

# EMERGING NON-VOLATILE MEMORY 2021

## Market & Technology Report - February 2021

*Embedded NVM readies to take off driven by low-power applications. Stand-alone NVM continues its journey toward mass adoption, despite ecosystem slowdowns.*

### WHAT'S NEW

- Re-definition of the AI market segment to include the following types of products:
  - (1) Edge AI chips with NVM replacing SRAM (digital approach)
  - (2) Analog in Memory Computing
- Financial analysis of leading emerging NVM companies
- Report on ferroelectric technologies (e.g., FeFET) and other newly emerging devices: SOT-MRAM, VCMA-MRAM, CeRAM and NRAM
- Overview of equipment – technology, challenges, and solutions – for manufacturing for manufacturing STT-MRAM
- Analysis of the impact of the COVID-19 pandemic on the memory business
- Updated presentation and analysis of emerging NVM activities in China
- Presentation of Intel's new products and activities to develop the persistent memory (PM) ecosystem

### KEY FEATURES

- 2020 - 2026 market forecast in \$US, Gbits, wafer-starts, and units
- Competitive landscape and market dynamics
- Emerging NVM applications and market drivers
- Technology roadmaps, with time-to-market
- Price evolution, by application and technology
- Technology description and main technical trends, along with overview of main players and product-development roadmaps

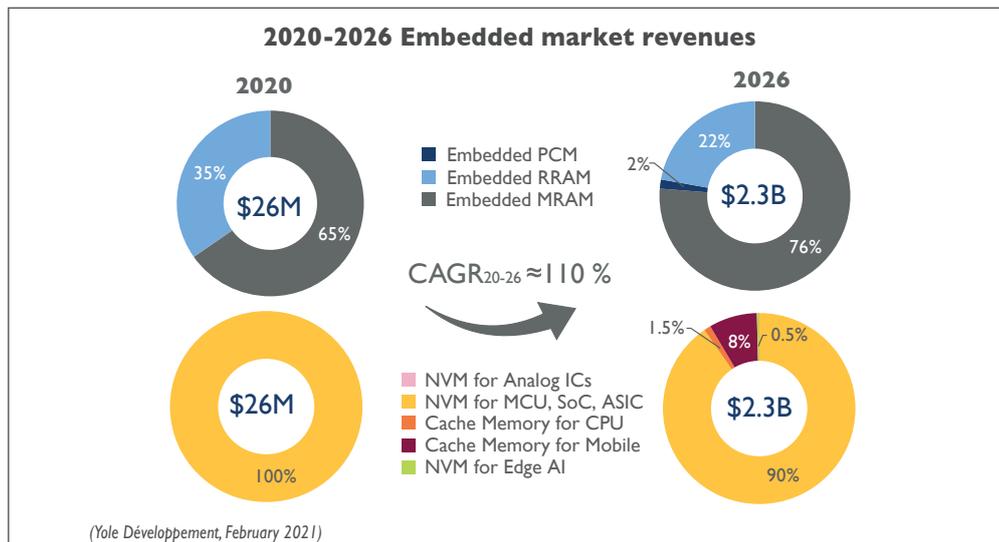
### THE FIRST PRODUCTS WITH EMBEDDED MRAM (eMRAM) HIT THE MARKET IN 2020, TRIGGERING THE TAKEOFF OF THE EMBEDDED NVM BUSINESS

After several years in development, embedded emerging NVM technologies have gained significant maturity and are now ready for market take off. The year 2020 has witnessed the introduction of the first commercial products based on eMRAM, namely Sony's GPS SoCs manufactured by Samsung (28nm FDSOI) and Ambiq's low-power MCUs manufactured by TSMC on 22nm ultra-low leakage (ULL) process. A number of eMRAM-based devices could enter volume production in 2021, among which are GreenWave's AI processors with GlobalFoundries' eMRAM (22nm FDSOI) as well as edge-AI accelerators developed by Numen and Gyrfalcon (22nm ULL at TSMC). Products incorporating embedded RRAM (eRRAM) also hit the market in 2020 with Nuvoton-Panasonic introducing new IC devices with 40nm OxRAM for security applications.

Embedded MRAM is expected to be adopted more rapidly than RRAM: in an optimistic scenario of effective roadmap execution, we

forecast a ~\$1.7B embedded MRAM market in 2026, which corresponds to ~76% of the overall embedded emerging NVM market. However, eRRAM will remain a strong competitor. In fact, leading players have been investing in RRAM targeting eFlash replacement at 40nm and beyond: TSMC has enriched its 40nm ultra-low-power (ULP) process with embedded OxRAM and currently offers OxRAM at 22nm; GlobalFoundries licensed Adesto's CBRAM™ from Dialog Semiconductor and is now implementing it on 22nm FDSOI for low-power consumer applications; UMC is pursuing 28nm OxRAM development in partnership with Nuvoton-Panasonic, and they could target the smartcard market in the coming years.

