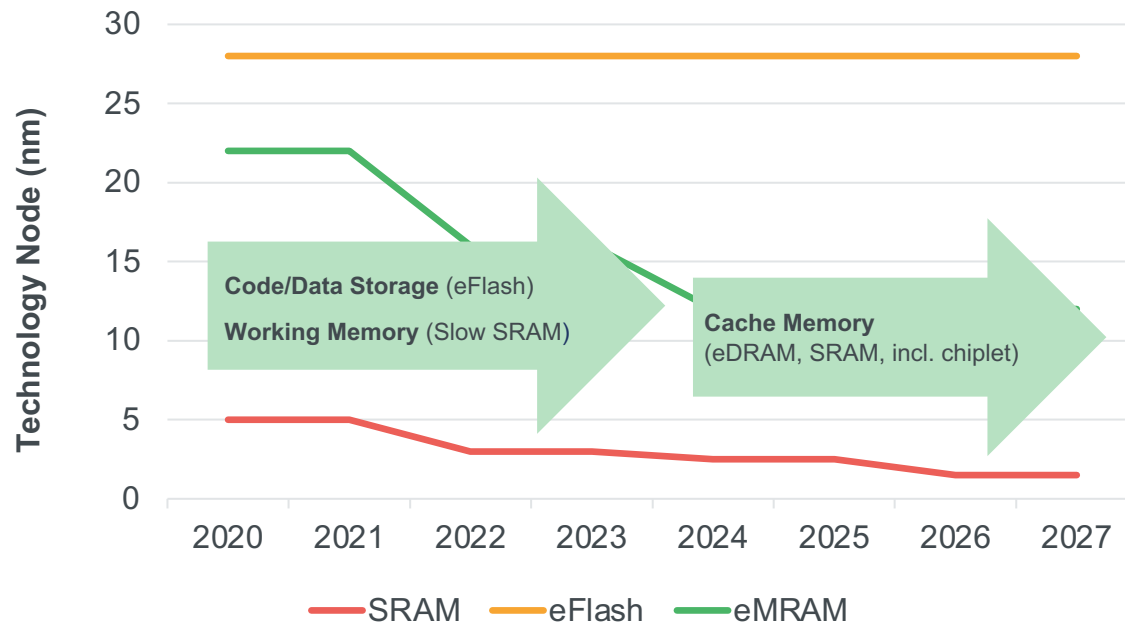
- NVM for Analog IC
- NVM for MCU
- NVM for CIS (Buffer RAM)
- NVM for ASIC and Other
- NVM for Cache Memory for (x)PU
- NVM for Edge AI



Embedded MRAM Market – Overview














- **eFlash** scaling is reaching its end: 28nm/22nm will be likely the last technology nodes. **SRAM** scaling is also slowing down, as the cell footprint (F^2) degrades at advanced FinFET nodes.
- **MRAM** offers non-volatility together with low power consumption, which is ideal for low-power MCUs, wearables and IoTs.

Embedded memory technology trends & MRAM market evolution



Embedded Emerging NVM Players

- Strategic alliances with top players are essential for mass adoption of embedded emerging NVM.














Foundry / IDM						
RRAM Players	Bulk 22nm (pre-production)	 22nm FD-SOI (pre-production)		 Bulk 28/22nm (production)	22nm FinFET (in development)	
(STT-)MRAM Players	 Bulk 22nm (production) 	 22nm FD-SOI (production)	 28nm FD-SOI (production)	 28/22nm bulk (production)	22nm FinFET (pre-production)	
PCM Players						28nm FD-SOI (production) 18nm FD-SOI (in development with Samsung)

