

Future Scenarios for Emerging Memory Markets

Rev 2

Mark Webb
MKW Ventures Consulting LLC
www.mkwventures.com

New Memories

- In previous presentations (FMS) we have shown WHY Emerging memories do not ever really emerge
- They need to be **Niche**, **Embedded**, or **no cost adder** to DRAM/NAND
 - Last year we also showed how Chiplets allow integration at low cost
 - Chiplets are breakthrough that ALLOWS moderate growth for Discrete.
- Optane showed that even with billions in spending and support for ecosystem, mass acceptance is too slow to build a fab around
 - We have spreadsheets to explain why finances don't EVER make sense.
- Hence most memories end up as niche or abandoned

Memory Technologies Reviewed

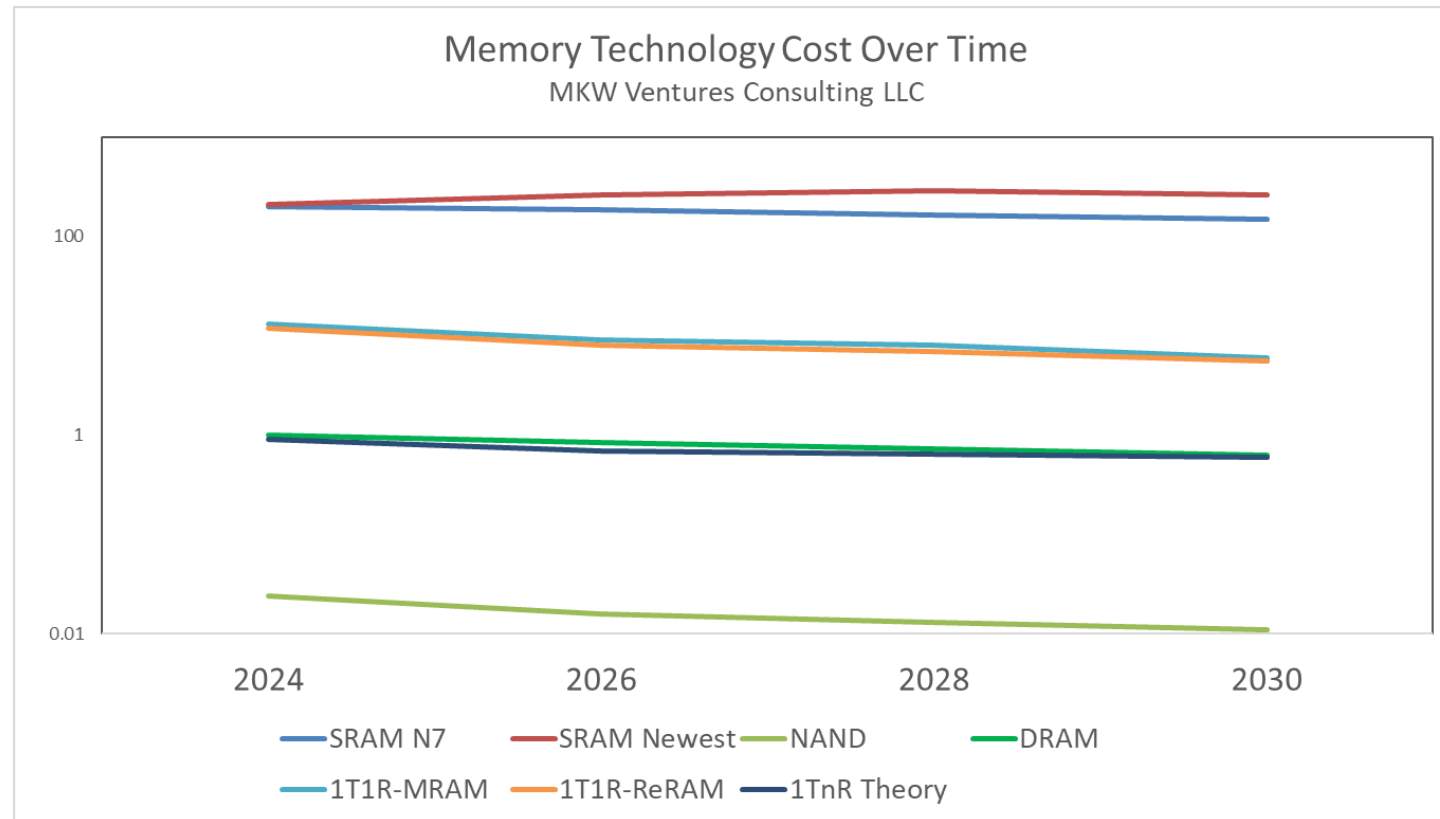
UPDATED Scorecard: We don't need Universal ... Lots of Yellow!