Finally, embedded PCM is still in the race and will target eFlash replacement in automotive MCUs. STMicroelectronics is its main promoter, having selected PCM as the best emerging NVM solution for 28nm FDSOI node in the automotive market.



### DESPITE IMPORTANT ECOSYSTEM-DEVELOPMENT CHALLENGES, STAND-ALONE NVMs CONTINUE TO EXPAND IN THE DATACENTER SPACE, THOUGH SLOWER THAN EXPECTED

The stand-alone emerging NVM market – comprising PCM, MRAM and RRAM – will grow from ~\$595M in 2020 to ~\$3.3B in 2026. It will be driven by two key segments, namely low-latency storage (enterprise and client SCM drives) and persistent memory (NVDIMM). PCM will be the leading technology thanks to the sales

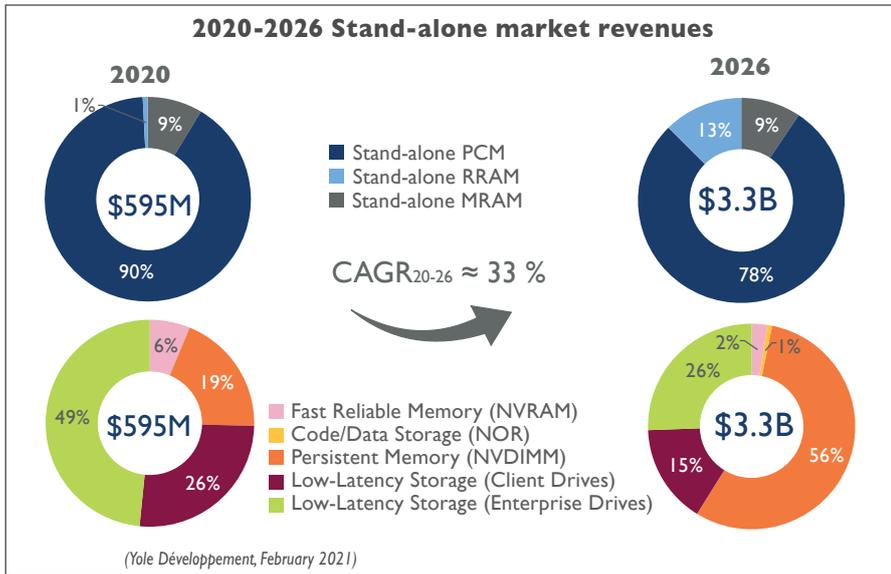
of 3D XPoint products – particularly persistent memory (PM) DIMMs – that are sold by Intel in a bundle with its server CPUs. New stand-alone Optane products have been launched in 2020, one of which is the long-awaited Alder Stream SSD. This is the first product that employs the 2<sup>nd</sup> generation 3D XPoint with four

stacked PCM layers. In late 2020, Intel confirmed that about 200 of the Fortune 500 companies have either directly deployed Optane PM or are in the Proof of Concept (POC) stages, and the POC-to-deployment conversion rate is expected to be over 85%. However, the effort to build up a software-

hardware ecosystem for PM deployment has been found to be extremely challenging and time-consuming, and is currently carried out by one key player, Intel.

In comparison to PCM, the MRAM and RRAM stand-alone markets will remain significantly smaller, holding a combined ~22% share of the stand-alone emerging NVM market in 2026. The sales ramp-up time for STT-MRAM chips that are sold to IDMs and OEMs in the low-latency storage business is taking longer than expected. The use of STT-MRAM in storage modules requires significant time and resources to engineer the system architecture and develop a suitable controller technology.

Stand-alone 3D RRAM with XPoint-like structure has also been delayed compared to previously reported roadmaps: RRAM-based SSD drives will presumably be introduced using new protocols – such as CXL or Gen-Z – that are not mature yet. More time is needed (>2 years) for the new interfaces to mature to the point of triggering the adoption of novel SCM drives as alternatives to the NVMe-based drives currently available (e.g., Z-SSD, Optane SSD).



### EVEN DURING THE PANDEMIC, EMERGING NVM ACTIVITIES KEEP PROLIFERATING, AND PROMISING NEW TECHNOLOGIES APPEAR ON THE HORIZON

COVID-19 with its global lockdowns had a mixed impact on the memory industry. Datacenters and laptop demand grew, automotive and smartphones faced a slow-down. The net result has been a relatively balanced memory demand. As the emerging NVM business is currently expanding mostly on the datacenter side with SCM applications enabled by 3D XPoint, there has not been a detrimental impact on the overall emerging NVM market evolution.

been launched by national and local governments. However, we expect that funding might not be as abundant and available as in the last years. In the past, the Chinese government invested significant resources in semiconductor activities, sometimes without a tight focus and control. Now, funding agencies are stricter and invest on the most reliable/promising players and on the key markets and applications.