Source: "Emerging Non-Volatile Memory 2022" report by Yole Group

Non-exhaustive list

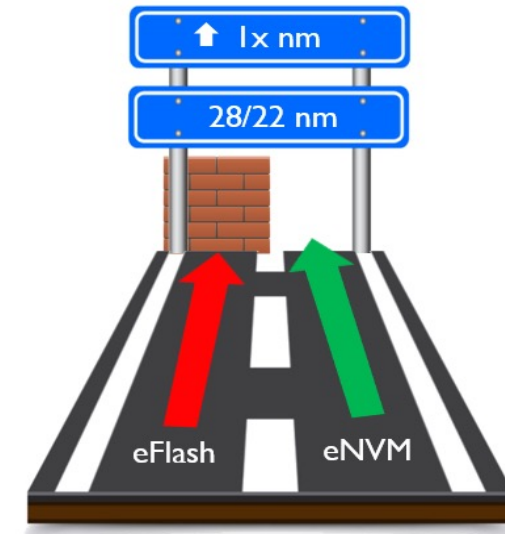
New Emerging NVM Technologies

- 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) and Correlated Electron RAM (CeRAM).
- Except for ferroelectric technologies that are reaching a degree of maturity and could have products in the next 2-3 years, these technologies are in their early development stages and their future adoption in commercial products is not likely to occur before 2027.

New Technologies	Novel Ferroelectric Memories	SOT-MRAM	VCMA-MRAM	CeRAM	NRAM
Key players involved in technology development	    	    	 Spin Orbitronics Technologies		

Summary & Outlook

- ✓ Despite growing technical challenges, **NAND** and **DRAM** will maintain their leading position over the next decade. **Stand-alone emerging NVM** will remain below 1% of the total stand-alone memory market.
- ✓ The **exit of Intel from the Optane business** would dramatically change the emerging NVM market perspectives. If no new 100Gb-class Xpoint-like technologies will be introduced in the coming years, the stand-alone emerging memory market will be limited to less than \$300M.
- ✓ In the embedded business, **eFlash is facing scaling barriers at 28/22nm**. Thus, embedded NVM alternative to eFlash are needed and are currently in production with relatively low volumes.
- ✓ **Embedded MRAM** is expected to be adopted more rapidly than embedded RRAM and PCM. The market growth will be driven by a variety of applications, including low-power **MCUs**, **IoT**s, memory buffers, display drivers, security ICs, as well as CMOS Image Sensors (CIS).
- ✓ In terms of **wafer production**, we expect that by 2027, more than ~650K wafers/year containing embedded emerging NVM will be manufactured (CAGR₂₁₋₂₇ of ~91%).