	Latency	Density	Cost	HVM ready
DRAM	*****	***	***	*****
NAND	*	*****	*****	*****
SRAM	*****	*	*	*****
NOR	***	**	**	*****
MRAM	*****	**	**	*****
ReRAM	***	**	**	*****
PCM (1T1R)	***	**	**	*****
FE DRAM (Gb)	***+	***	***	**
Other	***	**	**	*

Costs for All Memory Technologies Over Time

- Memory costs differ by orders of magnitude. Huge tradeoffs.
- SRAM on leading edge cost increases. SRAM on N7 node cost decreases

NOTE: *Numbers Updated in 2025. Huge differences hide changes*



MKW Ventures Cost Model

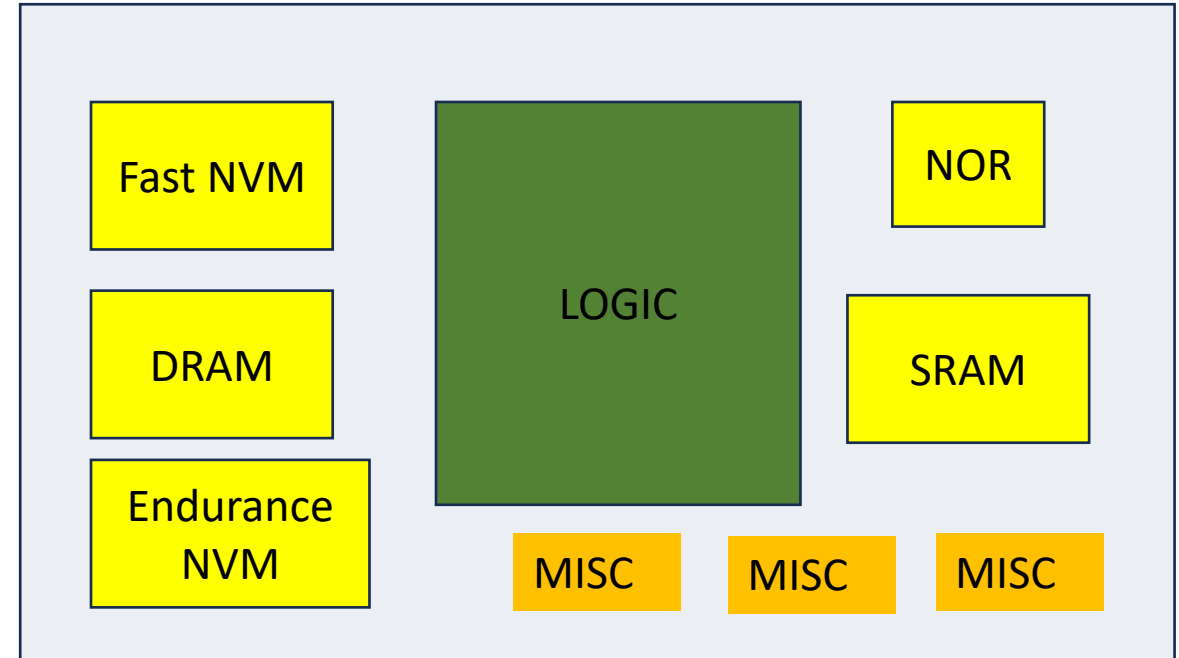
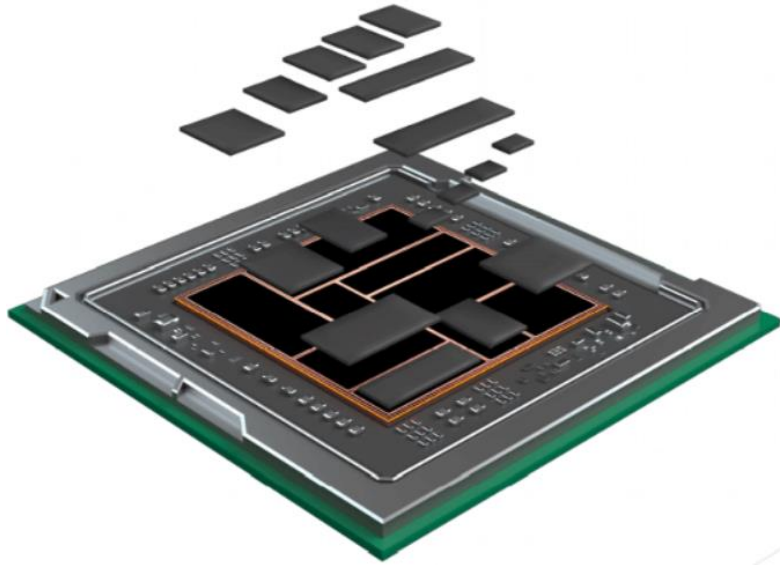
Status Updates In 2025