The pandemic created supply-chain disruptions in the first half of 2020, but these were largely cleared by the beginning of 2H-2020. Despite the challenging conditions set by COVID-19, emerging NVM activities have been proliferating worldwide, particularly in China, where several projects have

In the meantime, promising new technologies have appeared on the horizon: resistive memories exploiting correlated electron switching (CeRAM) are now in development at Cerfe Labs, an ARM spin-off; magnetic memories based Spin Orbit Torque (SOT) and Voltage Controlled Magnetic

#### Embedded Non Volatile Memory: status and new technology developments

Foundries and IDMs working on eNVM	TSMC	GLOBALFOUNDRIES	SAMSUNG	UMC	intel	STMicroelectronics
<b>RRAM</b>	Bulk 22nm (sampling)	22nm FD-SOI (in development)		Bulk 28/22nm (in development)	22nm FinFET (in development)	
<b>(STT-)MRAM</b>	22nm bulk (production)	22nm FD-SOI (production)	28nm FD-SOI (production)	28/22nm bulk (in development)	22nm FinFET (pre-production)	
<b>PCM</b>						28nm FD-SOI (in qualification for automotive)

New Technologies	FeFET	SOT-MRAM	VCMA-MRAM	CeRAM	NRAM
<b>Key players involved in technology development</b>	FMC, GLOBALFOUNDRIES, intel, imec KIOXIA	antaios, imec	imec, Spin Orbitronics Technologies (Japan)	arm, CerfeLabs	NANTERO

Non exhaustive list of companies\*

Anisotropy (VCMA) could become viable options for high-speed embedded caching applications; ferroelectric FET devices have also drawn huge interest and are currently in the works at major players: GlobalFoundries, Intel, Kioxia, just to mention a few. Although promising, these technologies are still in their early development stages and have significant challenges ahead. We are carefully tracking

their evolution as we expect they could be disruptive in the long term.

Leveraging our sound expertise in emerging memory technologies and related markets, Yole introduces the 8<sup>th</sup> edition of its Emerging Non-Volatile Memory report, providing the most comprehensive analysis of the emerging NVM business and its competitive landscape.

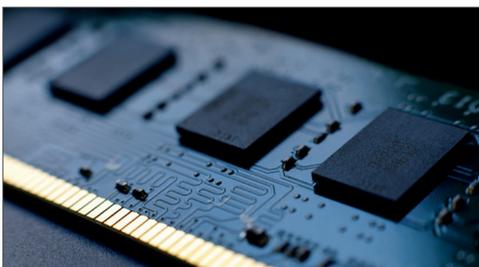
**COMPANIES CITED IN THE REPORT (non exhaustive list)**

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**REPORT OBJECTIVES**

- Present an overview of the semiconductor memory market:
- Stand-alone (NAND, DRAM, NOR, etc.) and embedded memory (eFlash, SRAM)
- Provide an understanding of emerging NVM applications:
- Market drivers & challenges, technology roadmap, players, and trends
- Offer market forecasts for emerging NVM business:
- 2020 - 2026 market forecast in \$US, M Gb, number of dies, and wafers for 10 applications and 3 technologies (MRAM, RRAM, PCM)
- Describe emerging NVM technologies:
- Working principles, manufacturing methods, advantages/limitations, development status, price, time-to-market
- Latest product development status for each key market player
- Detail and analyze the competitive landscape



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The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, epidemics, major health event (e.g. Corona virus), equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not attributable to the fault of the Seller.

## 6. PROTECTION OF THE SELLER’S IPR

6.1 All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.

6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish a Product, or any part of it to any other party other than employees of the Buyer Company (and only in the country of the Primary User for Multi-User Licenses). The Buyer shall have the right to use Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use any Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmittals over any network (including any local area network);
- Use in any timesharing, service bureau, bulletin board or similar arrangement or public display;
- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning a Product or any derivative thereof.

6.3 If the Buyer would like to use data coming from a Product for presentations, press announcements and any other projects, the Buyer needs to contact Yole Développement’s Public Relations Director (info@yole.fr) to get an official authorization and confirm that the data are up to date. In return the Seller will make sure to provide up-to-date data under a suitable public format.

6.4 The Buyer shall be solely responsible towards the Seller for any infringement of the obligation described in Article 6.3 above, whether such infringement originates from the Buyer’s employees or any person to whom the Buyer has sent the Products. Furthermore, the Buyer shall initiate and personally take care of any related proceedings in coordination with the Seller, and the Buyer shall bear the related financial consequences in their entirety.

6.5 The Buyer shall define within its Company an identified user who shall serve as a contact person for the License purchased by the Buyer. This person will be the recipient of each new report. This person shall also be responsible on behalf of the Buyer, for compliance with all copyrights and other obligations relating to the protection of the Seller’s IP rights and general compliance with the terms of the License purchased by the Company. In the context of Bundle and Annual Subscriptions, the contact person shall decide within the Buyer which person(s) shall be entitled to receive the protected link that will allow the Buyer to access the Products.

6.6 It is acknowledged and accepted by the Buyer that whether purchased in the form of Bundles or Annual Subscription, all unselected reports will be deemed cancelled and lost after a period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above .

6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

## 7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

## 8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

## 9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.