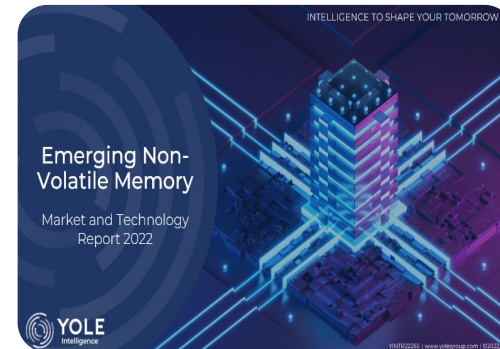
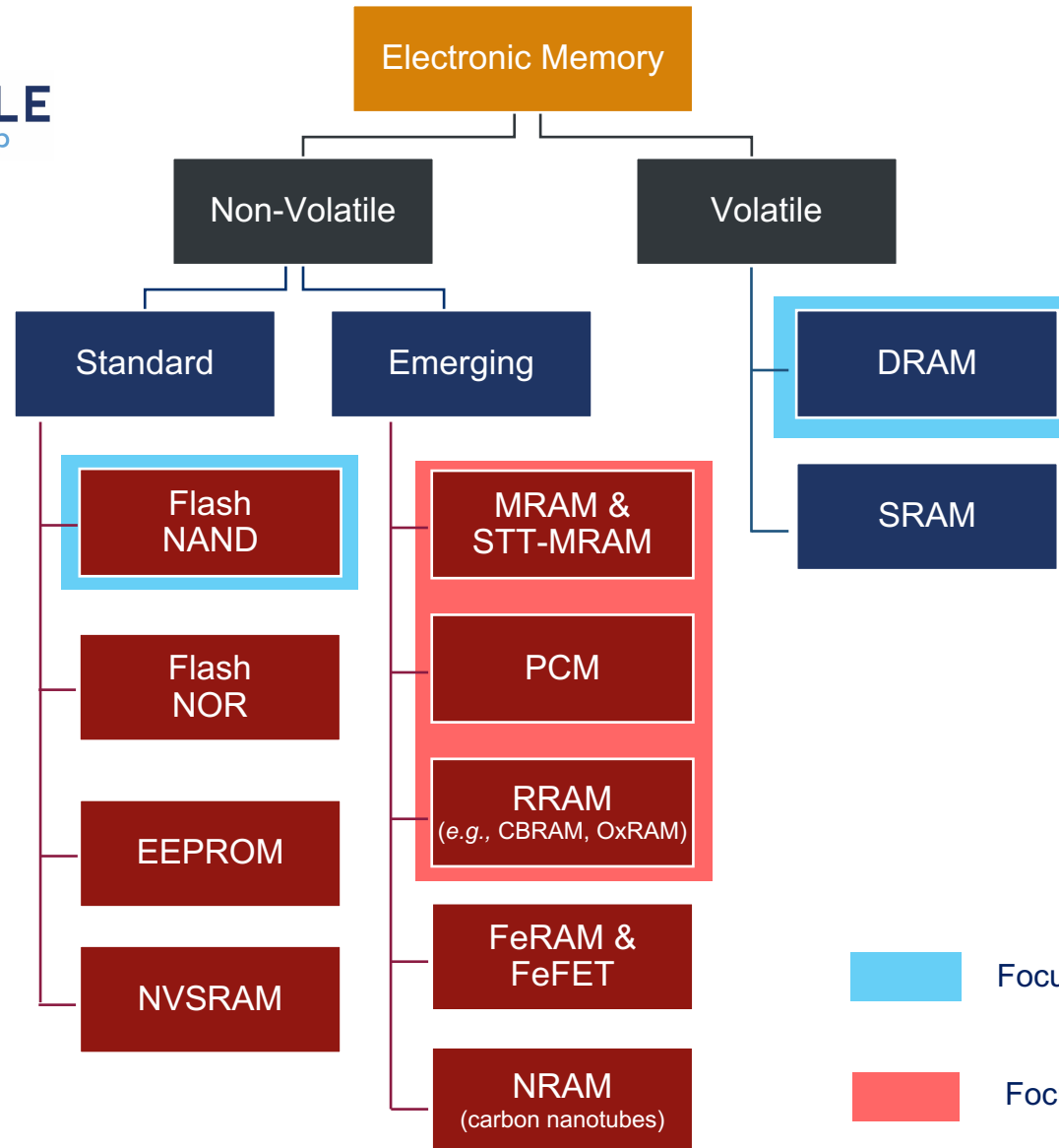


Acknowledgements – Yole's Memory Team



Walt Coon VP of NAND and Memory Research	Mike Howard VP of DRAM and Memory Research	Simone Bertolazzi, PhD Senior Technology and Market Analyst - Memory	Thibault Grossi Senior Technology and Market Analyst - Memory	Diego Alfaro, PhD Technology and Market Analyst - Memory	Belinda Dube Technology and Cost Analyst – Memory & Integrated Circuit
					
› Experience 15+ years in memory	› Experience 15+ years in memory	› Experience 12+ years in emerging semiconductor devices	› Experience 15+ in Electronic Procurement (Semiconductor, PCBA and software)	› Experience 5+ years in emerging semiconductor devices	› Experience 4 years in memory and integrated circuits
› At Yole NAND	› At Yole DRAM	› At Yole Memory	› At Yole Memory	› At Yole Memory	› At Yole SystemPlus Memory
› Education MBA Bachelor of Science in Chemical Engineering Bachelor of Arts in Finance	› Education MBA Bachelor of Science in Chemical Engineering Bachelor of Arts in Finance	› Education Ph.D. in Nanoelectronics M.Sc. in Micro & Nanotechnology M.Sc. in Engineering Physics	› Education M.Sc. in Electronic and Computing science	› Education Ph.D. in Nanoelectronics and Nanotechnology M.Sc. in Electronic Integrated Systems	› Education M.Sc. in Nanoelectronics and Nanotechnology

Memory Technology & Market Analysis at Yole Group



 Focus on the “NAND and DRAM Market Monitors” (published every quarter)

 Focus on the “Emerging Non-Volatile Memory” report (updated every year)

Thank you for your attention

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