- **MRAM and ReRAM continue to have their place and are growing slowly**
 - Embedded options with foundries large and small
 - MRAM has performance advantages, ReRAM can be simpler
 - Both are more cost effective than eFLASH long term
- **Phase Change is still publicized by those with PCM experience (ST/IBM)**
- **Historic FerroElectric (<Gbit) still used by companies who have used it**
- **None are close to SRAM/DRAM in performance or NAND in Cost.**
 - No replacement, no universal memory YET
- **Newer technologies are in the early phases of development (Single cell/Small arrays). They are 8+ years from productization.**
 - We have details on Product lifecycle with all the milestones
 - If you are not currently making 1Mb or larger arrays with detailed Bit Error Rates, Production will not happen in next 5 years and success probability is low

Market Changes in 2025

- **Chiplets are becoming more widespread and are game-changing**
 - This enables “special memory” to be used regardless of other processes. AI Applications
 - Used with N2, N7, TSMC, Intel on same base die Without need for true embedding.
- **Only a “Low Cost Adder” with >90% reuse from DRAM or NAND process can EVER ramp as a high volume technology.**
 - FE Capacitor DRAM is the ideal candidate due to tools and processes
 - Micron Presented NV DRAM with FE Storage node (NVM in DRAM process) at IEDM in 2023. No Product is being sampled at this time on this process
 - FMC (FerroElectric Memory Corporation) Publicized FE based NV DRAM in 2025. Caching and DRAM replacement applications for multiple applications. Performance matching DRAM
 - Other memory companies are working on HF based DRAM replacement as the simplest, most cost effective NV DRAM implementation. Those results have not been published.
- **If the memory technology does NOT have 90% reuse, the development costs and market dynamics PREVENT growth above a niche market.**
- **HBM market growth has caused memory companies to change priorities and this makes support for new memories and markets MORE difficult**
 - This plus 4F/3D DRAM hurts new memory funding in major companies

Chiplet Hypothetical



NAND/CXL DRAM off Chip



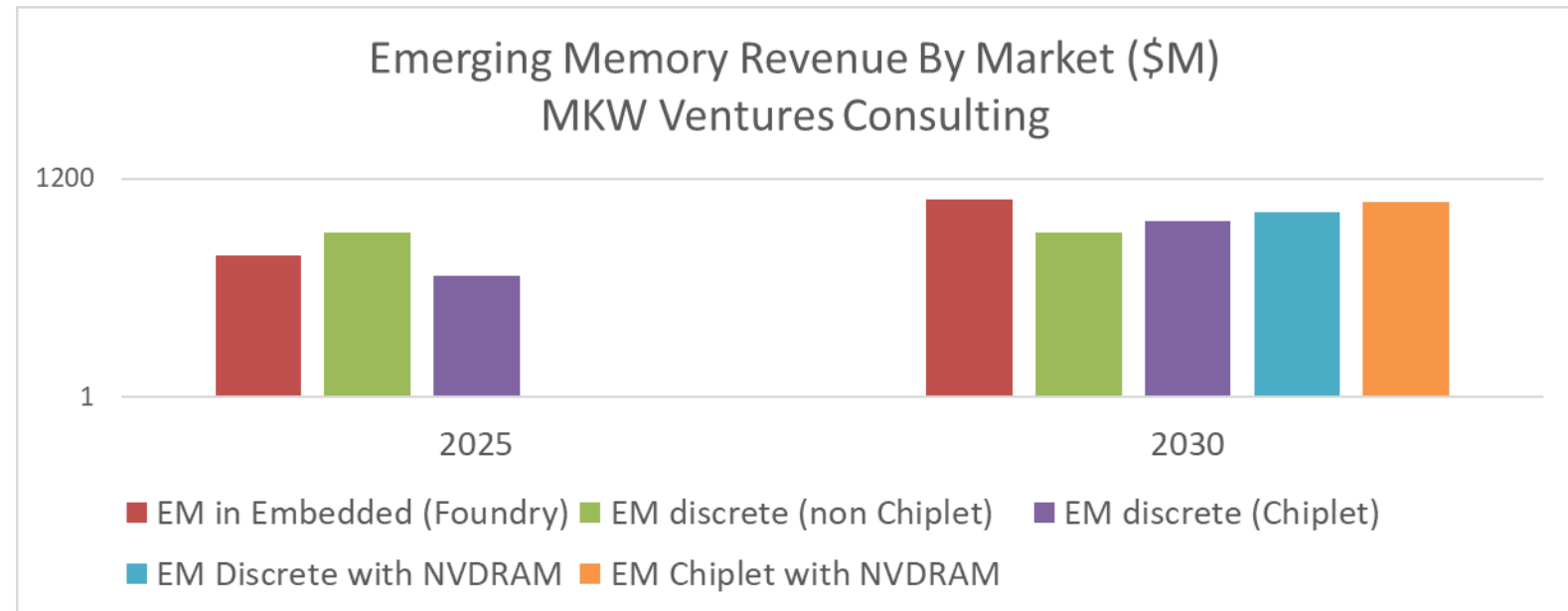
Emerging Memory Market Revenue

A New Partitioning

- Existing technologies (MRAM, RRAM, PCM, FERAM) will be 99% of the revenue through 2030. Other Technologies may ramp after that
- Embedded is modelled based on amount of die area used (not real revenue)
- Discrete is broken out by chiplet and non-chiplet (this can blur)
- IF a memory company releases a FE DRAM (Like Micron or FMC), that market has significant discrete and chiplet applications. IF Performance close to DRAM

CAGR through 2030

40% Embedded
20% Discrete Non-Chiplet
50% Discrete Chiplet
50%+ NV DRAM



Summary

- RRAM, MRAM, PCM, FE “mature memories” are out and growing modestly. Classic niche Markets with some Chiplet applications
- Newer technologies have not emerged and are 8+ years from HVM or measurable revenue
- FE based NV DRAM (Multi GB) is the likely “no cost adder” process capable of high volume. Likely implementation with 4F/3D DRAM
- We break out market revenue possibilities in new way to allow the very different implementations to be tracked
- Total Revenue for all Emerging Memory technologies and segments is \$1B in 2030. \$2B if we add FE NVD RAM to the market.

Follow up

- Lots of details available on website and in follow up discussions
- Spreadsheets to discuss trade off numbers available for discussion
- Memory Product lifecycle allows you to track when new technologies are implemented

Mark Webb

www.mkwventures.com

Mark@mkwventures.com

505-681-7614

BACKUP